NATIONAL SCIENCE FOUNDATION

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Editors:

Prof. Ranjith Senaratne
Prof. Dilanthi Amaratunga
Prof. Shanthi Mendis
Prof. Prema-chandra Athukorala

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Professor Ranjith Senaratne, Professor Dilanthi Amaratunga, Professor Shanthi Mendis and Professor Prema-chandra Athukorala
(edited by)

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ISBN 978-624-5896-00-4

Suggested citation:

Senaratne, R., Amaratunga, D., Mendis, S. & Athukorala, P (eds) (2021), COVID 19: Impact, Mitigation, Opportunities and Building Resilience "From Adversity to Serendipity", Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka, Vol. 1, National science Foundation, Sri Lanka: ISBN 978-624-5896-00-4

The published book chapters will be made available open access on the National Science Foundation web site: Home (nsf.gov.lk)

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Preface

The COVID-19 pandemic is one of the most defining moments of our times and it has upended life and established systems across the globe with devastating and far-reaching impacts not only on health, but on the economy, society, multilateral trade, cooperation and aid. While those disruptions have been destabilizing, they have also provided opportunities to discover and develop new models and pathways in many areas, including health, education, business, agriculture and trade. As Winston Churchill once said, "A pessimist sees the difficulty in every opportunity; an optimist sees the opportunity in every difficulty". Prof. Mehmet Yildiz says adversity is a blessing in disguise because it helps to create new neural pathways in the brain, which is an essential factor for neuroplasticity and resilience.

In the course of combatting COVID-19 in Sri Lanka, a wide range of lessons were learnt, many best practices were identified and new knowledge, insights, competencies and experiences were gained. They ought to be further studied, refined, analysed, interpreted and documented for the benefit of posterity. This should be done without delay, lest a lot of the valuable information gathered and the knowledge gained is lost forever.

In this decisive and critical hour, scientists and professionals in the country have an inescapable responsibility and a profound moral obligation to support the nation and its people. It is in this context, that the National Science Foundation, the premier national institution mandated to promote S&T for socio-economic development of the country and wellbeing of its people, organized a 2-day national conference on 27th and 28th January 2021. It was entitled "COVID-19: Impact, Mitigation, Opportunities and Building Resilience" and the theme of the conference was "From Adversity to Serendipity". It brought together scientists, academics, professionals, economists, planners, and policy makers, as well as movers and shakers of industry. They deliberated on how best to tackle high priority health, economic, social and environmental issues emanating from the global pandemic while minimizing its impact on the economy and people of Sri Lanka. This endeavor was augmented by drawing upon the knowledge, expertise and insights of top-flight Sri Lankan scientists across the globe, i.e. in Asia, Africa, Europe Oceania and North America, thereby giving the event an international dimension.

Immediately after the conference, editors and associate editors of the volume swung into action, calling for full papers of selected abstracts. The submissions were processed swiftly with the support of a panel of competent international and national reviewers. In addition, scholarly contributions were invited from renowned local scientists to complement and supplement the proceedings. The outcome is a comprehensive volume of more than 730 pages with 65 papers, including keynote and plenary speeches and invited and technical papers, collating local and global perspectives of combatting the COVID-19 pandemic

The volume comprises nine sections, i.e. six themes namely Health, Mental Health and Wellbeing, Economy, Environment (Natural and Built), Resilience and Society and Education and three cross-cutting themes, namely Governance, Supply Chain, and Research and Inventions. Each section has an Introduction which provides a brief overview on the relevance, scope of papers, their salient points, gaps and areas for future research investigations. This obviated the need to include a separate chapter on Conclusions and Future Perspectives at the end.

COVID-19 emerged as an outbreak in the Wuhan Province in China in December, 2019 and spread rapidly across the globe becoming a pandemic. Thus far, there have been three waves in some countries including Sri Lanka and further waves are likely if the pandemic is not brought under control swiftly. Besides, more virulent variants of COVID-19 with greater transmissibility and severity have been recently identified in several parts of the world which has made combatting the pandemic more challenging and complex. The papers in this publication, i.e. Volume 1, have mainly

focused on the management and impact of COVID-19 in relation to the first wave and it is intended to produce more volumes in the future.

Climate change will exacerbate not only extreme weather conditions and the prevalence of vector-borne diseases such as dengue, chikungunya and zika, but also zoonotic diseases such as COVID-19. Therefore, SARS and COVID-19 may not be the end of the line, but the beginning of the line of increased zoonotic diseases.

Health experts from around the world have been using Sri Lanka's healthcare system as a case study since the 1980s. During the first wave, high testing rates and mobility restrictions coupled with the established surveillance and primary health care network in Sri Lanka have kept COVID-19 mortality at bay in comparison to more advanced healthcare systems in the world. Therefore, this landmark volume will be valuable not only to Sri Lanka, but also to the rest of the world for coping with and mitigating such pandemics in the future.

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Professor Dilanthi Amaratunga, UK

Professor Shanthi Mendis, Switzerland

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July 2021

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Prof. Ranjith Senaratne, former Senior Professor of Crop Science, Faculty of Agriculture, University of Ruhuna, possesses over 40 years of experience in higher education, including teaching, research and administration and community development. He has held several senior administrative positions with distinction for a period of over 20 years, i.e. the posts of Dean, Faculty of Agriculture and Vice-Chancellor, University of Ruhuna, Chairman of the Committee of Vice-Chancellors and Directors, Chairman of the Ocean University and Vice Chairman, University Grants Commission. Presently, he serves as the Chairman of the National Science Foundation.

As Vice Chancellor, University of Ruhuna, he has been strongly committed to promoting academic excellence, high impact research, creative enterprise, strategic partnership with industry, community development and international cooperation. In recognition of his outstanding contribution in education, science, community development and international cooperation, the University of Durham, UK conferred a honorary Doctorate (honoris causa) on him in 2007

Prof. Senaratne has been the recipient of several internationally competitive and prestigious research grants and has held a number of coveted fellowships, including the Andre Mayer Fellowship of the FAO and the Marie Curie Fellowship of the European Community. He has over 100 research communications and papers to his credit and has written and edited about 10 books related to agriculture, higher education, science & technology and national development. Professor Senaratne can be contacted on: ransen.ru@gmail.com

Professor Dilanthi Amaratunga

Professor Dilanthi Amaratunga holds the chair in Disaster Risk Management at the University of Huddersfield, UK, where she leads it Global Disaster Resilience Centre, responsible for supporting research on disaster management portfolios. She is a leading international expert in disaster resilience with an extensive academic career that has a strong commitment to encouraging colleagues and students to fulfil their full potential. She has project managed to successful completion a large number of international research projects generating significant research outputs and outcomes. She provides expert advice on disaster resilience to national and local governments and international agencies including the United Nations Office for Disaster Risk Reduction. She is engaged in many significant research engagements around the world, in partnership with key academic and other organisational stakeholders. To date, she has produced over 400 publications, refereed papers, and reports, and has made over 100 keynote speeches in around 30 countries. Among many leadership roles, she is the joint chief editor of the International Journal of Disaster Resilience in the Built Environment and the Chair of the International Conference on Building Resilience (ICBR) series, which she co-created. In 2019, she won the prestigious Newton Prize which recognises the best research and innovation projects which create an impact socially and economically, between Indonesia and the United Kingdom from 2016 to 2019. Newton Prize is supported by the UK's Department for Business, Energy, and Industrial Strategy (BEIS). She is a member of the European Commission and UNDRR's European Science & Technology Advisory Group representing the UK, a Steering Committee member of the Frontiers of Development programme, a Collaborative Programme of The Royal Academy of Engineering, The Academy of Medical Sciences, The British Academy and The Royal Society., and a Steering Committee member of the UK Alliance for Disaster Research, motivation of which is to bring together the UK's rich and diverse disaster research community to facilitate collaboration and partnership in order to aid representation of the research community at government level in the UK and to facilitate the implementation of the Sendai Framework for Disaster Risk Reduction. She is a Fellow of the Royal Institution of Chartered Surveyors (RICS), a Fellow of The Royal Geographical Society, and a Fellow and a Chartered Manager of the Chartered Management Institute, UK.

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Professor Shanthi Mendis

Professor Shanthi Mendis is the former Professor of Medicine, Faculty of Medicine, University of Peradeniya, Sri Lanka and the former Senior Adviser, World Health Organization (WHO), Geneva, Switzerland. She has contributed to clinical medicine, medical research and undergraduate and postgraduate medical education in Sri Lanka for two decades. WHO recruited her on a Rockefeller Global Health Leadership Fellowship to coordinate the Global Program on Noncommunicable Diseases. During her tenure in WHO, she led numerous Global Health Initiatives and Multi-country Research Initiatives and made major contributions to Global Health. She has provided technical and health policy advice to more than 73 countries in Africa, America, Western Pacific, Eastern Mediterranean, Europe and South Asia. She has been a visiting professor at the University of Oxford and the University of Nottingham.

She is a Fellow of the Royal College of Physicians of London and Edinburgh and a Fellow of the American College of Cardiology. In 2005 she was awarded Vidya Jothi in recognition of her contribution to medical research in Sri Lanka. She is in the 2020 Stanford University List of World`s Top two per cent of researchers and is the author/editor of 8 books and more than 200 publications.

She continues to serve on the WHO Expert Advisory Panel on Noncommunicable Diseases and the WHO Consortium on Healthy Ageing and as a consultant in Global Health at the Geneva Learning Foundation, Geneva, Switzerland.

Professor Prema-chandra Athukorala

Prema-chandra Athukorala is Emeritus Professor of Economics at the Australian National University (ANU), Fellow of the Academy of the Social Sciences in Australia, and Honorary Professorial Research Fellow at the University of Mancester, UK. He has been listed in Who's Who in Australia since 2005. His research interests are primarily in the fields of development macroeconomics, international trade and development, multinational enterprises and foreign direct investment, and international labour migration. His publications include ten books, seven edited volumes, and over two hundred papers in scholarly journals and multi-author volumes. He has served, at various times, as a consultant to the World Bank, Asian Development Bank, Asian Development Bank Institute, International labour Organisation, United Nations Industrial Development Organisation, Economic and Social Commission for World Trade Organization, United Nations International Trade Centre, United Nations Economic and Social Commission for Asia and the Pacific, and the Commonwealth Secretariat. These assignments have resulted in work on Bangladesh, Cambodia, Ethiopia, Georgia, India, Indonesia, Jordan, Laos, Malaysia, Nepal, Pakistan, Sri Lanka, Thailand, Vietnam, Mongolia and the Kyrgyz Republic.

About the associate editors

Dr Palitha Abeykoon

Track chair - Health

Dr Palitha Abeykoon is a Senior Advisor to the World Health Organization and the WHO Director General's Special Envoy for Covid-19 for South East Asia. He was also the Director of Health Systems and Non Communicable Diseases of the WHO South East Asia Region. He was Chairman of the National Authority on Tobacco and Alcohol, is a Member of National Medicines Authority of Sri Lanka and was President, Sri Lanka Medical Association. He has a medical degree from the University of Peradeniya, and had his post graduate education in the University of Southern California and Harvard University where he was a Taro Takemi Fellow. At the Global level he currently serves as a Member of the Advisory Committee of the WHO Global Learning Academy and is Member of the Research Advisory Committee of the Regional Director.

Professor Saroj Jayasinghe

Track chair - Health

Professor Saroj Jayasinghe MBBS, MD (Colombo), MRCP (UK), MD (Bristol), FRCP (London), FCCP, PhD (Colombo), FNASSL. He was the fifth Chair Professor of Medicine, University of Colombo and one of the longest serving consultants at the NHSL. He has been a member of the NSF's Working Committees on Health Sciences and STEMI Education and is currently a consultant to the Faculty of Medicine, Sabragamuwa University of Sri Lanka. He organized several activities on urban systems after being nominated by the NSF to the International Science Council's Science Committee on Urban Health and Wellbeing: A Systems Approach. He has co-authored 12 papers in peer reviewed indexed journals in COVID-19. The topics range from its clinical aspects, international comparisons of control policies, ethical issues, mathematical modelling and using a systems approach to understand the pandemic. He has been an invited speaker in several local and international webinars on COVID-19.

Professor Athula Sumathipala

Track chair - Mental health and well-being

Professor Athula Sumathipala MBBS, DFM, MD (Colombo), MRCSych (UK), PhD (Lon), FRCPsych (UK), FSLCGP, was the Professor of Psychiatry, School of Medicine, University of Keele and also Emeritus Professor of Global Mental Health at Kings College London, Honorary Consultant Psychiatrist, Midlands Partnership NHS Foundation Trust. He is also the Chairman, of the National Institute of Fundemental Studies, Kandy, Sri Lanka and the founder and Hon. Director, Institute for Research and Development, Sri Lanka. He is internationally recognised for his contribution into disaster and complex emergencies especially ethical management of such calamities and mental health consequences. He was involved in post Tsunami intervention in Sri Lanka particularly working for policy impact He has co-authored over 15 peer reviewed indexed journals on COVID-19. He has been an invited speaker in several leading international conferences on the subject and has also closely worked with the WHO too.

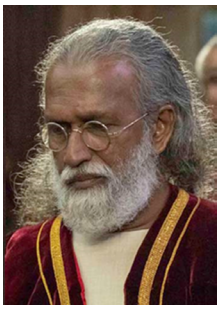
Professor Siri Hettige

Track chair - Society

Siri Hettige is Emeritus Professor of Sociology at the University of Colombo, Sri Lanka . He is also an Adjunct Professor at the RMIT University, Melbourne, Australia. Professor Hettige was recently appointed as a member of Sustainable Development Council, Sri Lanka. He was also the Honorary President of the Association of Sri Lankan Sociologists from 2003 to 2014 and former Chairman, the Working Committee on Social Sciences, National Science Foundation, Sri Lanka. He has published widely on such themes as youth, education, social and political conflict, social policy and governance and development. He has also served as a Visiting Professor/ Researcher at a number of overseas universities such as University of Zurich, Switzerland, University of Kuopio, Finland, Melbourne University, and University of Adelaide, Australia. His most recent publications include: Globalization, Employment and Education, co-authored with Angela Little, Rutledge, London (2013), Governance, Conflict and Development in South Asia, co-edited with Eva Geherz, Sage publications, Delhi, (2014), Towards a Sane Society, Sarasavi, Nugegoda, Sri Lanka (2015). His other publications include: Globalisation, Employment and Education, (with Angela Little), London: Routledge, 2013, Governance, Conflict and Development, co-edited with Eva Gerard, Sage publications, Delhi, (2014), and Sri Lanka at Cross Roads, co-edited with Markus Mayer, Macmillan, London, 2000.

Vidya Jothi Emeritus Professor Sarath Wimalabandara Kotagama

Track chair - Natural environment



Having graduated in Marine Ecology in 1974 from University of Colombo. Purseued my dream to become an Ornithologist with a PhD in 1982 from University of Aberdeen, Scotland.

Academic since 1974, at University of Colombo and at the Open University of Sri Lanka. First Sri Lankan Professor in Environment at University of Colombo. Over 100 peer reviewed publications, Author of 25+ books in English and Sinhala. Recipient of Presidents Science Research Award, since 2004.

Member of the Environment Council (12 years, Chairman for 6yrs), Board Member of the Authority for 06 years; Member /North Western Environmental Authority Board 2004 -to date. Was the Director of Wildlife Conservation from 1989 to 1992. Member of the Biodiversity Experts Committee, since 1996 - 2015, including Chairmen for 02 terms (06 yrs); Author of the National Wildlife Policy, National Wetland Policy and active contributor to the Environment, Environment Education and Land Policy.

Recipient of over 16 National awards, including the highest award Vidya Jothi (2017); President Lifetime "Haritha abimani" Award for Environment (2016); National Exemplary Citizens Award (2011); "Nijabima Harasara" (2011); "Desha Mamya Parisara vedi Samaja Daja Deshamanya" (2007), and "Sabaragamuwa Sarasavi Keerthi Sri" (2005), and **03 International awards** "Love Nature interpreter" (2015) Nagoya Prefecture, Japan; Distinguish Achievements Award for extraordinary service for Conservation (2003), Society for Conservation Biology, USA; and Outstanding Voluntary Service Certificate, International year of Volunteers (2001) -UNDP/GEF/ UNR/GEFSGP.

Professor Ajith de Alwis

Track chair - Built Environment & Cross cutting theme 3- Research, Inventions and Innovations

Prof Ajith de Alwis PhD (Cambridge), BSc Eng (Moratuwa), MBA (PIM-USJP), FNASSL completed his Ph.D. at University of Cambridge, UK post completing his B.Sc. (Eng) honours from University of Moratuwa. MBA from PIM of University of Sri Jayewardenepura. Post doctoral Research Fellow at University of Reading, UK and Visiting Scientist at the Indian Institute of Science (IISc) in Bangalore.

Senior Professor in the Department of Chemical and Process Engineering at the University of Moratuwa and was also the former Director of the University of Moratuwa-Cargills Food Process Development Incubator, A Science team leader for Sri Lanka Institute of Nanotechnology (SLINTEC), Project Director of Coordinating Secretariat for Science, Technology and Innovation (COSTI) Sri Lanka, Intellectual Property Advisory Commission as a member and also a Governing Council member of the National Institute of Occupational Safety and Health.

Columnist to the Daily FT on innovations, Science, Technology and National Development.

Professor Dilanthi Amaratunga

Track chair - Resilience

Professor Dilanthi Amaratunga holds the chair in Disaster Risk Management at the University of Huddersfield, UK, where she leads it Global Disaster Resilience Centre, responsible for supporting research on disaster management portfolios. She is a leading international expert in disaster resilience with an extensive academic career that has a strong commitment to encouraging colleagues and students to fulfil their full potential. She has project managed to successful completion a large number of international research projects generating significant research outputs and outcomes. She provides expert advice on disaster resilience to national and local governments and international agencies including the United Nations Office for Disaster Risk Reduction. She is engaged in many significant research engagements around the world, in partnership with key academic and other organisational stakeholders. To date, she has produced over 400 publications, refereed papers, and reports, and has made over 100 keynote speeches in around 30 countries. Among many leadership roles, she is the joint chief editor of the International Journal of Disaster Resilience in the Built Environment and the Chair of the International Conference on Building Resilience (ICBR) series, which she co-created. In 2019, she won the prestigious Newton Prize which recognises the best research and innovation projects which create an impact socially and economically, between Indonesia and the United Kingdom from 2016 to 2019. Newton Prize is supported by the UK's Department for Business, Energy, and Industrial Strategy (BEIS). She is a member of the European Commission and UNDRR's European Science & Technology Advisory Group representing the UK, a Steering Committee member of the Frontiers of Development programme, a Collaborative Programme of The Royal Academy of Engineering, The Academy of Medical Sciences, The British Academy and The Royal Society., and a Steering Committee member of the UK Alliance for Disaster Research, motivation of which is to bring together the UK's rich and diverse disaster research community to facilitate collaboration and partnership in order to aid representation of the research community at government level in the UK and to facilitate the implementation of the Sendai Framework for Disaster Risk Reduction. She is a Fellow of the Royal Institution of Chartered Surveyors (RICS), a Fellow of The Royal Geographical Society, and a Fellow and a Chartered Manager of the Chartered Management Institute, UK.

Professor Ajantha Dharmasiri

Track chair - Cross cutting themes 1 & 2 - Governance, & Building a Robust and Resilient Supply Chain

Prof. Ajantha Dharmasiri has a rare combination of being a Chartered Manager, Chartered HR Professional and a Chartered Electrical Engineer. He is acclaimed as a conference speaker, corporate trainer, strategy consultant, author and an academic. He is the immediate past Director and Chairman of the Board of Management of Postgraduate Institute of Management (PIM), University of Sri Jayewardenepura. He is a Past President of the Chartered Institute of Personnel Management (CIPM), Sri Lanka, and was a Vice President of the Asia Pacific Federation of Human Resource Management (APFHRM). He is an Adjunct Professor at Price College of Business, University of Oklahoma. He was the editor of the pioneering Sri Lankan Journal of Management (SLJM). Being a Commonwealth AMDISA Doctoral Fellow Fulbright Postdoctoral Fellow, and a Commonwealth Postdoctoral Fellow, he is also an independent director of several boards and serves in several governing councils. He carries three decades of private and public sector experience including Unilever and Nestle, with consultancy engagements in Asia, Africa, and the Middle East. He has transitioned himself from being an "Engineer of Electrical" to an "Engineer of Hearts and Minds."

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Invited Papers

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- W A Wijewardena, Former Deputy Governor of the Central Bank of Sri Lanka

Technical Papers

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- S Abeysinghe, Verité Research Pvt. Ltd, Colombo 05, Sri Lanka
- D Abeywardana, Verité Research Pvt. Ltd, Colombo 05, Sri Lanka
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Acknowledgements

In keeping with its mandate, the National Science Foundation (NSF) took the initiative to conduct a national conference on the current pandemic entitled "COVID-19: Impact, Mitigation, Opportunities and Building Resilience". The event took place on January 27-28, 2021 in Colombo, Sri Lanka, under the theme "From Adversity to Serendipity". A total of ninety papers involving over 200 scientists and other professionals were presented. This included high ranking scientists of Sri Lankan origin from across the world.

The NSF received exceptional help and support from a number of people, organisations and other bodies, without which, a task of this nature and magnitude would have been impossible. First and foremost, the NSF wishes to express its profound gratitude to His Excellency Gotabaya Rajapaksa, President of the Democratic Socialist Republic of Sri Lanka for his gracious patronage, and Prof. G.L. Peiris, Hon. Minister of Education and Dr. Seetha Arambepola, Hon. State Minister of Skills Development, Vocational Education, Research and Innovation for gracing the occasion amid their heavy commitments and busy schedules. Internationally renowned scientists of Sri Lankan origin, namely Prof. Malik Peiris from Asia, Prof. Shanthi Mendis from Europe, Prof. Dilantha Fernando from North America, Prof. Prema-chandra Athukorale from Oceania and Prof. Mahesh Nirmalan from Africa, shared their expert knowledge as well as experiences from around the world of the failures and successes in other countries in combatting COVID-19. Their contribution which added a valuable dimension and momentum to the conference is gratefully acknowledged.

As co-editors, Prof. Dilanthi Amaratunga, Professor of Disaster Risk Reduction and Management, Global Disaster Resilience Centre, University of Huddersfield, UK, Prof. Shanthi Mendis, former Professor of Medicine, Faculty of Medicine, University of Peradeniya, Sri Lanka and former Senior Adviser, World Health Organization (WHO), Geneva, Switzerland and Prof. Prema-chandra Athukorala, Emeritus Professor of Economics, Australian National University, Canberra, Australia provided immense support to me in the editorial oversight, content evaluation and review process which contributed substantially to enhance the relevance and value of the volume.

Immediately after the conference, Associate Editors, namely Dr Palitha Abeykoon, Emeritus Prof. Siri Hettige, Prof. Dilanthi Amaratunga, Emeritus Prof. Sarath Kotagama, Prof. Ajantha S. Dharmasiri, Prof. Saroj Jayasinghe, Prof. Ajith De Alwis and Prof. Athula Sumathipala, swung into action, calling for full papers of selected abstracts and processing them with the support of a panel of competent international and national reviewers who are too many to be listed individually here, but whose names are given under "Editorial Board, Scientific Review Committee and Technical Support Staff". They have been working with great dedication and devotion amidst the manifold constraints and challenges posed by the COVID-19 pandemic and the outcome is a comprehensive volume running to more than 750 pages with 65 papers. The NSF wishes to record its profound gratitude to the Associate Editors, reviewers and contributors for their utmost commitment which enabled us to bring out the volume within a few months despite disruption caused by the pandemic. In order to complement and supplement the proceedings, several invited papers from distinguished scientists were also included. The NSF expresses its deep gratitude to them for their scholarly contribution.

Deep appreciation is owed as well to Prof. Dilanthi Amaratunga, Head, Global Disaster Resilience Centre, University of Huddersfield, United Kingdom who provided generous financial and technical support in partnership with UKRI/GCRF from the outset till the end, enabling us to bring out an imposing volume. Linked projects include: "Improving COVID-19 and pandemic preparedness and response through the downstream of multi-hazard early warning systems", funded by the UKRI/GCRF (Led by University of Huddersfield, UK, with University of Colombo, Sri Lanka; University of Moratuwa, Sri Lanka; Ministry of Health, Sri Lanka; Disaster Management Centre, Sri Lanka; and Federation of Local Government Authorises, Sri Lanka), and "Integrating pandemic,

tsunami and other multi-hazard preparedness into early warning and urban planning", funded by QR/GCRF (Led by University of Huddersfield, UK, with Ministry of Health, Sri Lanka; University of Colombo, Sri Lanka; University of Moratuwa, Sri Lanka; University of Peradeniya, Sri Lanka; State Ministry of Urban Development, Sri Lanka; Federation of Local Government Authorities, Sri Lanka; Disaster Management Centre, Sri Lanka; Intergovernmental Oceanographic Commission of UNESCO IOTWMS [Indian Ocean Tsunami Early Warning and Mitigation system]; Chamber of Commerce, Sri Lanka; Asian Disaster Preparedness Centre, Thailand; Bandung Institute of Technology, Indonesia.

The Board of Management, Director General, Additional Director, Heads of Divisions, scientific and other staff of the NSF extended their fullest support and cooperation from the inception of the conference until the publication of the volume. In addition, the NSF provided financial support for the publication of the conference proceedings as a special volume of the NSF. The editors wish to express their profound gratitude to the NSF and its staff for the unstinted support and cooperation extended without which the volume would have never seen the light of day.

The NSF is grateful to Mr. Chameera Randil, a freelancer, who did all the designs and did the formatting of the volume swiftly. Finally, Dr. Duwini Padukkage, Scientific Secretary cum Editorial Assistant, worked incessantly with great dedication and devotion from the inception of the conference till the volume was published, and the NSF is most grateful to her for her unremitting efforts.

Professor Ranjith Senaratne
Chief Editor and Chairman, National Science Foundation

July 2021

NATIONAL SCIENCE FOUNDATION

Section 1

Keynote and Plenary Papers

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

COVID-19: The virus, transmission, pathogenesis and prevention‡

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ABSTRACT

We are currently confronting the greatest challenge to global public health in over a hundred years. SARS-CoV-2 is a virus closely related to SARS-CoV-1, which caused the SARS epidemic in 2003, and both originated in bats of the Rhinolophus genus. Unlike SARS-CoV-1, SARS-CoV-2 is shed at peak levels prior to, and around the time of symptom onset; and as a consequence, transmission is maximal before the onset of symptoms and in the first few days thereafter. Furthermore, SARS-CoV-1 infections were predominantly symptomatic, while those of SARS-CoV-2 are largely asymptomatic, especially so in children and young adults. Both pre-symptomatic, as well as truly asymptomatic infections, are likely contributing to onward transmission. These features of SARS-CoV-2 requires us to go beyond the testing and case isolation that was sufficient to contain SARS-CoV-1, to get ahead of the virus transmission chain by contact tracing and quarantine. These measures need to be supplemented by physical distancing as well as face masks/face covering and hand hygiene. Large scale adaptive clinical trials are providing definitive conclusions on what therapeutics are beneficial and in which subpopulations of patients. Vaccines have been rapidly developed and appear to be safe and effective. Even so, it is unlikely that this disease will be eradicated; we will be living with this disease for many years to come. Newly emerged virus variants that appear to partially evade vaccine immunity suggest that we need a global surveillance system to detect newly emerged viral variants and inform ongoing updating of SARS-CoV-2 vaccines.

Keywords: ***SARS Coronavirus 2, COVID-19, Virology, Epidemiology, Vaccines, Treatment, Mutations***

1. INTRODUCTION

Coronavirus disease 2019 (COVID-19) is a highly contagious respiratory disease that emerged late in 2019 in Wuhan, China, rapidly spreading worldwide, to cause a pandemic which by February 2021 had caused over 100 million confirmed infections and 2 million deaths affecting most countries in the world (WHO 2021). It has led to massive economic disruption costing the global economy an estimated 10.3 trillion US$ (Editorial 2021). It has caused lasting harm to investment, human capital and the growth potential of the world economy. The debt that governments and companies have issued to help them weather the pandemic may harm future economic growth. Both the health and economic effects have disproportionately impacted the poorer segments of society, significantly increasing the global poverty.

It was caused by a novel virus, very likely emerging from insectivorous bats into the human population (Zhou et al., 2020). It is still unclear if this "spill-over" occurred directly from

‡ **Keynote speech**

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bats to humans or via an intermediate host. The global community had indeed been repeatedly warned over the past 25 years, with new viral diseases emerging with predictable regularity; examples being avian influenza H5N1 in 1997, SARS in 2003, the "swine flu H1N1 pandemic" of 2009, MERS in 2012, Ebola in 2014, Zika in 2015 (Morens & Fauci, 2020). A multi-national "Commission on a Global Health Risk Framework for the Future" convened in the aftermath of the Ebola crisis in West Africa in 2015 warned of the global lack of preparedness to face inevitable future pandemics and made a compelling case for "greater investment in countering infectious-disease threats, arguing that potential pandemics should be considered not just as important health risks but as major threats to the global economy and global security." They noted that "when the issue is framed as one of security or threat to human lives, it seems remarkable how little we spend. Pandemics arguably pose more of a threat to human lives than war, terrorism, or natural disasters. Framed as a risk to economic growth and stability, the danger is equally stark. Both the intrinsic dynamics of infectious-disease outbreaks and the behavioural and policy responses can have an immense economic impact." Their analysis estimated that economic losses from potential pandemics could amount to around $60 billion per year and suggested implementing a number of initiatives, including upgrading public health systems in low- and middle-income countries, enhancing the WHO's pandemic prevention and response capabilities, financing the WHO and World Bank contingency funds and investment in research and development, in total estimated to be about $4.5 billion per year on a recurrent basis. The Commission's report argues that reinforcing public health capabilities should be a top priority. As COVID-19 demonstrates, these estimates of impact have been too low, and their advice too late (Sands et al., 2016). When COVID-19 hit a woefully ill-prepared world, public health systems, even (indeed sometimes especially) in the developed world was poorly prepared, global supply chains were disrupted, and essential medical supplies such as personal protective equipment were in short supply. Global cooperation disintegrated. Perhaps, the one faint glimmer of hope was the very rapid scientific research collaboratio and response, which lead to rapid sharing of data, novel technologies and importantly, the development of vaccines in an unprecedented-time scale,. The first vaccines received emergency use authorization within 12 months of the virus being initially detected and its genetic code deciphered. This rapid vaccine response was partially helped by organizations such as the Coalition for Epidemic Preparedness Innovations (CEPI), a global partnership launched in 2017 to develop vaccines to stop future epidemics (CEPI 2017).

2. THE VIRUS

Covid-19 is caused by a coronavirus belonging to the sarbecovirus subgenus which includes SARS-coronavirus (which caused SARS in 2003) and other closely related coronaviruses found in *Rhinolophus* bats (Zhou et al., 2020). These are enveloped viruses and are thus relatively labile in the environment and spread by the respiratory route. This is in contrast to non-enveloped viruses (enteroviruses, noroviruses), which can survive in the environment and be spread by the faeco-oral route. They have an RNA genome, and thus virus replication is associated with a regular accumulation of mutations in the viral genome. The mutation rate is lower than that of other RNA viruses such as influenza or HIV but still allows the capacity for these viruses to adapt in new hosts or to evade host immune responses. Most viral mutations are detrimental to the virus or have no functional significance. But rarely, mutations provide a transmission or survival advantage to the virus, and these get selected and amplified in the human population, as we will discuss later.

3. EPIDEMIOLOGY AND TRANSMISSION

Unlike SARS-CoV-1, SARS-CoV-2 is shed at peak levels prior to, and around the time of symptom onset; and as a consequence, transmission is maximal prior to the onset of symptoms and in the first few days thereafter (He et al., 2020). Furthermore, SARS-CoV-1 infections were predominantly symptomatic

while those of SARS-CoV-2 are largely asymptomatic, especially so in children and young adults. Both pre-symptomatic as well as truly asymptomatic infections are likely contributing to onward transmission. These features of SARS-CoV-2 requires us to go beyond the testing and case isolation that was sufficient to contain SARS-CoV-1, to get ahead of the virus transmission chain by contact tracing and quarantine (Cowling et al., 2020). These measures need to be supplemented by physical distancing as well as face masks/face covering and hand hygiene.

Even though patients may continue to shed detectable virus RNA for many weeks, the persistence of virus RNA is not necessarily evidence of infectiousness because the infectious virus that can be cultured is not detectable beyond nine days after onset in most mild and asymptomatic infections, though it may be infectious for longer in severely ill or immunocompromised patients (Perera et al., 2020). Transmission can take place via large or small respiratory droplets and perhaps, also via indirect contact. Asymptomatic infections may also contribute to transmission although the efficiency of transmission may be less that from pre-symptomatic or symptomatic infections. Since the airborne transmission is most efficient within the short range of the infectious source (i.e. usually maximal within 2 meters), social distancing is an effective mode for the prevention of transmission. Face masks reduce the release and spread of infectious airborne droplets from infected persons, as well as providing protection to the wearer of the mask (Leung et al., 2020).

4. TREATMENT

Most patients have a mild clinical course and recover uneventfully. Severe disease is more commonly seen in older people and those with underlying co-morbidities (Cevik et al., 2020). Since most patients recover uneventfully, treatments or vaccines need to be carefully assessed in well-designed double-blinded, randomised controlled clinical trials; otherwise, the natural course of the illness and recovery may be mistaken for therapeutic efficacy. The Recovery trial in the UK is an excellent example of a well coordinated randomised adaptive clinical trials which has so far identified the two therapeutics that provide significant clinical benefit, i.e. dexamethasone and the IL-6 inhibitor "TocilizumabR". Equally important, they identified a number of candidate drugs, such as hydroxychloroquine, have no therapeutic benefit (RECOVERY 2020).

5. VACCINES

Classical approaches to viral vaccines include inactivated whole virus vaccines, live attenuated vaccines, and protein subunit vaccines, and all of these have been explored as strategies for COVID-19. In addition, a number of novel strategies have also been explored, including adenovirus vectored vaccines, mRNA vaccines and DNA vaccines (Krammer, 2020). Based on previous studies with SARS-CoV-1, many COVID-19 vaccines have targeted the virus spike protein as the protective immunogen, and these include the RNA vaccines, adenovirus vectored vaccines and protein subunit vaccines. There are also the whole virus inactivated vaccines that contain multiple viral proteins. The urgency of the pandemic has led to a plethora of vaccine candidates being developed. As of February 2021, four vaccines have been approved, six have received emergency use authorization and 84 are in different phases of human clinical trials; 20 in phase 3, 27 in phase 2 and 37 in phase 1 clinical trials (Table). Two RNA vaccines (BNT162bs and mRNA1273), an adenovirus 26 prime adenovirus five boost (Gamaleya Sputnik V) and protein (Novavax) vaccines have demonstrated vaccine efficacy >90%. A chimpanzee adenovirus vectored vaccine (Oxford-Astra Zeneca) and adenovirus 26 vectored vaccine (J&J) have vaccine efficacy of approx. 70% and 72% respectively. Whole virus inactivated vaccines Sinopharm and Sinovacc have vaccine efficacy of 79% and 50%, respectively (Table). All of these vaccines require two vaccine doses, with the exception of the J&J vaccine, which is a single-dose vaccine. The mRNA vaccines require ultra-low temperature storage while the other vaccines

Table 1. COVID-19 Vaccines with phase 3 clinical trial data

	Pfizer Biontech BNT162b2 Comirnaty	**Moderna* mRNA-1273**	**Oxford-Astra Zenica**	**Gamaleya Sputnik V**	**J&J Ad26, COV2.5**	**Novavax**	**Sinopharm**	**Sinovac Corona Vac PiCoVacc**	**Bharat Covaxin**
Platform	mRNA	mRNA	Chimpanzee Adeno	Ad26 →Ad5	Ad26	Protein	Whole virus inactivated	Whole virus inactivated	Whole virus inactivated
Point estimate of vaccine efficacy	95%	94.5%	70.4%	92%	72% in USA 57% S Africa	90% UK 60% S Africa (exclude HIV)	79%-86%	50% (depends end point)	NK
No doses (interval between doses)	2 (3 wks)	2 (4 wks)	2 (4 wks)	2 (3 wks)	1	2	2 (3 wks)	2 (2 wks)	2 (4 wks)
Cold Chain	- 80C 2-8C 5 days	-20 C 2-8C for 30 days	2-8C	2-8C	-20C 2-8C for 3 mon	2-8C	2-8C	2-8C	2-8 <1 weeks RT
Licensure approved/EUA	USA / UK / EU / Israel, other	USA, UK, EU, other	UK, EU, India, other	Russia, other			China, UAE, Bahrain, Egypt, other	China, Brazil, other	India

can be stored at 2-8oC, i.e. the storage required by many other routine vaccines hitherto used in humans.

There are a number of knowledge gaps in regard to these vaccines at present (Peiris & Leung, 2020). Since follow up periods are still limited to a few months, the duration of protection is still not well defined. The correlates of protection are also yet unknown. However, it is known that virus neutralizing antibody titres are one correlate of protection, although the minimal antibody titers required for protection remain unclear. After natural COVID-19 disease, it is estimated that neutralizing antibody will remain detectable for over an year, although this is likely to be shorter after asymptomatic infection (Lau et al., 2021). Furthermore, immune memory is likely to persist, even after neutralizing antibody may have declined. Since most of the COVID-19 vaccines elicit neutralizing antibody titers of greater magnitude than natural infection, it is reasonable to expect that vaccine-mediated protection is likely to last longer than one year at least. Since the end-points in vaccine clinical trials have been protection from symptomatic illness, the extent of protection against asymptomatic infection and transmission is unclear.

Overall, COVID-19 vaccines have the potential to have a major impact on the containment of morbidity and mortality associated with the pandemic. It is unlikely that vaccines can eradicate SARS-CoV-2 infection because it is likely to become an endemic disease. However, vaccines have the potential to make this disease a relatively mild illness with which we can co-exist. In order to achieve this, vaccines need to be rapidly made available globally; not restricted to a few wealthy countries. As the Director General of the WHO Dr Tedros Adhanom Ghebreyesus has stated, "Vaccine allocation must not become a zero-sum game. Vaccine nationalism is not just morally indefensible. It is epidemiologically self-defeating and clinically counterproductive." He says, "The pandemic will not be over anywhere until it is over everywhere. This is the reality of an interconnected world, and that reality can be met only by a reaffirmation of solidarity and an inclusive public-health order that distributes vaccines globally, quickly, and equitably. To the virus, we are all one "herd". To beat it, we must act as one community." (Tedros, 2021)

6. VIRAL VARIANTS OF CONCERN

The recent emergence of viral variants has posed additional concerns. Viral variants with a mutation in the spike protein D614G emerged in the spring of 2020 and has increased binding affinity to viral receptors, increase viral replication competence in human respiratory epithelium, increased transmissibility between humans and has rapidly become the dominant

virus strain globally (Baric, 2020). More recently, virus variants of concern, B.1.1.7, 501Y.V2 and P1, have been first detected in the UK, South Africa and Brazil, respectively, with multiple amino acid substitutions in the spike protein (Fontanet et al., 2021). Viral variant B.1.1.7 has increased transmissibility between humans and is associated with a slight increase in disease severity. It is now rapidly becoming the dominant strain in areas into which it has been introduced. Viral variant 501Y.V2 and P1 have a characteristic mutation E484K which appears to be associated with partial evasion from neutralization with convalescent sera and vaccine immune sera elicited with the previous virus strains, i.e. they appear to be neutralization escape mutants (Wu et al., 2021). There is evidence that these virus variants are associated with reduced vaccine efficacy and are thus a cause of particular concern. The ongoing emergence of these variant viruses highlights the need for a global surveillance system to monitor viral variants. This requires an extensive and systematic effort to genetically sequence viruses across the world and share these sequences globally to detect novel SARS-CoV-2 variants of concern. As they are detected, these viral variants will have to be biologically and epidemiologically characterized to assess which of these variants are of public health concern. A similar global surveillance system is already in place to monitor antigenic changes in influenza viruses that inform influenza vaccine strain selection. Such information is likely needed to update COVID-19 vaccines on an ongoing basis to keep pace with emerging viral mutants.

7. CONCLUSIONS

The pandemic has highlighted a number of issues that are pertinent beyond COVID-19. It has highlighted that novel viruses continue to emerge and have the potential to cause a massive impact on human health and well-being and cause dislocation of the global economy. The factors that predispose to such novel emerging infections are well known and are mainly related to human activities, such as the wild game animal trade, intensive livestock industry, urbanization, international travel and trade, environmental and ecological degradation and climate change (Morens & Facui, 2020). It is important that we change some of these risk behaviours or modify them to mitigate and minimise these risks. This also involves the use of a "One Health" approach to these other problems. One health is defined as the "collaborative efforts of multiple disciplines working locally, nationally and globally to attain optimal health for people, animals and the environment". The COVID-19 pandemic is also an illustration of the limits of human hubris, where we have assumed unlimited "economic growth" without costing the impacts such grown has on our environment. In "nature", nothing grows forever. Blind pursuance of the "GDP" growth without costing its impact on our planetary resources risk rupturing the limits of planetary sustainability. A new economic paradigm is urgently needed (Raworth, 2017). Otherwise, the insidious crises of climate change, environmental pollution and the degradation of our ecosystems will lead to a catastrophic outcome. Rene Dubos presciently warned that "at some unpredictable time and in some unforeseeable manner, nature will strike back." COVID-19 illustrates a relatively minor experience in how "Nature" strikes back.

ACKNOWLEDGEMENTS

This work was supported by the US National Institutes of Health (contract no. HHSN272201400006C)

REFERENCES

Baric, R.S. (2020). Emergence of a Highly Fit SARS-CoV-2 Variant. *N Engl J Med*. 383(27):2684-2686. doi: 10.1056/NEJMcibr2032888.

Cevik, M., Kuppalli, K., Kindrachuk, J., Peiris, M. (2020). Virology, transmission, and pathogenesis of SARS-CoV-2. *BMJ*. 371:m3862. doi: 10.1136/bmj.m3862. PMID: 33097561.

Coalition for Epidemic Preparedness Initiative. https://cepi.net/ (accessed 18 Feb 2021)

Cowling, B.J., et al. (2020). Impact assessment of non-pharmaceutical interventions against coronavirus disease 2019 and influenza in Hong Kong: an observational study. *Lancet Public Health*.5(5):e279-e288. doi: 10.1016/S2468-2667(20)30090-6.

Editorial The pandemic's price tag. The Economist, Jan 9, p61; 2021 https://www.economist.com/finance-and-economics/2021/01/09/what-is-the-economic-cost-of-covid-19. (accessed 18 Feb 2021)

Fontanet, A., Autran, B., Lina, B., Kieny, M.P., Karim, S.S.A., Sridhar, D. (2021). SARS-CoV-2 variants and ending the COVID-19 pandemic. *Lancet*. S0140-6736(21)00370-6. doi: 10.1016/S0140-6736(21)00370-6.

He, X., et al. (2020). Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med*. doi: 10.1038/s41591-020-0869-5. [Epub ahead of print].

Krammer, F. (2020). SARS-CoV-2 vaccines in development. *Nature*. 586:516-527.

Lau, E.H.Y., et al. (2021). Neutralizing antibody titres in SARS-CoV-2 infections. *Nat Commun.* 12(1):63. doi: 10.1038/s41467-020-20247-4.

Leung, N.H.L., et al. (2020). Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nat Med.* 26(5):676-680. doi: 10.1038/s41591-020-0843-2.

Morens, D.M. & Fauci, A.S. (2020). Emerging Pandemic Diseases: How We Got to COVID-19. *Cell.* 182(5):1077-1092. doi: 10.1016/j.cell.2020.08.021.

RECOVERY Trial. https://www.recoverytrial.net/results. (accessed on 18 Feb 2021)

Peiris, M., Leung, G.M. (2020). What can we expect from first-generation COVID-19 vaccines? *Lancet*. 396(10261):1467-1469. doi: 10.1016/S0140-6736(20)31976-0.

Perera, R.A.P.M., et al. (2020.) SARS-CoV-2 Virus Culture and Subgenomic RNA for Respiratory Specimens from Patients with Mild Coronavirus Disease. *Emerg Infect Dis.* 26(11):2701-2704. doi: 10.3201/eid2611.203219.

Raworth, K. (2017). Doughnut economics. Chelsea Green Publishing, White River Junction, Vermont.

Sands, P., Mundaca-Shah, C., Dzau, V.J. (2016). The Neglected Dimension of Global Security--A Framework for Countering Infectious-Disease Crises. *N Engl J Med.* 374(13):1281-7. doi: 10.1056/NEJMsr1600236.

Tedros, A.G. (2021). https://foreignpolicy.com/2021/02/02/vaccine-nationalism-harms-everyone-and-protects-no-one/ (accessed Feb 18 2020)

WHO Coronavirus disease (COVID-19) Dashboard. https://covid19.who.int/?gclid=Cj0KCQiAvbiBBhD-ARIsAGM48bw-6Uw8a4onXpxUltMCrL9Bj9fgw-qCXKFLYRi4r2WdR5fPjZRvIgsaAvjBEALw_wcB ((accessed 18 Feb 2021)

Wu, K., et al. (2021), Serum neutralizing activity elicited by mRNA-1273 vaccine – Preliminary report. *New Engl J Med* DOI: 10.1056/NEJMc2102179

Zhou, P., et al. (2020). A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature.* 579(7798):270-273.

The COVID-19 pandemic in Europe: The magnitude, response and impact‡

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ABSTRACT

According to epidemiological data from Europe at the end of November 2020, the COVID-19 situation is stable and under control only in six countries : Cyprus, Estonia, Finland, Greece, Liechtenstein and Norway. In all other European countries, the COVID-19 status has been labelled as `serious` by the European Center for Disease Control, based on high case notification rates and high mortality rates. Hospital and Intensive Care Unit admissions have also been increasing in sub-national areas in high-risk countries exerting substantial pressure on healthcare systems and undermining routine health service delivery.

The vast majority of European countries have implemented a range of public health measures to slow down the spread of COVID-19 infection including lockdowns, closure of businesses, schools, bars and restaurants, social distancing measures, mask-wearing mandates, handwashing, testing, tracking and quarantine, which have been moderately effective in curbing the spread of the disease. A recent analysis shows that countries that adopted lockdowns when COVID-19 cases were few experienced much better epidemiological outcomes than countries that intervened when cases were already high. At present, a tier system based on epidemiological indicators is used in some European countries to match better the degree of restrictions with the level of risk of COVID-19 transmission. Mass testing and a range of stringent interventions are implemented in regions which show high rates of infection.

In the early months of the pandemic, the infection was mostly among older adults and people with cardiovascular disease, diabetes and other chronic diseases. However, the recent surges in Covid-19 cases across Europe have been mainly due to a rise in infections among young people, with those aged between 20 and 39 accounting for about 40% of new Covid-19 cases in many countries.

As in other parts of the world, the COVID-19 health crisis and counter-measures have resulted in an economic crisis in Europe. To dampen the blow to people's livelihoods and the economy, the European Commission has adopted a comprehensive economic response to the outbreak.

The stressful working conditions have exposed the vulnerabilities of frontline health workers such as safety concerns and inadequate remuneration. COVID-19 has increased stress and anxiety mainly due to concerns for personal and financial wellbeing and job security. Measures such as quarantine, closure of public and business enterprises and lockdowns have affected many people's routine activities, livelihoods, levels of loneliness, depression, harmful alcohol and drug use,

‡ **Keynote speech**

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suicidal behavior and domestic violence. Addressing mental health issues has become a priority and will remain so in the recovery period.

The pandemic has changed health service delivery and medical education by limiting the amount of face-to-face time physicians could spend with patients and trainees. Technological interventions such as telemedicine consultations, virtual meetings, webinars and e-learning have been introduced.

The United Kingdom is the first Western country to approve a coronavirus vaccine for emergency use, and vaccination of high-risk groups has commenced. The European Medicines Agency is in the process of reviewing six vaccines and has already approved the BioNTech and Pfizer vaccine for use in Europe. Germany and France have announced plans to roll out vaccination soon after Christmas. European Union has purchased adequate vaccine doses to cover all countries in the bloc. The pandemic has imparted many lessons related to improving preparedness and response to future disease outbreaks and provided opportunities to strengthen European solidarity.

Keywords: SARS-CoV-2, COVID-19, case-fatality, pandemic, Europe

1. CURRENT SITUATION OF THE PANDEMIC IN EUROPE

Europe has been struck especially hard by the COVID-19 pandemic As shown in Table 1 and Figure 1, almost one-third of global COVID-19 cases and deaths emanated from Europe (World Health Organization, 2020a). According to epidemiological data from countries in Europe (Figure 2), at the end of November 2020, the COVID-19 situation was stable and under control only in six countries:

Table 1. COVID-19 situation by WHO Region (2)

WHO region	Total number of cases (%)	Total number of deaths (%)
Americas	37,975,799	896,318
Europe	**28,275,208 (33%)**	**616,084 (33%)**
South-East Asia	12,194,847	186,845
Eastern Mediterranean	5,097,306	124,097
Africa	2,047,423	46,116
Western Pacific	1,158,612	20,869
Global	86,749,940 (100%)	1,890,342 (100%)

Source: World Health Organization 8.1.2021 WHO Coronavirus Disease (COVID-19) Dashboard

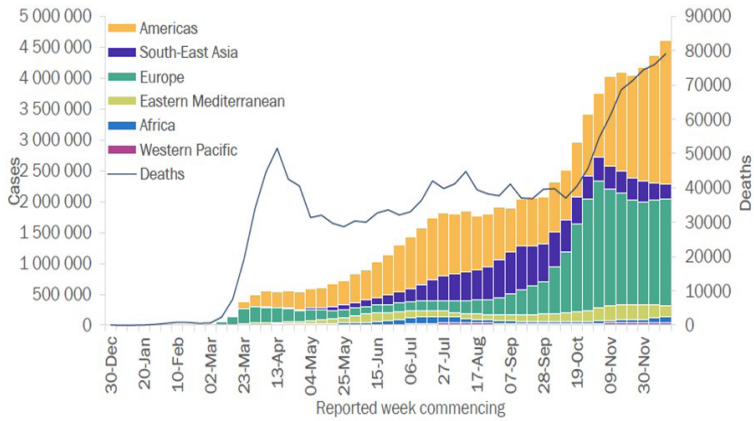

Figure 1. COVID-19 cases reported weekly by WHO Region, and global deaths, as of 20 December 2020.

Source: World Health Organization. Coronavirus disease (COVID-19) Weekly Epidemiological Update and Weekly Operational Update (1)

Figure 2. Countries of Europe (WHO European Region covers 51 countries)

(European Union countries, 27: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden. Countries in the European Economic Area, 30: European Union countries, Iceland, Norway and Liechtenstein)

Cyprus, Estonia, Finland, Greece, Liechtenstein and Norway. In 25 other European countries, the epidemiological situation has been labelled as 'serious' by the European Center for Disease Control, because of high case notification rates and high mortality rates (European Center for Disease Prevention and Control, 2020). The probability of infection for the population remains very high in Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden and the United Kingdom. As of 9 January 2021 (World Health Organization, 2020b), countries in the WHO European countries reporting the most number of cases were the Russian Federation (3 379 103), United Kingdom (2 957 476), France (2 701 658), Italy (2 237 890), Spain (2 025 560) and Germany (1 891 581) (World Health Organization, 2020b). Hospital and Intensive Care Unit admissions have also been increasing in sub-national areas in high-risk countries exerting substantial pressure on healthcare systems and disrupting the provision of routine services.

In the early months of the pandemic, in Europe as in the rest of the world, the infection was mostly among older adults and people with cardiovascular disease, obesity, diabetes, chronic respiratory disease, kidney disease and immune-compromised status (Comas-Herrera et al., 2020; Team et al., 2020; Mendis, 2020). Pre-existing medical conditions were also

associated with severe illness and admission to intensive care units (Götzinger et al., 2020). However, the recent surges in Covid-19 cases across Europe have been mainly due to a rise in infections among young people, with those aged between 20 and 39 accounting for about 40% of new Covid-19 cases in many countries. Countries that have established surveillance systems in long-term care facilities have reported that 5-6% of all residents died of COVID-19 and that they accounted for up to 72% of all COVID-19 related deaths (Comas-Herrera et al., 2020).

The spread of the SARS-CoV-2 pandemic has been globally tracked using phylogenetic analysis of viral genome sequences (Korber, 2020). SARS-CoV-2 spread was unchecked in much of Europe until mid-March when many countries introduced control measures including, travel restrictions. Member Countries of the European Union and Schengen-area countries, including Switzerland, the Netherlands, and France, reopened their borders on 15 June 2020. When border restrictions were lifted, a novel SARS-CoV-2 variant, which emerged in Spain in summer, spread to multiple countries in Europe (Hodcroft et al., 2020). At present, diverse variants of SARS-CoV-2 continue to circulate across Europe and coordinated genomic surveillance of SARS-CoV-2 will be critical for informing ongoing containment strategies.

2. HIGH LEVEL OF POLITICAL COMMITMENT IN ADDRESSING THE PANDEMIC IN EUROPE

The initial European response to the pandemic was fragmented and lethargic in providing support to countries such as Italy that struggled to cope during the first wave. Political leadership overall, was slow to recognize the need for swift action as a result of which Europe soon became the epicenter of the pandemic. However, high- level political commitment was evident when the European Council agreed on a joint European approach to covid-19 in March 2020. The Council identified four priorities areas for action: limiting the spread of the virus, provision of medical equipment, promotion of research, and dealing with the socio-economic consequences. In April, the European Commission published a roadmap on phasing out containment measures based on different epidemiological situations (European Commission, 2020a). However, countries' failure to work together on their exit strategies was one of the reasons for second waves of the pandemic. Despite high- level political commitment, the ongoing spread of covid-19 exposed significant barriers to developing a cohesive European response to the pandemic (Anderson, 2020). The desire of countries to exercise autonomy in operating their health systems, Inadequate capacity of existing coordination mechanisms such as the Health Security Committee and the European Centre for Disease Prevention and Control and legal concerns regarding the transfer of data hampered cooperation, data sharing and exchange of information between member states. Despite the European legislative framework for joint procurement of equipment and medicines when faced with cross border threats to health, few member states even introduced limits on the export of protective medical equipment such as face masks despite severe shortages elsewhere undermining solidarity with other European countries (Sánchez, 2020).

3. PUBLIC HEALTH MEASURES TO CONTAIN THE PANDEMIC

European countries have implemented a range of public health measures to slow down the spread of COVID-19 infection including lockdowns, closure of businesses, schools, bars and restaurants, social distancing measures, mask-wearing mandates, handwashing, testing, tracking and quarantine. A recent analysis shows that countries that adopted lockdowns when COVID-19 cases were few experienced much better epidemiological outcomes than those that intervened when cases were already high. A retrospective analysis in eleven European countries showed that lockdowns were effective in reducing transmission driving the reproduction number (R0) below one (Flaxman, 2020).

At the end of the first wave, the European roadmap unveiled a gradual exit strategy from lockdown situations. It had three key elements.

1. Restrictions were to be lifted when data indicated that the spread of the disease has significantly decreased and stabilized for a sustained period.

2. Sufficient health system capacity, especially to provide intensive care was to be ensured, given the risk of a second wave of infection.

3. Sufficient capacity for large scale testing and monitoring, linked to the ability to track and trace contacts of those infected was to be established before lifting restrictions.

The roadmap did not prescribe the measures that should be taken, leaving them to the responsibility of national governments. However, it emphasized that changes should be gradual and accompanied by a robust system of reporting and contact tracing, expanded testing capacity, strengthened health systems that are adequate to cope with any resurgence of infection, improved personal protection, and progress in developing new treatments.

4. THE SECOND WAVE OF COVID-19 IN EUROPE

By October 2020, second waves erupted in many European countries due to relaxation of lockdowns, public's loosening of precautionary behaviours, the arrival of cold weather and emergence of more transmissible forms of the virus (Looi, 2020). Ireland was the first country in Europe to reintroduce a lockdown on 22nd of October 2020. A strict curfew was imposed in Paris and eight other major cities in France. Due to a sharp rise in cases, Germany also imposed curfews in Berlin and four other major cities and placed Bavaria under lockdown. Spain relaxed one of the world's longest lockdowns in May but, on 21 October Spain became the first European country to pass one million cases. The Czech Republic reintroduced a second national lockdown after the country recorded nearly 12 000 positive tests in 24 hours; the worst infection rate in Europe. Belgium reported a steep rise in incidence with more than 8000 new cases each day. Already suffering the world's third worst covid-19 mortality per capita, the Belgian government closed bars and restaurants, imposed a curfew and limited gatherings to no more than four people.

Sweden is one European country which did not implement official lockdowns or mandates on mask-wearing. Although herd immunity has not been achieved without a vaccine in the past, the Swedish national strategy appears to have been crafted with the hope of protecting people through the development of herd immunity. Nonetheless, Sweden has performed worse than all Nordic countries.

During the second wave, the United Kingdom introduced a four tier system based on epidemiological indicators to match better the degree of restrictions with the level of risk of COVID-19 transmission. Mass testing and a range of stringent interventions are being implemented in regions that show high infection rates and hospital admissions and are categorized as falling into the fourth tier.

5. HIGH CASE FATALITY IN SOME EUROPEAN COUNTRIES

There are striking differences in the fatality rate of COVID-19 in countries in Europe. The three countries with the highest case fatality were France, Italy and Belgium (Table 2). The case fatality rate estimated per total cases remains the best tool to express the fatality of COVID-19, even though it might be underestimated or overestimated due to a range of factors. These factors include the population's age structure , population density, comorbidity burden, differences in testing and reporting and variation in health system capacities and societal and social psychological factors (Dongarwar & Salihu, 2020; Amoo et al., 2020). Germany's relatively low covid-19 fatality rate has been attributed partly to the swift action of political leaders and high level of testing among a wide sample of the German

Table 2. Country specific case fatality rates (18)

Country	Case fatality rate	Cases >70 years %
France	18.10	35.14
UK	16.14	32.66
Belgium	15.75	40.42
Italy	14.04	39.48
Netherlands	12.12	34.92
Spain	11.27	37.23
Sweden	7.43	21.10
Ireland	6.82	21.84

population (Stafford, 2020). An analysis focused on the impact of social relations, restrictions, and institutional trust within 25 countries in Europe showed that late reaction to the crisis and lower Institutional trust were associated with higher COVID-19 mortality (Oksanen et al., 2020). Another analysis of 20 European countries indicates that the predominant determinant of case fatality is the proportion of patients older than 70–75 years of age diagnosed with SARS-CoV-2 (European Center for Disease Prevention and Control, 2020; Hoffmann & Wolf, 2020).

6. UNPREDICTABLE BEHAVIOUR OF THE VIRUS

Soon after SARS-CoV-2 emerged from China, researchers started analyzing virus samples and posting the genetic sequence online. Despite the slow mutation rate of SARS-CoV-2, more than 12,000 mutations have already been catalogued (see www.gisaid.org). They had little or no impact on the virulence or transmissibility until new strains were identified from the United Kingdom and South Africa (Volz, 2020). The United Kingdom variant was found to be responsible for the rapid spread of the disease in South East England in December 2020 (Volz, 2020). Denmark and the Netherlands have reported a few cases with the new variant. The emergence of this 70% more transmissible strain of SARS-CoV-2 in the UK caused alarm leading many countries in Europe including France, Germany, Ireland, Austria, the Netherlands, Italy and Belgium to close their borders to travelers arriving from the United Kingdom in mid-December 2020. The virus will keep on mutating, and different SARS-CoV-2 strains have the potential to change the course of the pandemic if they gain the ability to make vaccines ineffective. Monitoring of COVID-19-vaccinated individuals needs to be ensured to identify possible vaccination failure and breakthrough infections. Virus isolates from these cases need to be sequenced and characterized genetically and antigenically, to identify strains that may have the ability to outsmart the effect of available vaccines.

Although SARS-CoV-2 is mainly transmitted between people, there have been reports of transmission between humans and animals. Several animals that have been in contact with infected humans, such as minks, dogs, domestic cats, lions and tigers, have tested positive for SARS-CoV-2 (World Health Organization, 2020c). Since June 2020 SARS-CoV-2 variants isolated from farmed minks have been isolated from twelve human cases in Denmark. The variant responsible also had moderately decreased sensitivity to neutralizing antibodies. Minks can act as a reservoir of SARS-CoV-2 passing the virus between them and pose a risk for virus spillover from mink to humans. In addition to Denmark, the Netherlands, Spain, Sweden, Italy and the United States of America have also reported SARS-CoV-2 in farmed minks. Danish authorities have taken steps to cull more than 17 million minks to limit the spread of the mink-associated variant. Members of the WHO SARS-CoV-2 Virus Evolution Working Group are working with Danish scientists on further scientific and laboratory-based studies to understand the implications of these mink associated variants in terms of available SARS-CoV-2 diagnostics, therapeutics and vaccines in development (World Health Organization, 2020c). This event highlights the critical role of strong surveillance, sampling and sequencing SARS-CoV-2 and the importance of sharing epidemiological, virological and full genome sequence data between countries and research teams.

7. OVERWHELMED HEALTH SYSTEMS

An adequate health-system capacity is crucial for responding to the pandemic. This capacity includes having a sufficient number of hospitals equipped with intensive care units and adequate numbers of health workers, community health facilities to manage patients with mild disease, medical equipment such as ventilators, personal protective equipment for staff. Notwithstanding wide-ranging disease control measures, the pandemic overwhelmed the health system capacity of many developed countries such as France. The burden was so severe during the second surge that patients from certain areas in France had to be transferred by military planes, helicopters, air ambulances and trains to Intensive Care Units in Germany, Switzerland, Austria and Luxembourg (Parsons, 2020). High-speed TGV trains were converted into mobile hospitals, with a single patient in each carriage. Helicopters were fitted with epishuttles which carried patients sealed inside and supplied with air without risk to the crew.

Due to concerns of capacity, most countries adopted triage systems in which only patients with severe disease were treated in hospital, and patients with mild disease were monitored at makeshift community facilities or at home (https://www.ecdc.europa.eu/sites/default/files/documents/nove-coronavirus-infection-prevention-control-patients-healthcare-settings.pdf; Organization for Economic Co-operation and Development, 2020). Germany was an exception. Before the COVID-19 outbreak, the country already had 34 critical care beds per 100 000 population (Organization for Economic Co-operation and Development, 2020). Thus, Germany's intensive care units were well under capacity even during the peak of the outbreak.

All over the world and in Europe, COVID-19 has changed health service delivery and medical education by limiting the amount of face-to-face time physicians could spend with patients and trainees. Technological interventions such as telemedicine consultations, virtual meetings, webinars and e-learning have been introduced. Driven by need, authorities have developed regulatory guidance to successfully navigate the challenging issues of cybersecurity and patient privacy related to digital health.

8. COVID-19 AND NON-COMMUNICABLE DISEASE CONDITIONS

Noncommunicable diseases such as cardiovascular diseases, cancer, diabetes and chronic respiratory diseases account for an estimated 89% of deaths and 84 per cent of life-years lost due to disability in the WHO European Region. Among adults, an estimated 23 per cent have raised blood pressure, 7 per cent have raised blood glucose, and 59 per cent are overweight or obese (Global Health Observatory data repository, 2016). People with cardiovascular disease and cardiovascular risk factors such as hypertension, diabetes and obesity also had increased susceptibility to COVID-19 and a higher risk of becoming severely ill or dying from COVID-19. People with noncommunicable diseases were also negatively impacted by the reduction of routine outpatient and inpatient health services, delays in diagnosis, and interruption in the supply of medicines. There were delays in care-seeking for acute episodes, such as heart attack and stroke, particularly during curfew times and lockdowns (World Health Organization, 2020d).

The stressful working conditions have exposed the vulnerabilities of frontline health workers such as safety concerns and inadequate remuneration. Surveys conducted in several countries including Belgium, France and Italy, have found that COVID-19 resulted in elevated rates of stress and anxiety mainly due to fear of illness, concerns for personal and financial wellbeing and job security. Sickness, loss of loved ones, control measures such as quarantine, isolation, closure of public and business enterprises and lockdowns have adversely affected public mental health (Brooks et al., 2020; Lima et al., 2020; Thome et al., 2020). Vulnerable people have experienced

increasing levels of loneliness, anxiety and depression, harmful alcohol and drug use, suicidal behavior and domestic violence. Addressing mental health issues has become a priority and will remain so in the recovery period.

9. ECONOMIC AND ENVIRONMENT IMPACT OF COVID-19

As in other parts of the world, the COVID-19 health crisis and countermeasures have resulted in an economic crisis in Europe with varying economic losses in different countries. Based on the size of the decline in the Gross Domestic Product (GDP), the five most-affected countries were Croatia (-13.4 per cent), Spain (-12.5 percent), Ireland (-12.1 per cent), France (-11.7 percent) and Italy (-11.5 per cent) (Sapir, 2020). The five least-affected countries were Sweden (-6.5 per cent), Denmark (-6.7 per cent), Germany (-7.4 per cent), Finland (-7.8 per cent) and Poland (-7.9 per cent). It has been estimated that countries in the European Union will suffer an average GDP loss of nearly 10 per cent in 2020, with no country suffering a loss of less than 6 per cent. The sternness of lockdown measures, the share of tourism in the economy and the quality of governance were the key determinants that explained differences in economic losses in different countries (Sapir, 2020). It has been estimated that 55 per cent of small and medium businesses in Europe, which contribute significantly to the economy and account for more than two-thirds of the workforce could close down by the end of 2020 (European Commission, 2020b).

The European Alps make up more than a third of the world's ski resorts and generate around €28bn in revenues during the ski season making a significant contribution to the tourism market in Europe. Ski resorts across the Alps -in Austria, France, Germany and Italy- were closed in mid-December to limit the spread of the virus, crushing winter tourism. Meanwhile, the Swiss government has decided to keep it's ski resorts open, rankling many neighbouring alpine countries that are ending 2020 in a state of lockdown.

To dampen the blow to people's livelihoods and the economy, the European Commission has adopted a comprehensive economic response to the outbreak. On 21 July 2020, a €750 billion Recovery and Resilience Fund was set up to help all European Union countries recover from the COVID-19 crisis (European Council, 2020). Countries have to prepare national recovery and resilience plans setting out their reform and investment agendas, which will then be assessed by the European Commission against pre-agreed criteria.

There have been a few short-term positive impacts on Europe's environment, according to an assessment by the European Environment Agency (EEA). These include temporary improvements in air quality, lower greenhouse gas emissions and lower noise pollution levels (European Environment Agency, 2020). However, the assessment also stresses that there have been negative consequences, such as increased use of single-use plastics.

10. VACCINES, RESEARCH AND DEVELOPMENT

The United Kingdom is the first Western country to approve a vaccine against SARS-CoV-2 for emergency use. It has already vaccinated about a million people in high-risk groups (Mahase, 2020). Although Russia started administering the Russian Sputnik V vaccine to its citizens earlier, it has not been internationally approved

(Gamaleya Research Institute of Epidemiology and Microbiology, Russian Direct Investment Fund, 2020; Balakrishnan, 2020). The United Kingdom uses the Pfizer and BioNTech mRNA vaccine, which was found to be up to 95% effective 28 days after the first dose in a phase III trial (https://www.pfizer.com/news/press-release/pressrelease-detail/pfizer-and-biontech-conclude-phase-3-study-covid-19- vaccine). Two other less costly vaccines, Astra-Zeneca and Moderna, are also seeking approval from the UK regulators (Voysey,2020; https://investors.modernatx.com/node/10316/ pdf; https://www.astrazeneca.com/).

In late December, the European Commission granted a conditional marketing authorization to Pfizer and BioNTech vaccine to prevent COVID-19, in individuals 16 years of age and older, following the approval of the vaccine by the European Medicines Agency's Committee for Medicinal Products for Human Use. The conditional marketing authorization is valid in all 27 member states of the European Union. However, the European Medicines Agency estimates, that it might take at least until the beginning of 2021 before a vaccine against COVID-19 is available in sufficient quantities to enable widespread use in Europe.

Most countries in Europe are planning to start the initial phase of vaccination in January 2021, starting with nursing home residents and high-risk care workers. The second phase will expand to those over 65 years, and any healthcare workers over the age of 50 who are considered vulnerable. The third phase is scheduled to start by spring targeting people under 65 and all other healthcare workers. Phase four will prioritize people who are most exposed to the virus in their careers. The final phase will expand the programme to all citizens above 18 years, between April and June of 2021 (Bingham, 2021; Joint Committee on Vaccination and Immunisation, 2020).

The United Kingdom Joint Committee on Vaccination and Immunisation has recommended that the second dose of both vaccines can be delayed to 12 weeks for public health benefit in the context of limited supplies (Joint Committee on Vaccination and Immunisation, 2020). For the AstraZeneca/Oxford vaccine the shifting of the second dose has some evidence from the trials while for the Pfizer/BioNTech vaccine the position is less secure.

11. LESSONS AND OPPORTUNITIES TO RESHAPE PANDEMIC PREPAREDNESS OF EUROPE

The pandemic has exposed weaknesses in the public health capacity to respond to emergencies. Even though most countries in Europe are well resourced, as of 8 January 2021, of over 86 749 940 COVID-19 cases (with 1 890 342 deaths) worldwide, countries in the WHO European Region accounted for 28 275 208 cases, (with 616 084 deaths), approximately one-third of the global COVID-19 burden (Table 1). Many European countries also had high case fatality rates (Table 2) (Oksanen, 2020). Europe and indeed the world, need to learn from the successes and failures in responding to the of the COVID-19 pandemic and improve the ability to face future infectious disease outbreaks (Mendis, 2020).

First, **Europe needs to revamp the public health infrastructure and pandemic preparedness and response.** The COVID-19 exposed weaknesses in the public health infrastructure, including in prevention and surveillance systems and human resources. A robust pandemic preparedness plan must include better testing, contact tracing, quarantine and isolation capabilities that can swiftly respond to growing demand.

Second, **public health policy-making and implementation processes need to be reformed.** As demonstrated by the response to the pandemic, better collaboration between political decision-makers, public health professionals and the public based on mutual respect and understanding is essential for implementing a cohesive and effective prevention and control strategy to address outbreaks.

Third, steps need to be taken to **address health inequalities.** COVID-19 spread using people with comorbidities and the elderly and disproportionately affected vulnerable populations, a reminder of the importance of addressing health inequalities and protecting disadvantaged segments of populations.

Fourth, **investment in health systems, research and development need to be increased.** The pandemic overwhelmed the capacity of health care workers and health systems in most countries. Many, if not most, COVID-19–related deaths particularly in health workers could have been prevented if there were adequate supplies of Personal

Protective Equipment, hospital beds and equipment for Intensive Care. Ending this pandemic and responding to future pandemics will require further advances in treatment and unprecedented commitment and resource allocation to health research including genome sequencing, vaccine development and use of robotics and artificial intelligence (Bhaskar et al., 2020; Adly et al., 2020).

Finally, **countries could work more cohesively together and in solidarity with all other countries to promote common interests in health.** The pandemic demonstrated that to contain infectious agents that cross borders, national measures alone are insufficient. Coordinated and transparent efforts are needed across the world to limit the spread of infectious diseases, acquire and distribute personal protective equipment, medicines, and vaccines and share data and information.

Although several vaccines have been approved for worldwide use, administering the vaccine to cover a high percentage of the population in all countries in Europe will require resources, time and strong solidarity. Even with an effective vaccination program, Europe will not be safe until the rest of the world is safe (Mendis, 2020). The public health crisis caused by the COVID-19 pandemic is likely to be brought under control in 2022 when transmission of the virus is halted worldwide through the widespread use of a vaccine. A longer period of time will be required for sustained recovery of social and economic crises.

REFERENCES

Adly, A.S., Adly, A.S., Adly, M.S. (2020). Approaches Based on Artificial Intelligence and the Internet of Intelligent Things to Prevent the Spread of COVID-19: Scoping Review. *J Med Internet Res.* 2020 Aug 10;22(8):e19104. doi: 10.2196/19104. PMID: 32584780; PMCID: PMC7423390

Amoo, E.O., Adekeye, O., Olawole-Isaac, A., Fasina, F., Adekola, P.O., Samuel, G.W., et al. (2020). Nigeria and Italy divergences in coronavirus experience: impact of population density. *Sci World J.* 2020;21:8923036.

Anderson, M., Mckee, M., Mossialos, E. (2020). COVID-19 exposes weaknesses in European response to outbreaks. *BMJ* 2020;368:m1075.

AstraZeneca. AZD1222 vaccine met primary efficacy endpoint in preventing COVID-19. Nov 23, 2020. https://www.astrazeneca.com/media-centre/press releases/2020/azd1222hlr.html

Balakrishnan, V.S. (2020). The arrival of Sputnik V. *Lancet Infect Dis.* 2020;20(10):1128. doi:10.1016/S1473-3099(20)30709-X

Bhaskar, S, Bradley, S., Sakhamuri, S., Moguilner, S., Chattu, V.K., et al. (2020). Designing Futuristic Telemedicine Using Artificial Intelligence and Robotics in the COVID-19 Era. *Front Public Health.* 2020 Nov 2;8:556789. doi: 10.3389/fpubh.2020.556789. PMID

Bingham, K. (2021) The UK Government's Vaccine Taskforce: strategy for protecting the UK and the world. *Lancet* 2021:397:68-70

Brooks, S., Webster, R., Smith, L., Woodland, L., Wessely, S., Greenberg, N., & Rubin, G. J. (2020). The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *The Lancet Psychiatry*, 2020(395), 912–920.

Comas-Herrera, A., Zalakaín, J., Lemmon, E., Henderson, D., Litwin, C., Hsu, A.T., et al. (2020). Mortality associated with COVID-19 outbreaks in care homes: early international evidence [Internet]. London: International Long-term Care Policy Network (ILPN) and Care Policy and Evaluation Centre (CPEC) at the London School of Economics and Political Science (LSE); 2020 [updated 14 October 2020; cited 15 October 2020]. Available from: https://ltccovid.org/2020/04/12/mortality-associated-with-covid-19-outbreaks-in-care-homes-early-international-evidence/.

Dongarwar, D., Salihu, H.M. (2020). COVID-19 pandemic: marked global disparities in fatalities according to geographic location and universal health care. Int *J MCH AIDS*. 2020;9:213–6.

European Center for Disease Prevention and Control. (2020). "COVID-19 situation update worldwide, as of 18 December 2020.

European Center for Disease Prevention and Control. (2020). Threat Assessment Brief: Rapid increase of a SARS-CoV-2 variant with multiple spike protein mutations observed in the United Kingdom. 20 Dec 2020

European Commission. (2020a). Coronavirus: European roadmap shows path towards common lifting of containment measures. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_652

European Commission. (2020b). Coronavirus crisis: "Commission will use all the tools at its disposal to make sure the European economy weathers the storm." https://ec.europa.eu/commission/presscorner/detail/en/IP_20_440

European Council. (2020) 'Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020)'. https://www.consilium.europa.eu/en/press/press-releases/2020/07/21/european-council-conclusions-17-21-july-2020/

European Environment Agency. (5 November 2020). Briefing: COVID-19 and Europe's environment; impact of a global pandemic.

Flaxman, S., Mishra, S., Gandy, A. et al. (2020). Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe. *Nature* 584, 257–261 (2020). https://doi.org/10.1038/s41586-020-2405-7

Gamaleya Research Institute of Epidemiology and Microbiology, Russian Direct Investment Fund. (Nov 11, 2020). The first interim data analysis of the Sputnik V vaccine against COVID-19 phase III clinical trials in the Russian Federation demonstrated 92% efficacy. https://sputnikvaccine.com/newsroom/pressreleases/the-firstinterim- data-analysis-of-the-sputnik-v-vaccine-against-covid-19- phase-iii-clinical-trials-/ .

Global Health Observatory data repository (online database) Geneva. (2016). World Health Organization. 2016 Observatory data repository [online database]. Geneva: World Health Organization https://www.who.int/data/gho

Götzinger, F., Santiago-García, B., Noguera-Julián, A., Lanaspa, M., Lancella, L., Calò Carducci, F.I., et al. (2020). COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. *The Lancet Child & adolescent health*.

Hodcroft, E.B., Zuber, M., Nadeau, S., et al. (2020). Emergence and spread of a SARS-CoV-2 variant through Europe in the summer of 2020. Preprint. *medRxiv*. 2020; 2020. 10.25.20219063. Published 2020 Nov 27. doi:10.1101/2020.10.25.20219063

Hoffmann, C., Wolf, E. (2020). Older age groups and country-specific case fatality rates of COVID-19 in Europe, USA and Canada. *Infection*. https://doi.org/10.1007/s15010-020-01538-w

Infection prevention and control for the care of patients with 2019-nCoV in healthcare settings. European Centre for Disease Prevention and Control website. https://www.ecdc.europa.eu/sites/default/files/documents/nove-coronavirus-infection-prevention-control-patients-healthcare-settings.pdf. Published 2020.

Joint Committee on Vaccination and Immunisation (JCVI). (30 December 2020). Priority groups for coronavirus (COVID-19) vaccination: advice from the JCVI. Department of Health and Social Care. Published 30 December 2020. Last updated 6 January 2021.

Korber, B. et al. (2020). Tracking changes in SARS-CoV-2 Spike: evidence that D614G increases infectivity of the COVID-19 virus. *Cell* 182, 812–827 (2020).

Lima, C., Carvalho, I. P., Lima, A., et al. (2020). The emotional impact of coronavirus 2019-Ncov (new coronavirus disease). *Psychiatry Research*, 287, 112915.

Looi, M.K. (2020). Covid-19: Is a second wave hitting Europe? *BMJ*. 2020 Oct 28;371:m4113. doi: 10.1136/bmj.m4113. PMID: 33115704.

Mahase, E. (2020). Covid-19: UK approves Pfizer and BioNTech vaccine with rollout due to start next week. *BMJ*. 2020 Dec 2;371:m4714. doi: 10.1136/bmj.m4714. PMID: 33268330.

Mendis, S. (1 November, 2020). The COVID-19 Story. No one is safe unless everyone is safe: Prevent future pandemics. ISBN: 978-2-8399-3090-1 (e book)

Mendis, S. (28 April, 2020) The COVID-19 pandemic: Why did the world fail to prevent it. Daily Mirror online 28 April 2020 http://www.dailymirror.lk/news-features/ The-COVID-19 - pandemic-Why-did-the-world-fail-to-prevent-it/131-187342

Mendis, S., (2020) Review article: Cardiovascular disease in the context of COVID-19 epidemic. International Journal of Noncommunicable Diseases. 2020;5;2;49-57

Moderna. Moderna's COVID-19 vaccine candidate meets its primary efficacy endpoint in the first interim analysis of the phase 3 COVE study. Nov 16, 2020. https://investors.modernatx.com/node/10316/ pdf

Oksanen, A., Kaakinen, M., Latikka, R., Savolainen, I., Savela, N., Koivula, A. (2020). Regulation and trust: 3-month follow-up study on COVID-19 mortality in 25 european countries. *JMIR Public Health Surveill*. 2020;6:e19218.

Organization for Economic Co-operation and Development. (2020) Beyond containment: health systems responses to COVID-19 in the OECD. April 16, 2020. https://www.oecd.org/coronavirus/policyresponses/ beyond-containment-health-systems-responses-to-covid-19-in-the-oecd-6ab740c0/

Parsons, A. (2020). Coronavirus: how Germany is helping other European nations transport covid-19 patients. 2020. https://news.sky.com/story/coronavirus-how-germany-is-helping-other-european-nations-transport-covid-19-patients-11970745

Pfizer. Pfizer and Biontech conclude phase 3 study of COVID-19 vaccine candidate, meeting all primary efficacy endpoints. (18 November, 2020). https://www.pfizer.com/news/press-release/pressrelease- detail/pfizer-and-biontech-conclude-phase-3-study-covid-19-vaccine

Sánchez, N. E. (2020). Coronavirus: EU ministers urge members to share supplies. https://euobserver.com/social/147659

Sapir, A. (2020). 'Why has COVID-19 hit different European Union economies so differently?', Policy Contribution 2020/18, Bruegel

Stafford, N. (2020). Covid-19: Why Germany's case fatality rate seems so low. *BMJ.* 2020;7:m1395.

Team, E.P.H.E., Danis, K., Fonteneau, L., Georges, S., Daniau, C., Bernard-Stoecklin., S, et al. (2020). High impact of COVID-19 in long-term care facilities, suggestion for monitoring in the EU/EEA, May 2020. *Euro Surveill.* 2020;25(22).

Thome, J., Deloyer, J., Coogan, A.N., Bailey-Rodriguez, D., da Cruz, E., Silva, O.A.B. et al. (2020). The impact of the early phase of the COVID-19 pandemic on mental-health services in Europe. *World J Biol Psychiatry*. 2020 Nov 4:1-15. doi: 10.1080/15622975.2020.1844290. Epub ahead of print. PMID: 33143529.

Volz, E., Hill, V., McCrone, J.T., Price, A. et al. (2020). Evaluating the Effects of SARS-CoV-2 Spike Mutation D614G on Transmissibility and Pathogenicity. *Cell.* 2020 Nov 19:S0092-8674(20)31537-3. doi: 10.1016/j.cell.2020.11.020. Epub ahead of print. PMID: 33275900; PMCID: PMC7674007.

Voysey, M., Clemens, S.A.C., Madhi, S.A., Weckx, L.Y., Folegatti, P.M .et al. (2020) Safety and efficacy of the ChAdOx1 nCoV-19 vaccine (AZD1222) against SARS-CoV-2: an interim analysis of four randomised controlled trials in Brazil, South Africa, and the UK. *Lancet*. 2020 Dec 8:S0140-6736(20)32661-1. doi: 10.1016/S0140-6736(20)32661-1

World Health Organization. (2020a). Coronavirus disease (COVID-19) Weekly Epidemiological Update and Weekly Operational Update Dec 2020 https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports

World Health Organization. (2020b). Coronavirus disease Dashboard (9.1.21). WHO Coronavirus Disease (COVID-19) Dashboard

World Health Organization. (2020c). SARS-CoV-2 mink-associated variant strain – Denmark. Emergency preparedness and response. Disease Outbreak News: Update 3 December 2020. https://www.who.int/csr/don/03-december-2020-mink-associated-sars-cov2-denmark/en/

World Health Organization. (2020d). COVID-19 and the disruption of NCD services in the European Region WHO/EURO:2020-1721-41472-56548

COVID-19: an update on clinical practice and vaccine findings from the Americas‡

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ABSTRACT

Coronavirus disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). It is currently a pandemic, and as of 14th February 2021, there have been more than 109 million cases and over 2.4 million deaths worldwide. The pandemic has had a significant impact on health care systems, socioeconomic and mental health aspects and the livelihoods of many. This paper presents certain aspects of epidemiology, clinical management, effects of COVID 19 on mental health and the important role of vaccines in controlling the pandemic.

Key words: America, COVID-19, COVID-19 vaccines, SARS-CoV-2, Treatment

1. INTRODUCTION

COVID-19 is caused by the SARS-CoV-2 virus. It has spread globally with adverse healthcare, social and economic effects in all countries (Kariyawasam et al, 2021). The direct effects include long-term hospitalization, intensive care unit admission/ventilator use, long term cognitive and physical impairment, and deaths (Rahman et al, 2020). Indirect effects include: delayed or missed cancer screening and childhood vaccination. By April 2020, cancer screenings in the United States (US), were 85% (breast cancer), 75% (colon cancer), 74% (prostate cancer) and 56% (lung cancer) lower than at the same time the previous year. In some states of the US, less than 50% of infants were up-to-date with the routine childhood vaccination schedules.

Severe acute respiratory syndrome-1 (SARS-CoV-1), Middle East Respiratory Syndrome (MERS-CoV) and Swine Acute Diarrhea Syndrome (SADS) are zoonotic coronaviruses that have caused disease epidemics in humans (SARS in 2002; MERS in 2009) and animals (SADS 2017). They are believed to have originated from bats. An epidemic affects large numbers of people within a community, population, or region (Jayasekara et al, 2020). It becomes a pandemic when it spreads over multiple countries and continents. SARS-CoV-2 infection originated in Wuhan, China, in late 2019 and then spread globally. The World Health Organization (WHO) is responsible for tracking important human diseases, and declaring an epidemic or pandemic (World Health Organisation, 2020). Several commentators felt the WHO had delayed giving COVID-19 the status of a pandemic. Once a pandemic is declared,

‡ **Keynote speech**

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governments around the world are expected to institute the necessary precautions to mitigate the spread of the disease within their countries. Unlike in 2002, when an outbreak of SARS-CoV-1 occurred in China, there is a greater level of travel between countries. High numbers of individuals travel to and from China for both work and personal reasons. High levels of inter-country travel could have contributed to the initial rapid spread of the virus to all parts of the globe.

1.1. Role of governments during a pandemic

Any action instituted by governments depends on the social norms of the country and its economic and financial resources. For example, in North America, where individual freedoms are considered 'sacred', the first actions would not be to restrict the movement of people. The essential need to wear a mask was not emphasized. Senior officials publicly stated that masks were not needed for protection. Once the numbers of infected persons increased, workplaces and schools were closed for a few weeks and financial relief packages were given to those who lost their jobs. However, little was still done to restrict people from travelling between provinces and countries and this would have contributed to future loss of life, economic downturns and long term job losses. The tenet of 'freedom before responsibility' contributed to the wider spread of infection, especially to the vulnerable older population. Some countries, such as New Zealand and Australia imposed stringent travel restrictions and strict quarantine measures and were thus able to mitigate the resulting adverse health effects and high infection burden. Countries in Asia such as Sri Lanka and Vietnam restricted travel and movement of people as a first-line defence. Doing this helped keep transmission down and helped prevent burdening already financially stretched health systems. The social structure in these Asian countries allowed such measures to be put in place and helped curb the spread of the infection within the respective countries.

China followed a similar process from the start of disease detection, and at the time, these restrictions were viewed less favourably by some in western countries. However, gradually the West had to follow similar practices of restricting travel, lockdowns, quarantine processes etc. PCR testing of those travelling to Canada was only put in place at the end of January 2021, whereas this was in place in several Asian countries, including Sri Lanka for several months. Such delayed-action may have contributed to the vastly different numbers of infections/deaths in Canada (814,000 cases and 20,000 deaths) and Sri Lanka (72,174 cases and 375 deaths) as of 10 February 2021. The population in Canada and Sri Lanka is around 38 and 22 million, respectively; but Sri Lanka is 1/154th the size of Canada. Higher numbers of older people living in care homes and poorer ventilation of buildings due to the colder environment in Canada may have contributed to more extensive and faster spread of the disease. During the summer months, the number of COVID-19 cases and deaths in Canada was less than in the fall and winter months.

1.2. The Good, the Bad and the Ugly

1.2.1. The Good

A major advantage that North America had was advanced knowledge and infrastructure for vaccine development. In the US, parallel processes were put in place for vaccine development, clinical and laboratory testing and vaccine manufacture to reduce the overall time for producing an approved COVID-19 vaccine. Operation Warp Speed is a public–private partnership initiated by the US government to facilitate and accelerate the development, manufacture and distribution of COVID-19 vaccines, therapeutics, and diagnostics. Funding and other resources provided by this program helped several pharmaceutical companies to develop COVID-19 vaccines at a faster pace than previously. In approximately 10 months, Moderna and Pfizer/BioNTech successfully developed highly effective vaccines and these have already been administered to millions of persons. The Johnson & Johnson vaccine is under review by the FDA and

should receive approval shortly. More details on vaccine development and its efficacy would be discussed later. A well thought out and planned strategy for administering the vaccines have been put forward by different countries, with healthcare workers and social care residents at the front and then rolled out to all adults. Canada has also played a part in COVID-19 vaccine development. Providence Therapeutics, a company based in Alberta, Canada have developed a mRNA vaccine and when approved, would be manufactured at Emergent BioSolutions, located at the University of Manitoba.

1.2.2. The Bad

The US has the highest number of COVID-19 cases and deaths in the world. As of 11 February 2021, there have been 27.3 million COVID-19 cases and 471,000 deaths. It is nearly 25% of COVID-19 cases in the world. Cases have been high in Mexico and Canada too. The recently described United Kingdom (B.1.1.7) and South African (501Y. V2) SARS-CoV-2 variants have entered North America. They are important as they increase transmissibility and cause more severe disease. Initial results suggest the South African viral variant may decrease vaccine efficacy.

1.2.3. The Ugly

A disheartening aspect is that despite North America (Canada and the US) having some of the world's best hospitals, medical care, therapeutics, and medical knowledge, the highest number of COVID-19 cases and deaths have been reported from here. Individual freedom and individual rights taking precedence over responsibility and lack of accountability may have contributed to this situation. There have been more deaths in the US due to COVID-19 than during World War 2.

1.3. Epidemiological principles relating to COVID-19

The global population rapidly learned two key measures for mitigating the spread of SARS-CoV-2; two-meter social distancing and the wearing of masks. In countries where these were done stringently and correctly, the caseload of COVID-19 remained low or reduced quickly. As time goes by new information would become available and advice given to the population would need to keep up with such new findings.

1.4. The disparity among ethnic and marginalized populations in North America

There is a disparity in how the infection affects different social, ethnic and economic strata of the population. Disease outcomes have been poorer in Black, Hispanic and Asian populations where they are two to three times more likely to be hospitalized or die from COVID-19 than Caucasians. In Canada, the First Nations people and their communities have also been adversely and more severely affected. Commentators have suggested these disparities are likely due to socioeconomic factors with genetic elements playing some role. Governments and the WHO should take a critical look at this information and put in steps and processes to mitigate further disparities in disease outcomes.

1.5. Opportunities arising from COVID restrictions

While things have been difficult and tough for almost all population segments, we have learned to become more resilient and carry out tasks in alternative ways. The appropriate and more widespread use of the different technologies has allowed classroom teaching in schools/universities and medical conferences to occur. The reduced use of vehicles has contributed to a lower carbon footprint.

1.6. Hope for the future:

A positive outlook for North America is the rapid development, manufacture and administration of the COVID-19 vaccines. So far, over 40 million (10% of the population) have been vaccinated. It would be important to know what social, dietary, genetic and immune factors may contribute to poorer outcomes from COVID-19, as these could be targeted

and corrected. More in-depth information and discussion on patient care, vaccines, and mental health will follow.

2. CLINICAL MANAGEMENT OF COVID-19

2.1. Management of mild COVID-19

Mild COVID-19 infections do not require any pharmaceutical interventions or hospitalization. However, many of these patients take zinc sulfate 50-220mg daily, Vitamin D3 2000-5000IU daily and Vitamin C 1000-2000mg daily with the presumption that it would boost their immunity (Name et al, 2020). Melatonin, famotidine and colchicine have also been prescribed for mild infections (Zhang et al, 2020). Lying down on ones abdomen and sides, whilst in quarantine (at the early stages of infection) is suggested to reduce the development of respiratory symptoms (Caputo et al, 2020). In the appropriate clinical setting, antibiotics such as azithromycin, clarithromycin or doxycycline are prescribed to prevent and treat superimposed bacterial lung infections. Steroid and beta-agonist inhalers are used to reduce troublesome cough and wheeze (The Recovery Collaborative Group, 2021).

2.2. Convalescent Plasma and Monoclonal Antibody Cocktails

Convalescent plasma from patients recovering from an infection has been used since 1892. They have been used in bacterial and viral epidemics such as diphtheria, meningococcal and pneumococcal infections, measles and mumps. It formed the standard of care for Argentine Hemorrhagic Fever caused by the Junin virus, where it prevented 90% of the deaths. Convalescent plasma is inexpensive and could be prepared locally. It is used in many countries for the prevention and treatment of severe COVID-19 infections (Bloch et al, 2020). Yet, many studies have shown disappointing results (especially when the IgG antibody titer of the donors is not sufficiently high), and some studies have shown no significant mortality benefit except in elderly patients who are administered convalescent plasma within the first 72 hours of infection (Simonovich et al, 2021).

Monoclonal antibody cocktails against the SARS-CoV-2 virus are expensive. ZMapp (developed in the tobacco Nicotiana plant) is the classic example of a monoclonal antibody used in the U.S. and some African countries during the 2014-2015 Ebola pandemic. The US, currently has two FDA-approved monoclonal antibodies (Bamlanivimab by Eli Lilly and Casirivimab by Regeneron) against COVID-19 and would be used in settings such as pharmacy infusion centers, hospital emergency departments and urgent care facilities. The antibody cocktails are given as an infusion over an hour, to patients with mild-moderate infections at high risk of complications. Research studies and real-life experience points to this significantly reducing hospital admission (Cohen, 2021).

2.3. Management of severe COVID-19

In the US, hospitals have procured multiple medicines for treating severe COVID-19, including the hypoxic and hyper-inflammatory manifestations. A range of medicines such as remdesivir (RNA-dependent RNA polymerase inhibitor), anticoagulants (such as heparin and low-molecular -weight heparin to prevent end-organ damage by thrombi and microthrombi) and low-dose dexamethasone (as recommended by the Recovery trial in the UK) have been used as standard of care in hospitalised patients (Varghese et al, 2020).

Physicians worldwide use steroids such as dexamethasone for COVID-19 patients with respiratory distress and hypoxia (Oxygen saturation<92%) as dictated by the findings of benefit in the Recovery trial (The Recovery Collaborative Group, 2021). This medication is widely available worldwide, is low cost and supplies have been adequate. End-organ damage due to microthrombi are prevented by the judicious use of anticoagulants such as heparin and apixaban (Rahman et al, 2021). Whilst the patients should be monitored closely for bleeding, these medications have been found to have a mortality benefit. The

NIH ACTIV-4 trial reiterated the need for anticoagulants (in prophylactic or therapeutic doses) in all hospitalized COVID-19 patients on account of their high risk for ischemic events such as strokes, myocardial infarcts and peripheral arterial events (Collins & Stoffels, 2020). In intensive care units, intensivists prescribe IL-6 inhibitors (like Tocilizumab) and IL-1 inhibitors (like Anakinra) combined with corticosteroids to mitigate the cytokine storm observed in seriously ill patients. The recently concluded EMPACTA trial reiterated the importance of timely use of IL-6 inhibitors to reduce mortality (Salama et al, 2021). Several large clinical trials have addressed critical care protocols to handle the most severe COVID-19 patients who require high level oxygen supplementation and mechanical ventilation. A recent addition to the range of immune modulators in COVID-19 is Baricitinib, an oral JAK1 and JAK 2 inhibitor (Kalil et al, 2021). When used in combination with the anti-viral drug remdesivir, it was found improve clinical outcomes and reduce recovery times. IV antibiotics are deployed in a timely and judicious manner to prevent secondary gram-negative bacterial infections and Staphylococcal infections. Fungal infections like candida and aspergillus are looked for and managed appropriately.

3. COVID-19 AND MENTAL HEALTH

The COVID-19 pandemic has had several negative impacts on the mental health of individuals. The effects have been both direct and indirect.

3.1. Direct impact on mental health

COVID-19, can directly lead to changes in the brain. In a UK-wide surveillance study (carried out from 2 to 26 April 2020), there were 153 cases of brain injury (inset reference). These included 62% with a cerebrovascular event, 74% with stroke and 12% with an intracerebral haemorrhage. The majority (82%) were older than 60 years. Of these patients, 31% presented with an altered mental state due to COVID-19. Unspecified encephalopathy was seen in 23%, 18% had encephalitis, and 59% patients fulfilled a clinical definition of a psychiatric diagnosis. The psychiatric diagnoses were: new onset psychosis (43%), a neurocognitive syndrome (26%) and an affective disorder (17%). In 92% of them, it was a new psychiatric diagnosis and of the patients with an altered mental state, 51% were older than 60 years (Czeisler, 2020).

3.2. Indirect impact on mental health

As social distancing and stay at home orders were mandated across many communities, this in turn, led to a negative impact on some person's mental health. In several countries, there has been an increase in the number of suicides and overdose deaths which may be linked to some of the societal changes during the pandemic (Sher, 2020). A study from the US in June 2020, found anxiety disorders to be three times more common than in the previous year (Czeisler, 2020). Furthermore, depressive episodes were four times more common, and one in ten individuals had started or increased substance use. Suicidal ideation was two times more likely. In Japan, in October 2020, more people died by suicide than from COVID-19 during a whole year (Wang et al, 2020). In January 2021, the 5th largest school district in US, announced a plan to phase back in-person learning. This was due to a rise in student suicides since the start of the lockdown, and a school alert system had also flagged more than 3,000 potential suicide risks (Varatharaj et al, 2020).

3.3. Abuse during the pandemic

The number of cases of physical and sexual abuse increased during the pandemic due to increased stress brought on by the uncertain aspects of the pandemic and the inability move out of households freely. There has been a rise in emergency room visits in the US due to domestic violence, with most of the victims been female. By the end of March 2020, there was a 22% increase in monthly calls from minors to the National Sexual Assault Hotline to report sexual abuse (Kamenetz, 2020). Of these, 79% occurred from individuals living in the same household as the victim. Physical and sexual abuse may lead to a future diagnosis of Post-Traumatic Stress Disorder (PTSD), and

other mental health disorders such as substance use disorders.

3.4. Individuals at risk during the pandemic

The mental health of particular groups of individuals have been disproportionately affected during the COVID-19 pandemic (Han et al, 2017). In particular, young adults, ethnic minorities, essential workers, those with pre-existing psychiatric conditions and unpaid caregivers of adults with disabilities are more likely to experience negative mental health outcomes. Unpaid caregivers, in particular, had a higher incidence of adverse mental health conditions compared to others.

3.5. How to combat mental health issues during the pandemic

Despite an increase in mental health disorders and trauma during the COVID-19 pandemic, there remain many ways in which people can be targeted and helped during these times. A universal approach designed for everyone in the general population, regardless of their risk for suicide, would best serve the greater public.

To reduce suicides during the COVID-19 pandemic, it would be necessary to reduce stress, anxiety, fears and loneliness in the general population. This could be difficult due to lockdown orders, but traditional and social media campaigns to promote positive mental health practices and reduce distress could be beneficial. Individuals should be encouraged to stay connected and maintain relationships by telephone or video, get enough sleep, eat healthy food and exercise regularly. It is vital to deliver community support for those living alone and encourage families and friends to check in with those at higher risk of mental health issues. Screening for anxiety, depression and suicidal feelings should be more regularly performed at medical offices. Outpatient primary care should integrate essential mental health services which may help to minimize the harmful psychological effects of the COVID-19 crisis.

Community or organizational gatekeepers including clergy, first responders, pharmacists, geriatric caregivers and school employees may have an opportunity to identify individuals at risk for suicide and direct them to proper evaluation and treatment. Utilizing telemedicine can greatly improve mental health care accessibility. Suicide prevention helplines should be available to the public and may be very useful in preventing suicides. If possible, governments and non-governmental organizations should provide financial support for people in need. This could include direct cash payments, postponement of loan repayments or tax credits. Transparent, timely and responsible media reporting is necessary. Vulnerable individuals should also be advised to limit watching, reading or listening to traditional and social media news stories due to the negative impact it may have on their mental health.

4. VACCINES FOR COVID-19

The availability of an effective vaccine is the best long-term answer to the current COVID-19 pandemic. There has been an international response to COVID-19 vaccine development (Kames et al, 2020).

4.1. Vaccine development cycle

Vaccine development occurs in several stages, known as the vaccine development cycle. This includes: preclinical, clinical (phase I, II and III) and the manufacturing (phase IV) stages. In the preclinical stage, the vaccine target is identified and assessed for feasibility and safety (Seo, 2020). During the clinical stages, safety, immunogenicity and efficacy are assessed in a stepwise manner using increasing numbers of individuals. During Phase IV, comparative clinical studies and post-marketing surveillance should take place. In general, completion of the different stages of vaccine development takes over a decade. However, during pandemic situations such as the COVID-19 pandemic, this process has been significantly shortened (to around one year) because several steps are carried out in parallel rather than sequentially. Prior to this,

the shortest time for vaccine development was four years, with the mumps vaccine.

4.2. Potential targets for a COVID-19 vaccine

SARS-CoV-2 is an enveloped β coronavirus. The viral envelope consists of the spike (S) glycoprotein and the envelope (E) and membrane (M) proteins. The S glycoprotein mediates host cell attachment and is required for viral entry. It consists of two subunits; S1 and S2. The S1 subunit has a receptor-binding domain (RBD) (Wrapp et al, 2020). The S protein has been identified as the major immunogenic target for vaccine development. Most of the COVID-19 vaccines in development are intended to induce antibody responses that neutralise SARS-CoV-2. The expectation is that this would prevent the virus from entering target cells and infecting the host (Shields et al, 2021). In some cases, the vaccines may also induce antibody and/or cellular immune responses that can kill and eliminate already infected cells (Rausch et al, 2020).

4.3. Categories of COVID-19 vaccines in development

The categories of vaccines for protection against SARS-Cov-2 infection and/or disease include the following: genetic/nucleic acid (mRNA or DNA) vaccines, viral vector (non-replicating or replicating) vaccines, recombinant spike or RBD-protein vaccines, inactivated virus vaccines and live attenuated virus vaccines.

4.3.1. RNA vaccines

DNA is the genetic code of living structures, and proteins are the building blocks. mRNA translates DNA into protein. An mRNA vaccine against COVID-19 would instruct the body's cells to produce specific coronavirus proteins (and not the virus per se). These proteins would then trigger an antibody and cellular immune response. mRNA technology is relatively new (only about 20 years old). Presently, three firms lead the field (two German firms – BioNTech and Curevac and the US biotech company Moderna) (Anderson et al, 2020; Corbett et al, 2020; Jackson et al, 2020; Mulligan et al, 2020; Sahin et al, 2020; Walsh et al, 2020). BioNTech has teamed up with Pfizer and Fosun from Japan. Moderna took around two months to enter phase 1 trials, after the SARS-CoV-2 viral sequence was released. mRNA vaccines are designed using the sequence of the virus. Thus, the lab does not need to work with the virus itself. Industrial production of mRNA is also easier and faster.

mRNA consists of simple chains of nucleosides, and no complex proteins need to be made. The persons own body cells become factories when mRNA is delivered into cells. mRNA is better than DNA at activating the immune system and has better access to cells. It is safer than the delivery of foreign DNA to an individual and does not carry the risk of integration into the genetic material of the target cell. Very recently, BioNTech/Pfizer announced their mRNA-based-vaccine candidate BNT162b2 was more than 90% effective in preventing COVID-19 in participants at seven days after the second dose of vaccine (Gallager, 2020). No serious safety concerns were announced. Approximately 42% of the global participants and 30% of the US participants have racially and ethnically diverse backgrounds. One needs to remember that the BioNTech/Pfizer vaccine comes with special storage challenges, as it needs to be stored at -70 degrees centigrade. Moderna also announced the findings of their phase 3 trial (Mason et al, 2020). They found their vaccine candidate mRNA-1273 to be safe and well tolerated and to have a vaccine efficacy of 94.5%.

4.3.2. DNA vaccines

With DNA vaccines, double-strand DNA is injected into the recipient (intradermal injection using an electroporation device). It has a better safety profile than live attenuated vaccines (Yu et al, 2020). Furthermore, the manufacturing process is well defined, and a freeze-dried formulation is possible (Smith et al, 2020). Inovio pharmaceuticals and Cobra biologics have initiated trials with DNA vaccines for COVID-19. In April 2020, Inovio announced the initiation of phase 1 human

clinical trials in the US and in June, the trials were extended to South Korea and China. In July 2020, the company announced positive interim data when the vaccine was given to non-human primates. However, at the end of September 2020, the FDA requested more information about the vaccine and its delivery device prior to granting approval for the commencement of the phase 2/3 trial.

4.3.3. Viral and bacterial vector-based vaccines

Potentially immunogenic parts of the SARS-CoV2 virus may be inserted into a viral or bacterial vector and this could then be used as a vaccine. The common vectors in use at present include adenovirus, adeno-associated virus, lentivirus and lactic acid bacteria (Tostanoski et al, 2020).

Oxford University and Astra Zeneca have developed a chimpanzee adenovirus vectored vaccine, which encodes the spike protein. It was found to be immunogenic and efficacious in non-human primate studies (Hassan et al, 2020). Phase 1/2 human trials found humoral and T cell responses in most recipients after the first dose of the vaccine further boosting the antibody responses after the second dose (Folegatti et al, 2020). The Gamaleya Research Centre have developed a vaccine consisting of recombinant adenovirus serotype 26 and 5 vectors. A phase 1/2 human trial reported seroconversion in 100% of recipients and a CD4+ and CD8+ T cell immune response in all subjects that peaked at 28 days post-vaccination (Logunov et al, 2020). Surprisingly, on August 12th 2020, this vaccine (now named Sputnik V) was granted approval for limited use in Russia, prior to completing the phase 3 trials. CanSino Biologics (Zhu et al, 2020 a&b) and Jonhson and Johnson have developed recombinant adenovirus 5 and adenovirus 26 vectored vaccines, respectively (King et al, 2020). Recent publications on the Oxford vaccine suggest it produces similar neutralising antibody titres and T cells responses across all three age groups (18-55, 56-69 and 70+ years) (Ramasamy et al, 2021).

4.3.4. Recombinant protein-based vaccines

When recombinantly synthesised SARS-CoV-2 viral proteins or protein fragments (such as the RBD) are injected, they stimulate an immune response. This technique mainly induces a humoral immune response and needs appropriate adjuvants to increase immunogenicity. The NVX-CoV2373 nanoparticle vaccine contains recombinant full-length wild-type SARS-CoV2 (rSARS-CoV-2) and the Matrix M1 adjuvant (Keech et al, 2020).

4.3.5. Inactivated virus vaccines

These vaccines require an adjuvant to boost immunogenicity (Xia et al, 2020). For instance, the vaccine candidate from SinoVac uses aluminium hydroxide (Alum). This induces a predominantly humoral based immune response (Palacios et al, 2020). Other adjuvants such as Monophosphoryl Lipid A (MPL) may help stimulate a cellular immune response too. Sinovac Biotech and Sinopharm have just completed phase 3 trials on their inactivated vaccines.

4.3.6. Trained immunity-based vaccines

Trained immunity-based vaccines stimulate the innate immune system and provide protection to unrelated pathogens. The BCG vaccine is currently under evaluation for its ability to induce trained immunity against SARS-CoV-2.

4.4. Vaccine efficacy

Vaccine efficacy involves the study of outcome data from randomized controlled trials (RCT) between participants that are vaccinated or not. Outcomes that may be assessed include: a reduction in infection, effect on severity of clinical disease or on duration of infectivity. Large scale prospective studies would help evaluate the effectiveness and immunogenicity in different strata of the population. Standardized approaches for assessing efficacy endpoints are important for making comparisons between the different vaccine candidates. Instead of measuring only clinical outcomes, validated and robust

immunological correlates of protection may be used as surrogate markers (Hodgson et al, 2021).

4.5. Vaccine safety

Having safe vaccines are critical for any widespread vaccination programmes. The population needs to be continuously updated on the safety aspects of all the evaluated COVID-19 vaccines. Furthermore, complete transparency in the reporting of findings from the various large-scale clinical trials is essential. Assessment of vaccine safety needs to be inbuilt into all stages of clinical development. Furthermore, they need to continue once a vaccine has been approved for use and then given to large population groups. With COVID19 vaccines, this is especially important as some of the vaccine platforms are novel (mRNA, DNA, nanoparticle, viral vector) and thus need careful safety checks. Human COVID-19 vaccine studies that have reported thus far have shown acceptable safety profiles of the different vaccine platforms and constructs (Gayle et al, 2020).

Three COVID-19 vaccines have been approved for use in the UK, two in the US and two within the European Union. Several countries have rolled out COVID-19 vaccination programs and over 98 million doses have been administered globally. However, currently there is a massive worldwide shortage of COVID-19 vaccines and several regions are still to commence their vaccination programs. Sri Lanka commenced its programme a few days ago using the AstraZeneca/Oxford viral vector vaccine. Novavax and Johnson & Johnson released initial information on their phase 3 clinical trials towards the end of last week. This article would outline up to date information on the UK and South African variants and discuss the newer variants. Recent phase 3 clinical trial findings released by Novavax and Johnson & Johnson, recognised laboratory and clinical trial effects of the viral variants on vaccine efficacy.

4.6. Viral variants and vaccine efficacy

Initial laboratory tests suggest the Pfizer and Moderna vaccines trigger smaller immune responses to the 501Y.V2 (South Africa) variant. Here several versions of the virus were exposed to blood samples from people who had been vaccinated. Neutralising antibodies produced in response to the Moderna vaccine were equally effective against the original SARS-CoV-2 virus and the UK B.1.1.7 variant. However, it was less effective against the South Africa variant. The Pfizer vaccine was also slightly less effective against the South Africa variant. It is well recognised that laboratory tests that measure antibodies alone are imperfect for understanding immune responses in individuals. Other parts of the immune system, such as T lymphocytes may play important roles in combating a viral variant, even when neutralising antibodies fail to do so effectively. The real proof would come from evaluating people who have got vaccinated to see if they get infected with the viral variant.

Both Novavax and Johnson & Johnson found their COVID-19 vaccines to be less effective in South Africa. In the Novavax South Africa study, nearly all the infections were with the 501Y.V2 South Africa variant. The Novavax UK trial efficacy was 96.6% against the original SARS-CoV-2 strain and 85.6% against the UK B.1.1.7 variant (Mahase, 2021). The Johnson & Johnson vaccine was tested on 6500 persons in South Africa and in more than 17,000 people in Argentina, Brazil, Chile, Colombia, Mexico and Peru. The weaker performance in South Africa is suggested to be due to the variant widely circulating there. Furthermore, variants were also considered as likely to account for the reduced efficacy in Latin America.

When the viral transmission is high, there is a greater opportunity for the virus to mutate randomly. Some mutations may give the virus a specific advantage and thus contribute to its expansion in the community. For instance, in Brazil, a number of persons contracted the SARS-CoV-2 virus for a second time. Following the first SARS-CoV-2 infection, the immune system response of the individuals

was failing to protect them from a new variant of the virus. Currently, the changes of greatest concern are those found in the spike protein found on the surface of the virus. The recently approved vaccines and those at the later stages of development train a person's immune system to recognise this protein. In the future, a more diverse set of vaccines, employing a variety of approaches may be needed.

Moderna has announced efforts to develop a booster injection (targeted at the South Africa variant) as an addition to its current two-dose regimen. The company is also planning to assess if an additional dose (that is the third dose) of the original formulation could help with combating the newer variants. Pfizer/BioNTech, has also considered developing an adjusted vaccine against some of the emerging variants. Vaccinating large numbers of persons in the shortest possible time would help to slow the virus's ability to mutate. Each infection is an opportunity for the virus to mutate. Viruses cannot mutate if they are not able to multiply. However, vaccination programs must also be accompanied by other measures such as wearing masks and appropriate social distancing. Effective vaccination campaigns need to be extended globally, as otherwise the emergence of important viral variants in countries that are not adequately vaccinated, could lead to rapid and distant spread of the new viral variant, as the originally administered vaccine may not neutralize it.

4.7. Vaccine hesitancy

COVID-19 vaccine hesitancy is an important aspect to be discussed and considered. Recent reports suggest between one-sixth, and one half of the UK population may refuse to receive a COVID-19 vaccine (Kreps et al, 2020; Lazarus et al, 2020). This in turn would pose a serious threat to achieving widespread SARS-CoV-2 immunity.

5. CONCLUSIONS

Epidemiological, clinical, psychological and vaccine-related findings from North America and the other parts of the world provides important insights into future infectious disease control strategies and major pandemic planning. Good practices and processes identified in one region should be considered for replication in other regions if they are socially and culturally congruent and acceptable.

REFERENCES

Anderson, E.J., Rouphael, N.G., Widge, A.T., et al (2020). Safety and Immunogenicity of SARS-CoV-2 mRNA-1273 Vaccine in Older Adults. *N Engl J Med*. Sep 29.

Bloch, E., Shoham, S., Casadevali, A., et al (2020). Deployment of convalescent plasma for the prevention and treatment of COVID-19. *J Clin Invest* Jun 1;130(6):2757-2765.

Caputo, N.D., Strayer, R.J., Levitan, R. (2020). Early Self-Proning in Awake, Non-intubated Patients in the Emergency Department: A Single ED's Experience During the COVID-19 Pandemic. *Acad Emerg Med* May 27(5):375-378.

Corbett, K.S., Flynn, B., Foulds, K.E., et al (2020). Evaluation of the mRNA-1273 Vaccine against SARS-CoV-2 in Nonhuman Primates. *N Engl J Med*.383(16):1544-1555.

Czeisler, M.É. (2020). Mental Health, Substance Use, and Suicidal Ideation During the COVID-19 Pandemic—United States, June 24–30, 2020. MMWR. Morbidity and Mortality Weekly Report, 69.

Cohen, M. (2021). Monoclonal Antibodies to Disrupt Progression of Early Covid-19 infection. N *Engl J Med*.

Collins, F.S. & Stoffels, P. (2020). Accelerating COVID-19 Therapeutic Interventions and Vaccines (ACTIV): An Unprecedented Partnership for Unprecedented Times. *JAMA*. 323(24):2455–2457.

Folegatti, P.M., Ewer, K.J., Aley, P.K., et al (2020). Safety and immunogenicity of the ChAdOx1 nCoV-19 vaccine against SARS-CoV-2: a preliminary report of a phase 1/2, single-blind, randomised controlled trial. Lancet. 396: 467-478.

Gallager, J. (2020). Covid vaccine: First 'milestone' vaccine offers 90% protection. BBC News 09th Nov.

Gayle, H., Foege, W., Brown, L., et al (2020). Framework for Equitable Allocation of COVID-19 Vaccine. Washington (DC): National Academies Press (US) Oct 2.

Han, B.H., Moore, A.A., Sherman, S., Keyes, K.M., & Palamar, J.J. (2017). Demographic trends of binge alcohol use and alcohol use disorders among older adults in the United States, 2005–

2014. *Drug and alcohol dependence*, 170, 198-207.

Hassan, A.O., Kafai, N.M., Dmitriev, I.P., et al (2020). A Single-Dose Intranasal ChAd Vaccine Protects Upper and Lower Respiratory Tracts against SARS-CoV-2. *Cell.*183(1):169-184..

Hodgson, S.H., Mansatta, K., Mallett, G., et al (2021). What defines an efficacious COVID-19 vaccine? A review of the challenges assessing the clinical efficacy of vaccines against SARS-CoV-2. *Lancet Infect Dis*, 21 (20; 26 - 35.

Jackson, L.A., Anderson, E.J., Rouphael, N.G., et al (2020). An mRNA vaccine against SARS-CoV-2 – preliminary report. *N Engl J Med*. 383:1290 – 1931.

Jayasekara, D., Seneviratne, S.L., Jayasekara, A., De Zoysa, I. (2020). Atypical Presentations of COVID-19. *Advances in Infectious Diseases* 10 (3) 136-142.

Kalil, A.C., Patterson, T.F., Mehta, A.K., et al (2021). Baricitinib plus remdesivir for hospitalized adults with COVID-19. *N Engl J Med* 384: 795 -807.

Kamenetz, A. (2020). Child Sexual Abuse Reports Are On The Rise Amid Lockdown Orders. NPR. 28th April.

Kames, J., Holcomb, D.D., Kimchi, O., et al (2020). Sequence analysis of SARS-CoV-2 genome reveals features important for vaccine design. *Sci Rep*. 10(1):15643.

Kariyawasam, J.C., Jayarajah, U., Riza, R., Abeysuriya, V., Seneviratne, S.L. (2021). Gastrointestinal manifestations in COVID-19. *Trans R Soc Trop Med Hyg*. Mar 16:trab042.

Keech, C.I., Albert, G., Cho, I.S. et al (2020). Phase 1-2 Trial of a SARS-CoV-2 Recombinant Spike Protein Nanoparticle Vaccine. *N Engl J Med*. Sep 2.

King, R.G., Silva-Sanchez, A., Peel, J.N., et al (2020). Single-dose intranasal administration of AdCOVID elicits systemic and mucosal immunity against SARS-CoV-2 in mice. *bioRxiv*. Oct 11

Kreps, S., Prasad, S., Brownstein, J.S., Hswen, Y., Garibaldi, B.T., Zhang, B., Kriner, D.L. (2020). Factors Associated With US Adults' Likelihood of Accepting COVID-19 Vaccination. *JAMA Netw Open*. Oct 1;3(10):e2025594.

Lazarus, J.V., Ratzan, S.C., Palayew, A., et al (2020). A global survey of potential acceptance of a COVID-19 vaccine. *Nat Med.* 20:1-4.

Logunov, D.Y., Dolzhikova, I.V., Zubkova, O.V., et al (2020). Safety and immunogenicity of an rAd26 and rAd5 vector-based heterologous prime-boost COVID-19 vaccine in two formulations: two open, non-randomised phase 1/2 studies from Russia. *Lancet*.396(10255):887-897.

Mahase, E. (2021). Covid-19: Novavax vaccine efficacy is 86% against UK variant and 60% against South African variant. *BMJ* 372:n296.

Mason, J., Guarascio, F., Erman, M., Burger, L., Banerjee, A., Smout, A. (2020). Instant View: Moderna says its vaccine is 94.5% effective in preventing COVID-19. Reuters 16th Nov.

Mulligan, M.J., Lyke, K.E., Kitchin, N., Absalon, J., Gurtman, A., Lockhart, S. et al (2020). Phase I/II study of COVID-19 RNA vaccine BNT162b1 in adults. *Nature.* 586(7830):589-593.

Name, J.J., Romondi Souza, A.C., Vasconocelos, A.R., et al (2020). Zinc, Vitamin D and Vitamin C: Perspectives for COVID-19 With a Focus on Physical Tissue Barrier Integrity. *Front Nutr* 7: 606398.

Palacios, R., Patiño, E.G.,de Oliveira P.R., et al (2020). Double-Blind, Randomized, Placebo-Controlled Phase III Clinical Trial to Evaluate the Efficacy and Safety of treating Healthcare Professionals with the Adsorbed COVID-19 (Inactivated) Vaccine Manufactured by Sinovac - PROFISCOV: A structured summary of a study protocol for a randomised controlled trial. Trials. 21(1):853.

Rahman, A., Niloofa, R., De Zoysa, I.M., Cooray, A.D., Kariyawasam, J., Seneviratne, S.L. (2020). Neurological manifestations in COVID-19: A narrative review. *SAGE Open Med*. 8

Rahman, A., Niloofa, R., Jayarajah, U., De Mel, S., Abeysuriya, V., Seneviratne, S.L. (2021). Hematological Abnormalities in COVID-19: A Narrative Review. *Am J Trop Med Hyg.* Feb 19:tpmd201536.

Ramasamy, M.N., Minassian, A.M., Ewer, K.J., et al (2021). Safety and immunogenicity of ChAdOx1 nCoV-19 vaccine administered in a prime-boost regimen in young and old adults (COV002): a single-blind, randomised, controlled, phase 2/3 trial. *Lancet* 396(10267):1979-1993.

Rausch, J.W., Capoferri, A.A., Katusiime, M.G., Patro, S.C., Kearney, M.F. (2020). Low genetic diversity may be an Achilles heel of SARS-CoV-2. *Proc Natl Acad Sci U S A*. 117(40):24614-24616.

Sahin, U., Muik, A., Derhovanessian, E., et al (2020). COVID-19 vaccine BNT162b1 elicits human antibody and T(H)1 T cell responses. *Nature.* 586(7830):594-599.

Salama, C., Han, J., Yau, L., et al (2021). Tocilizumab in patients hospitalized with COVID-19 pneumonia. *N Engl J Med.* 384(1):20-30.

Seo, S.H. & Jang, Y. (2020). Cold-Adapted Live Attenuated SARS-Cov-2 Vaccine Completely Protects Human ACE2 Transgenic Mice from SARS-Cov-2 Infection. *Vaccines* (Basel). 8(4): 584

Sher, L. (2020). The impact of the COVID-19 pandemic on suicide rates. QJM: An *International Journal of Medicine* Oct 1; 114(10: 707 - 712.

Shields, A.M., Burns, S.O., Savic, S., Richter, A.G. (2021). UK PIN COVID-19 Consortium

COVID-19 in patients with primary and secondary immunodeficiency: The United Kingdom experience. *J Allergy Clin Immunol*. Mar;147(3):870-875.e1.

Simonovich, V.A., Leandro, D., Pratx, B., et al (2021). A randomized trial of convalescent plasma in Covid-19 severe pneumonia. *N Engl J Med* 384: 619 -629

Smith, T.R.F., Patel, A., Ramos, S., et al (2020). Immunogenicity of a DNA vaccine candidate

for COVID-19. *Nat Commun* 11: 2601.

The RECOVERY Collaborative Group (2021). Dexamethasone in Hospitalized Patients with Covid-19. *N Engl J Med* 384: 693 - 704.

Tostanoski, L.H., Wegmann, F., Martinot, A.J., et al (2020). Ad26 vaccine protects against SARS-CoV-2 severe clinical disease in hamsters. *Nat Med*. 1070-6.

Varatharaj. A., Thomas, N., Ellul, M.A., Davies, N.W., Pollak, T.A., Tenorio, E.L. et al (2020). Neurological and neuropsychiatric complications of COVID-19 in 153 patients: a UK-wide surveillance study. *The Lancet Psychiatry.*

Varghese, G., John, R., Manesh, A., et al (2020). Clinical Management of COVID-19. *Indian J Med Res.* 2020 May; 151(5):401-410.

Walsh, E.E., Frenck, R.W. Jr, Falsey, A.R., et al (2020). Safety and Immunogenicity of Two RNA-Based Covid-19 Vaccine Candidates. *N Engl J Med*. Oct 14.

Wang, S., Wright, R., Wakatsuki, Y. (2020). In Japan, more people died from suicide last month than from Covid in all of 2020, and women have been impacted most. CNN. 29th Nov.

World Health Organization. Coronavirus disease (COVID-19) situation reports. 2020 (April) .

Wrapp, D., Wang, N., Corbett, K.S., et al (2020). Cryo-EM structure of the 2019-nCoV spike in the prefusion conformation. *Science*. 367: 1260-3.

Xia, S., Zhang, Y., Wang, Y., et al (2020). Safety and immunogenicity of an inactivated SARS-CoV-2 vaccine, BBIBP-CorV: a randomised, double-blind, placebo-controlled, phase 1/2 trial. *Lancet Infect Dis*. Oct 15.

Yu, J., Tostanoski, L.H., Peter, L., et al (2020). DNA vaccine protection against SARSCoV-2 in rhesus macaques. *Science* 369(6505):806-811.

Zhang, R., Wang, X., Ni, L., et al (2020). COVID-19: Melatonin as a potential adjuvant treatment. *Life Sci.* Jun 1; 250: 117583.

Zhu, F.C, Li, Y.H., Guan, X.H., et al (2020a). Safety, tolerability, and immunogenicity of a recombinant adenovirus type-5 vectored COVID-19 vaccine: a dose-escalation, open label, non-randomised, first-in-human trial. *Lancet* 395: 1845-54.

Zhu, F.C., Guan, X.H., Li, Y.H., et al (2020b). Immunogenicity and safety of a recombinant adenovirus type-5-vectored COVID-19 vaccine in healthy adults aged 18 years or older: a randomised, double-blind, placebo-controlled, phase 2 trial. *Lancet* Aug 15;396(10249):479-488.

COVID 19: Have we got our priorities right in planning for the pandemic in low resource settings in the global south?‡

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ABSTRACT

Planning the delivery of health services in poor countries, in the wake of the COVID pandemic has drawn considerable interest. The world media has highlighted the shortage or near absence of intensive care units and ventilators in several countries in Sub Saharan Africa and a disproportionate amount of focus has been paid on developing intensive care services- including mechanical ventilation, as an urgent priority for these countries. While mechanical ventilation and other critical care services are an important part in the management of a small group of very unwell patients, the overall mortality of such patients remains high even in centres with considerable experience in providing such services. In the wake of a pandemic wave, a much larger proportion of patients admitted to hospitals will require oxygen therapy, and many of these countries are currently ill-equipped to provide this very basic intervention which has the potential to save many more lives. Ensuring uninterrupted oxygen supply and planning to provide titrated oxygen therapy to multiple patients simultaneously perhaps in large field hospitals must be prioritised in health delivery planning in poor countries in the global south. An over-emphasis on ventilators and advanced organ support that may benefit a significantly smaller cohort of victims by developing ad-hoc intensive care units with high labour intensity will not serve the broader health needs of these countries in the wake of the current pandemic or its future iterations.

Keywords: Covid pnumonitis, Oxygen, Priorities, Low resource, Management, Ventilation, IPPV

1. BACKGROUND

The COVID 19 pandemic which was first reported in the Wuhan province in China in December 2019 has had a significant impact across the world. All countries have found the transmission rates and the large numbers of people manifesting severe disease a major challenge. In many countries the capacity of the acute health care systems was exceeded leading to dramatic images of over-worked staff, over-flowing wards (or intensive care units), dead bodies in make-shift morgues and bodies transported in military vehicles. In this context

‡ **Keynote speech**

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the consequences of COVID 19 spreading in some of the poorest countries have drawn considerable attention (WHO, 2020). An estimated two-thirds of Sub-Saharan Africa's urban population live in informal settlements (or slums), characterised by over-crowding, poor sanitation, poor sewage disposal and lack of access to safe water (UN Habitat, 2020) and the prospect of COVID 19 establishing itself within these settlements is particularly worrying. Even though the number of new officially confirmed cases reported in any one country in Sub-Saharn Africa (except South Africa) in the seven days leading to 6/5/20 was low (<1000) (WHO, 2020), significant concerns remain as to whether this is a true reflection of low levels of transmission or simply a case of under detection and under-reporting. This situation has however changed rapidly with most countries in the region reporting a sharp rise in case-loads in the second (and possibly) a third wave of the pandemic. For example, the case numbers in Kenya have nearly doubled within a period of four months. (approximately 50,000 in September 2020 to 100,000 by January 2021(Gavi.org, COVID-19 Dashboard, 2021), with a corresponding increase in fatalities. By January 2021 countries such as Uganda, Kenya, South Africa and Zimbabwe are all clearly demonstrating a distinct first and second waves with increasing case numbers. Further increases in case numbers and a possible third wave with even greater health and socio-economic consequences cannot be ruled out in any of these countries. The position in the Indian sub-continent with large informal settlements in all major cities is more worrying with the World Health Organization report placing India in a category of countries with higher numbers of new cases (10,000-100,000 in the similar time period (WHO 2020). According to WHO data, by January 2021, the reported case numbers for India has increased to >10,000,000 and the corresponding death numbers have also increased to over 150,000 (Gavi.org, COVID-19 Dashboard, 2021).

2. MECHANICAL VENTILATION AND OXYGEN THERAPY IN THE MANAGEMENT OF COVID-19

While health officials in these countries continue to plan for the pandemic, the relative lack of ventilators in Africa (and by inference other low and middle-income countries) has been highlighted by several news media and agencies. The following are a selection of direct quotes from some of the news channels/media/agencies in the past few weeks.

1. "*The United States has roughly 172,000 ventilator-and that isn't enough. Sierra Leone (about the population of Washington State) has 13 ventilators. CAR has three ventilators. Liberia also has only three; South Sudan has four*" (The Atlantic 10/04/20);

2. "*Few Doctors, Fewer Ventilators: African Countries Fear They Are Defenceless Against Inevitable Spread of Coronavirus*" (Time Magazine 07/04/2020);

3. "*The United Nations projects that, even in the best scenario, the continent's 54 countries with a population of 1.3 billion people, will need 30,000 ventilators this year*" (Right to Life 01/05/2020);

4. "*One medical equipment that has assumed star status in the wake of the current pandemic are ventilators*" (Africa News 05/04/2020);

5. "*South Sudan, for example, has just four ventilators and 24 ICU beds for a population of 12 million people…..That's one ventilator for every three million people. Burkina Faso has 11 ventilators, Sierra Leone 13, and Central African Republic 3*" (CNN 18/04/2020);

6. "*Fewer than 2,000 working ventilators have to serve hundreds of millions of people in public hospitals across 41 African countries*" (New York Times 18/04/2020);

Such news reports and the subtle underlying connotations are likely to apply considerable pressure on policy makers in the global south to procure new ventilators in order to reassure an anxious public. It is known that such campaigns have already prompted several countries to purchase large stocks of ventilators in order to equip and upgrade hospitals. For example, our enquiries have shown that the Federal Government of India alone has placed orders for 55-60 thousand new ventilators between March-May 2020. In addition to this the devolved regional governments in the different states and the corporate sector too have placed orders for thousands of new ventilators (Personal Communication, Dr D Chowdry, President, Indian Society of Critical Care Medicine, May 13 2020). Gulu Referral Hospital (GRRH) in Northern Uganda – an institution which currently does not have a functioning intensive care unit (and hence no previous collective experience in providing mechanical ventilation to critically ill patients), has also placed orders for new ventilators despite very significant competing demands on their budget (Personal communication, Dr S Magadah, Consultant Surgeon, Gulu Medical Faculty and Gulu Referral Hospital; May 18 2020). This approach, in our view, ignores two fundamental sets of observations that we wish to highlight.

1. Only a small minority of patients who acquire the COVID 19 infection require positive pressure ventilation. For example, it is currently estimated that even amongst the most vulnerable groups only about 20% will require hospitalisation (Gallagher, 2020) and of those hospitalised patients approximately 10-15% will require mechanical ventilation (Wang et al., 2020; Yang et al., 2020; Zhou et al., 2020). For example, at the Infectious Diseases Hospital (IDH) in Colombo, Sri Lanka which received 305 patients by 10th May 2020 (diagnosis confirmed by Polymerase Chain Reaction (PCR), with the majority of patients being either asymptomatic or very minor symptoms) only 5 patients (1.6%) had required mechanical ventilation (Personal communication, Dr A Wijewickrama, Senior Physician, IDH Colombo; August 8 2020). At the Kenyatta University Hospital (KUTRRH), Nairobi too, the need for mechanical ventilation amongst COVID patients has been low.

2. Patients who require ventilation carry a very high risk of dying – even in health systems with extensive experience in providing mechanical ventilation. The reported mortality rates among ventilated patients in intensive care units vary widely ranging from approximately 65% in the United Kingdom (ICNARC, 2020) to over 90% in some of the early reports from China (Zhou et al., 2020). Some reports from New York too place the mortality for ventilated ICU patients close to 90% (Cha A E 23/04/2020)). At Infectious Diseases Hospital in Colombo, Sri Lanka too the mortality amongst patients needing mechanical ventilation was exceedingly high (Personal communication Dr A Wijewickrama, Senior physician, IDH Colombo; August 8 2020). It is relevant to note that even in countries/centres with an extensive collective experience in providing mechanical ventilation through suitable postgraduate medical and nursing training programs in critical care medicine and mechanical ventilation the reported mortality rates amongst patients requiring multiple organ support have been prohibitive to date.

Overwhelming majority of patients presenting to the hospital following COVID 19 infections suffer from severe Type 1 respiratory failure characterised by low arterial oxygen saturation and hypoxaemia (Wang et al., 2020; Yang et al., 2020; Zhou et al., 2020; Grasselli et al., 2020). Most of these patients have been managed successfully in ordinary medical wards with oxygen therapy (of varying amounts to maintain oxygen saturation >90%), intravenous fluids (to correct pre-existing dehydration and to replace ongoing evaporative fluid loss), prophylaxis for deep vein thrombosis, systemic steroids (dexamethasone) and prophylactic antibiotics in a smaller sub-cohort of patients in whom secondary infections are suspected

(Yang et al., 2020). Almost every seriously ill patient admitted to the COVID wards however has required oxygen therapy – either via nasal cannulae or face masks. Therefore, the ability to provide life-saving care - for the overwhelming majority of hospitalised patients in the current pandemic, has been defined by the ability to provide simultaneous oxygen therapy to a large number of patients. Though this 'basic' facility is taken for granted in most European and United Kingdom hospitals, the situation is very different across poorer countries in Africa and South Asia. In our experience, there is very limited capacity to provide oxygen therapy in most hospitals – including large hospitals in the major cities, and small portable oxygen cylinders or oxygen concentrators are almost always the source of oxygen. Our telephone enquires in the month of April/May 2020 confirm that, at the Gulu Referral Hospital in Northern Uganda (GRRG), the largest teaching hospitals in Northern Uganda (Population 1.9 million), any given ward will have access to only one (or very rarely two) oxygen cylinders and at any given time only one patient may be provided oxygen therapy in any medical ward in this hospital. The Level 4 Health centre in Awach - a residential health facility with 32 beds in Northern Uganda, has only one oxygen cylinder and 2 oxygen concentrators for use in the operating theatre / labour ward with no provision for oxygen therapy in the wards. Similarly, at Kitgum General Hospital – a large District hospital with approximately 200 beds, only one patient can be provided oxygen in any ward at any given time. According to key stakeholders, the above scenario is by and large the norm across Uganda, Kenya, Ethiopia and Rural India. The supply of oxygen cylinders is not reliable as they have to be delivered from the capital cities – usually several hundreds of miles away. Oxygen cylinders run out very frequently and when they do so, there are no warning systems to detect this.

3. THE NEED TO PRIORITIZE LOW-COST HIGH-IMPACT INTERVENTIONS

While developing the capacity to provide safe mechanical ventilation and other critical care services is important in all countries, this can only be achieved safely in a more systematic fashion over a longer time scale with planned investments and changes to undergraduate and postgraduate medical/nursing programs. In the current pandemic therefore the ability to deliver low-cost - but higher impact, interventions such as water, soap, hand washing kiosks, protective masks, spacious quarantine centres and strategies for safe oxygen therapy to large numbers of patients in all peripheral hospitals and health centres need to be prioritised. It is encouraging to see that countries such as Sri Lanka that have implemented these basic interventions along with a robust contact tracing strategy have been successful in limiting the spread and severity of the disease so far. International agencies working with their local partners in government/academia are best placed to aid the process through defining the health economics, feasibility and sustainability of strategies for oxygen therapy – centralised units (manifolds of large cylinders/ liquid oxygen/oxygen concentrators) Vs retail cylinders, in these settings.

4. CONCLUSION

In this context, we wish to point out that the current disproportionate focus on developing the capacity for mechanical ventilation amounts to misplaced and muddled thinking. Western agencies, media channels, external expert advisors and their local counterparts have long been guilty of promoting transfer of inappropriate and unsustainable technology to poorer countries and the current COVID epidemic must not become yet another example of such misguided and ill-informed thinking – however well meaning.

REFERENCES

African News (2020). https://www.africanews.com/2020/04/04/africa-s-ventilator-dystopia-ethiopia-trains-doctors-on-covid-19-lifesavers//

Cha, A. E. (23/04/2020). Coronavirus: 88% of Covid-19 patients on ventilators didn't survive in New York's hospital system, study finds. I*NDEPENDANT.* https://www.independent.co.uk/news/world/americas/coronavirus-

us-new-york-hospital-ventilator-death-rate-latest-a9479411.html.

CNN (18/04/2020). https://edition.cnn.com/2020/04/18/africa/covid-19-ventilator-shortage-intl-scli/index.html

Gallagher, D. (2020). COVID-19: One in five over-80s need hospitalisation and death rate 0.66 per cent. Imperial College London, UK, https://www.imperial.ac.uk/news/196573/covid-19-one-five-over-80s-need-hospitalisation/.

Gavi.org Coivd 19 Dashboard (2021). https://www.gavi.org/covid19/dashboard?gclid=Cj0KCQjw9_mDBhCGARIsAN3PaFM8zvr_cUhNFm1Xba0zhFTOliT6kTGtuexNstHabQdAxVp4YY6xNJ8aAmeFEALw_wcB

Grasselli, G., Zangrillo, A., Zanella, A., Antonelli, M., Cabrini, L., Castelli, A. et al. (2020). Baseline Characteristics and Outcomes of 1591 Patients Infected With SARS-CoV-2 Admitted to ICUs of the Lombardy Region, Italy. *JAMA,* 323(16):1574-1581 . DOI:10.1001/jama.2020.5394

Intensive care National audit and research centre (ICNARC 17/04/2020). ICNARC report on COVID-19 in critical care. https://www.icnarc.org/Our-Audit/Audits/Cmp/Reports

New York Times (18/04/2020). https://www.nytimes.com/2020/04/18/world/africa/africa-coronavirus-ventilators.html

Right to Life (2020). https://righttolife.org.uk/news/africa-asks-for-ventilators-during-covid-19-uk-govt-sends-abortion-funds

The Atlantic (2020). https://www.theatlantic.com/ideas/archive/2020/04/why-covid-might-hit-african-nations-hardest/609760/

Time Magazine (2020). https://time.com/5816299/coronavirus-africa-ventilators-doctors/

UN Habitat (2012). State of the world's cities 2012/2013: Prosperity of Cities. United Nations Human Settlements Programme , 1-122; https://sustainabledevelopment.un.org/content/documents/745habitat.pdf .

Wang, D., Hu, B., Hu, C., Zhu, F., Liu, X., Zhang, J. et al. (2020) Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. *JAMA*; 323(11):1061-1069. DOI:10.1001/jama.2020.1585

World Health Organisation (2020). Coronavirus disease (COVID-19) Situation Report – 107; https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200506covid-19-sitrep-107.pdf?sfvrsn=159c3dc_2

Yang, X., Yu, Y., Xu, J., Shu, H., Xia, J., Liu, H. et al. (2020). Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *Lancet Respir Med,* 8(5): 475-481. DOI:https://doi.org/10.1016/S2213-2600(20)30079-5

Zhou, F., Yu, T., Du, R., Fan, G., Liu, Y., Liu, Z. et al. (2020). Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet,* 28;395(10229):1054-62. DOI:https://doi.org/10.1016/S0140-6736(20)30566-3

The importance of community engagement in combating COVID-19‡

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ABSTRACT

Community participation is considered an essential element in all aspects related to public health. Active engagement of communities is particularly important in prevention and control of infectious diseases and epidemics. Since the first local case of COVID-19 was reported on 11th of March 2020, cases have been reported from all 25 districts of Sri Lanka. Due to a multitude of actions by the government and the support received from the general public, the 1st wave was effectively controlled without reaching the stage of community transmission. However, there was a significant negative impact on people belonging to vulnerable groups. The community response mitigated this negative impact significantly. Sri Lanka then entered into a new phase with a rapid increase in the incidence of COVID-19 cases (2nd wave) on the 1st week of October 2020. Even though there is no official acceptance of a "community transmission" in Sri Lanka, many cases are being reported which are not connected to any identified disease cluster. Unlike during the 1st wave which was controlled with strict measures such as an island-wide curfew, and despite increasing numbers of cases being reported, there was no island-wide curfew and restriction of movements. In this context, promoting community engagement with COVID-19 is a critical element not only in the prevention and control of the epidemic, but also addressing issues such as stigma and discrimination related to the disease. Experience gained so far through specific interventions provide important insights into how community engagement can be enhanced to control the COVID-19 epidemic in Sri Lanka.

Key words: Civil society, Community participation, COVID-19, Stigma and discrimination

1. INTRODUCTION

COVID-19 is undisputedly the most unprecedented health challenge that we face in our lifetime. At the same time, it is not going to be the first or the last pandemic that the world will have to live with in this century.

Community participation in all aspects related to health, particularly in health promotion and prevention of disease is well recognized. The historical Alma-Ata Declaration on Primary Health Care identified community participation as a cornerstone in achieving a higher status of health (WHO, 1978). Since then, various methods have been used in different geographical, social and cultural settings to maximize community participation with significant results and proven effectiveness. There is no universally accepted standard definition of community participation in health. However, extensive research has been carried out on different aspects of community participation in health and analytical frameworks have been developed to capture the range of definitions and practices (Chu, 1997).

‡ **Plenary paper**

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Community engagement, if one looks at the meaning in practical terms without looking at it from a very technical or academic perspective, is the process of developing relationships that enable stakeholders to work together to address health related issues and promote wellbeing to achieve positive health impact and outcomes, and it can also be seen as an important intervention or element during public health emergencies (WHO, 2021). Community engagement involves those who are affected in understanding the risks they face and involves them in the response actions that are acceptable. It is very important how we involve them and what influences their thinking and their actions.

Community participation is about people and engaging them at all levels – from grass roots to national. There are multiple stakeholders. When you look at who is really involved in the process, it could involve, among others, religious leaders, community members, patients, health workers, policymakers, and professionals from other sectors as well. Hence in a broader sense, community engagement involves not only the people in rural and urban communities who are subjected to all kinds of health interventions but the larger society in which the participation take place.

However, the grass roots level remains as the most important level of community engagement. Participation or engagement is built on relationships. It is all about the relationships that we are having as citizens with health authorities, and relationships that we are having as professionals with decision makers. There is an element of respect and trust and a sense of purpose that involves community engagement. It is within this context that we approach community engagement in combatting COVID-19.

In recent years, with the rise of epidemics and the increasing threat of pandemics, community participation has received greater attention as an important tool in preparedness and response.

Prior to the COVID-19 pandemic, the Ebola outbreak in West Africa was considered the largest outbreak in the world and the most protracted one. It brought home the strong message that culture and community are critical determinants in successful outbreak control. The Ebola experience was a pivotal turning point in the re-recognition of the importance of community engagement which resulted in WHO itself recruiting social scientists and mobilizing social mobilization staff to mainstream community engagement to work closely with technical staff (WHO, 2017).

Perhaps it was the experience gained from the Ebola outbreak that prompted the WHO to encourage member States to pay attention to ensuring community engagement in responding to the pandemic. At a very early stage of the COVID-19 pandemic (On 5th May 2020) the WHO released the Interim Guidance on *"Role of community engagement in situations of community transmission of extensive community transmission of COVID-19"* (WHO, 2020). The guidelines identified three priorities for community engagement in situations of extensive community transmission:-

1. Further strengthening of existing partnerships and establishing new partnerships to reach and engage with wider community networks,

2. Further strengthening community governance structures, and

3. Optimizing the role of community care workers engaging with communities.

This paper explores the status of community engagement in the COVID-19 response in Sri Lanka during the period March to December 2020 and makes recommendations to build on successful interventions and to address the gaps.

2. METHODS

This paper is based on Author's own experience in working with communities on COVID-19 related interventions between

the period March to December 2020 and on published literature on the subject. The level and character of community participation is presented and analysed in 3 distinct phases related to the COVID-19 epidemic in Sri Lanka (Figure 1).

The period ranging from 11th March 2021, when first Sri Lankan COVID-19 patient was identified, to the 31st of December 2020 was considered for the analysis. Selected publications related to community engagement in COVID-19 prevention and control both from local and international sources were referred to in the analysis. The experience and lessons learned through the Author's involvement in promoting community participation through a leading civil society organization (CSO) in Sri Lanka, namely the Sarvodaya Shramadana Movement and other non-governmental partners, is also documented and incorporated in the paper.

3. RESULTS

In terms of community engagement, when one studies the three phases, distinct characteristics related to each phase emerge.

3.1. Phase I

Phase I is the emergency phase during the 1st wave of COVID-19, which is taken to be the period between March and June 2020. Phase II is considered the period between the 1st and 2nd waves, July to September 2020, when there was a relaxation of lockdowns and there was an attempt to recover from the socio-economic impact that had taken place during the lockdown. Phase III is the period starting from the onset of the 2nd Wave in October 2020 and which continues to-date.

Phase I can be characterized as a period of confusion, fear, and uncertainty, with COVID-19 being a whole new experience not only for ordinary citizens but also for medical professionals as well. Everyone was relying on information received from international media as conveyed to the public through popular electronic and print media. On the other hand, the immediate island-wide lockdown starting from the last week of March 2020, and the resulting impact on the daily wage earner, the informal sector workers, the poor and the marginalized, was the trigger for the initial response of community engagement. Helping each other during disasters is an age-old tradition in Sri Lanka. Both spontaneous as well as organized response in times of calamities is a norm, but the situation was markedly different this time. Voluntary organizations who have had long years of experience in disaster management could not mobilize themselves as first responders. We

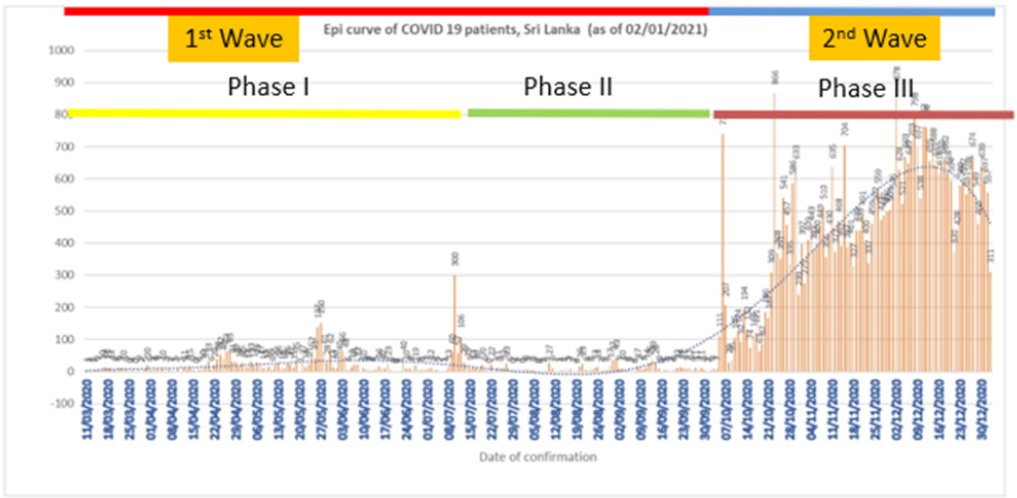

Figure 1. Phases of Analysis of Community Engagement in COVID-19 Response in relation to the Epi Curve of Sri Lanka March – December 2020 (Source: Epidemiology Unit, 2020)

were dealing with an invisible enemy – a highly infectious disease agent, a new virus whose behaviour was not much known even to the medical community. The initial reaction by the public was strict compliance. People adhered to and complied with the regulations 100%, even though it had a devastating impact on their lives and livelihoods.

3.1.1. Spontaneous Community Action

What was observed during this first phase of community engagement was an *organic* community response. The people themselves started helping each other within their own localities as movement restrictions barred the humanitarian and voluntary organizations from mobilizing themselves. We could see neighbourhood groups supplying food packs to low-income groups, farmers sharing their own produce by bringing them to public places. Though it is difficult to quantify this spontaneous community response during the first few days after the curfew was imposed, it can be considered a major buffer to mitigate the negative impact of the lockdown on the vulnerable communities that vastly complemented the Rs.5000 allowance that was given to low-income households by the Government.

This was followed by, within a few days, a more formal response once the situation became a bit clearer. The Civil Society Organizations (CSOs) and groups were the able to mobilize themselves and have a more organized action plan.

3.1.2. Organized community action to address the needs of care homes

By the second week into the lockdown, the "Presidential Task Force for directing, coordinating and monitoring of essential public services" (PTF) requested the support of the CSOs to help coordinate and aid care homes around the country. This gave an opportunity for civil society actors in all twenty-five districts to work with relevant government officials and address the urgent food security, hygiene, and medical needs of identified vulnerable groups in Sri Lanka. Pursuant to the government circular No. PTF/01/Circular/02 of 29 March 2020, CSO organisations led by Sarvodaya extended their support in contributing to this initiative. Sarvodaya played a central role in providing leadership to the CSO initiative coordinating and managing its operations. The beneficiaries were residents living in government and non-government run centres comprised of:

- Government and Private children's homes
- Government and Private elder's homes
- Centres for people with special needs Rehabilitation centres
- Safe houses for women
- Rehabilitation centres
- Probation centres

Lockdowns and curfews posed severe hardships for the government and private institutions providing care for children, elders, the differently abled and other vulnerable groups included in the mandate. This initiative has been an immediate response to a critical need due to care homes being identified as highly vulnerable places because their reliance on *dāna* (giving of alms, mostly cooked meals, and other utensils) offerings by well-wishers to sustain their daily operations. Since well-wishers could not keep up to their promises due to travel restrictions, the beneficiaries of care homes were at grave risk and required regular care where the Collective of CSO organisations large and small stepped into their identified roles and assumed overseeing of care homes in the districts where they had a strong presence.

As of 30 June 2020, this initiative ministered to approximately 525 centres island wide and 15,600 individuals, across all twenty-five administrative districts. The total amount spent on the initiative had been a sum of Rs. 50 million (CSO Collective, 2020). Assistance provided to the centres had been two-fold. First, emergency relief and, second, restoring service gaps such as facilitating medical visits, health, and psychosocial wellbeing. In addition to this, the Collective had also identified concerns related to protection, psychosocial wellbeing, and mental health which have been

brought to the attention of the authorities in their periodic updates to the government.

3.1.3. Risk Communication

The community response also included risk communication. Although there were messages designed centrally and then given to the public, they did not often reach the "last mile". To complement the risk communication messages by the Health Promotion Bureau (HPB), complementary and more innovative messaging was carried out using social media. For example, how to carry out messaging that reflects a religious perspective, for there are teachings in any religion that can be related to a pandemic situation or epidemic situation. An expert group representing the four religions, Buddhist, Hindu, Islamic and Christian, identified content based on the teachings of the respective faiths. Based on this content, effective social media posts and short videos were created and disseminated widely. The messaging also touched on connected issues such as food security, child protection, gender violence and psychosocial wellbeing.

An important feature of this risk communication campaign was that it was based on the real concerns and knowledge gaps of the communities, identified through online consultations, and then linking them with the best of scientific knowledge available at that time in relation to the spread of COVID-19. Among the the success factors in the initial phase of responding to the needs of the communities was the fact that there were determined volunteer groups, mainly youth, who were at the forefront of driving this community engagement process.

One of the key factors of success of engagement is "trust". From a sociological perspective, identifying the needy through an inclusive approach was important so as not to leave anyone behind. Those who are marginalised are the ones that community engagement programmes reach out to and then provide protection for.

3.1.4. Use of Information Communication Technology (ICT)

Information Communication Technology (ICT) is an important tool which provides a safe and reliable means of promoting community engagement during an epidemic where physical movement and gatherings are restricted. However, we are yet to use to the full the potential ICT provides.

3.1.5. Sustainability of community interventions

It is of vital importance that community engagement which involves support to communities during an emergency does not create dependency. There is a strong tendency for communities to continue to rely on external support even after the emergency phase is over. All the examples of interventions presented above ensured that such dependency is not created. In the case of the CSO Collective support for care homes, it was made very clear to the recipients from the very beginning that this assistance was time bound. They were to understand that the support was available only until the curfew was lifted and after that they would have to revert back to the pre-existing mechanisms for their sustenance. However, the Collective remained committed to support the care homes in other ways such as providing guidance on health and safety measures to protect the residents from contracting COVID-19.

3.2. Phase II

Phase II consists of the period between the 1st and 2nd waves of COVID-19, that is, the 4-month period between July and September 2020. During this period the restrictions that were imposed were gradually relaxed and some degree of normalcy started to return to social life. However, it also created a false sense of security that the epidemic was fully under control and the routine preventive measures that were promoted and practised by the public were not taken seriously.

Recognizing the danger of this complacency, Sarvodaya took the lead to launch

a new community mobilization campaign. This initiative was centred around building the capacity of community leaders to engage in COVID-19 preventive activities.

Supported by a grant received from the WHO, a comprehensive community engagement programme consisting of 6 key interventions was implemented during this 3-month period. The interventions were:-

1. Mobilizing and engaging community leaders/volunteers and community based organizations (CBOs) in the prevention and control of COVID-19 and in addressing its health and social impact,

2. Engaging, sensitizing and capacitating communities, including vulnerable community groups, on COVID-19 preventive measures and supporting to equip vulnerable communities with adopting practical protective measures,

3. Strengthening the leadership and meaningful participation of women and girls in all decision-making in addressing the COVID-19 outbreak,

4. Mobilizing religious/faith leaders in COVID-19 prevention and control activities,

5. Strengthen partnerships with state and non-state stakeholders (CSOs and Private sector) to promote community engagement. (

6. Develop and disseminate COVID-19 risk communication materials in Sinhala, Tamil and English targeting specific social groups and settings.

3.3. Phase III

Phase III of community engagement is considered to be from 1st week of October 2020 onwards which marks the beginning of the 2nd wave of COVID-19 in Sri Lanka.

3.3.1. Building community resilience through "COVID Ready Village" concept

With the COVID-19 epidemic in Sri Lanka taking a new turn with a rising number of cases, it was very clear that the efforts should be focused on primary prevention to break the chain of transmission in the community, even though the country was still considered to be in the stage of cluster transmission.

With the 6 months experience gained in working with communities since the epidemic started, it was felt that the focus of community engagement should be on the smallest geographic unit – the village. Initially around 30 villages were selected from all districts to implement the concept. The aim was to build community resilience by initiating a set of coordinated actions at village level led by a village committee named *"Suwodaya"* (Awakening of Health) Committee. The objective was to develop a model in which basic preventive information on COVID-19 will be provided and to empower the village to protect itself from infection collectively and by building effective partnerships with local health officials.

The aim was to minimize the number of new infections to prevent possible risk of the health care system being overburdened. The COVID-ready village concept is also envisaged to address disinformation, misinformation, stigma, and discrimination and to prepare the community to address the medium and long term socio-economic impact.

The impact of this initiative is yet to be seen. However, the initial feedback received so far indicates high enthusiasm and participation by communities through the Suwodaya committees that have been set up.

4. DISCUSSION

It was very encouraging to note that, in Sri Lanka, the decision makers in the State health sector recognized the importance of community engagement in COVID-19 at an early stage by formulating new strategies and/or incorporating into existing strategies the

different elements of community engagement as given in the WHO Interim Guidance. The Health Promotion Bureau (HPB), the apex body having the official mandate to facilitate community engagement in the national covid response, prepared the initial strategy for COVID-19 Risk Communication and Community Engagement (RCCE) in Sri Lanka (Health Promotion Bureau, 2020).

The Epidemiology Unit of the Ministry of Health which is the lead technical agency responsible for COVID-19 control in Sri Lanka also highlighted the significance of community engagement in COVID-19 in Sri Lanka by publishing a 2-part leading article in its Weekly Epidemiological Report (WER) on the theme *"Risk Communication and Community Engagement in COVID-19; Challenges and way forward"* (WER Epidemiology Unit, 2020). In this analysis, i) *uncertainly* resulting from social and economic consequences, ii) *shortcomings in communicating messages to the public*, (iii) *pandemic fatigue*, and (iv) *trust,* were identified as key challenges that needed to be addressed. Whilst the importance of maintaining *community trust* in a long-lasting pandemic is highlighted in the WER, in actual practice, the efforts have not been adequate to build and sustain the trust element in the public mind. Not having a single authoritative voice on government policies and strategies in COVID-19 control, conflicting messaging given to the public from different sources, not fully disclosing data required to mount a "whole of society approach" as recommended by the WHO, continue to be serious impediments to promoting community engagement in Sri Lanka.

Another challenge that is observed in community engagement in COVID-19 response in Sri Lanka is the low level of involvement of civil society and non-governmental organizations in the national COVID-19 prevention and control program. Traditionally, CSOs and NGOs have been recognized as important stakeholders or even equal partners during times of disasters. Generally, the CSOs, NGOs and Community-based organizations (CBOs) are vital players in promoting and engaging communities, mobilizing local resources and volunteers. However, this "people's sector" is not represented in higher national level decision making bodies such as the National Operation Centre for Prevention of COVID-19 Outbreak (NOCCO).

It is interesting however to note that, China, a country with a much more centralized governance structure, made a conscious effort to promote community engagement in all COVID-19 prevention and control work at a very local level. As Hui and Wu (2020) observe in their study on RCCE in China in the prevention and control of COVID-19.

"most local community response teams included members not only from the primary healthcare facility and quarantine office but also from many mass, grass-roots, and self-governing organizations in an urban or rural community. The teams are very familiar with the residents and more effective in conducting screenings of suspected cases and epidemiological investigation of community outbreak".

However, it was very encouraging to note that the HPB subsequently developed strategies enabling the CSOs to engage in RCCE activities and build strong partnerships (Wijesinghe & Karunapema, 2020). Formal partnerships were formed with organizations such as Sarvodaya and the Alliance for Development Trust (ADT), and a range of outreach activities to promote community engagement were carried out from June to December 2020 (during Phase II). The activities included training (both in-person and online), and mobilizing community leaders, women and youth leaders, pre-school teachers and the clergy to educate the public and to implement activities at village level to address misinformation, disinformation, stigma and discrimination. Armed with this knowledge, the trained personnel conducted regular checks and monitored compliance of preventive health practices at public places such as markets, religious institutions, pre-schools and local schools, shops and groceries, and government institutions in their own locality. The youth were engaging in activities

such as painting floor markings for 1 metre distance, displaying posters with COVD-19 preventive messages in public places, and providing support for families in quarantine in the community.

5. CONCLUSIONS

The importance of community engagement in combatting COVID-19 in Sri Lanka is well recognized at a policy level. However, there are gaps in the implementation and a supportive and enabling environment need to be created. The nine month experience of engaging communities in COVID-19 prevention and control activities has demonstrated the potential that is there to make them contribute to national efforts. The highly centralized COVID-19 prevention and control strategy that is currently in place need to be shifted to a more devolved and decentralized model where communities are given greater authority and freedom and be made equal partners.

REFERENCES

Chu, C. (1997). Community participation in public health: Definitions and conceptual framework. In R. Simpson (Ed.), *Ecological Public Health: From Vision to Practice* (pp. 232–239). Ecological Public Health: From Vision to Practice (pp.232-239Institute of Applied Environmental Research, Griffith University and Centre for Health Promotion , University of Toronto, Canada. https://www.researchgate.net/publication/306239533_Community_participation_in_public_health_Definitions_and_conceptual_framework

CSO Collective for COVID-19 Response. (2020). *CSO Collective for COVID-19 Response - Final Report*. Civil Society Collective for COVID-19 Response.

Epidemiology Unit: Ministry of Health. (n.d.). Epidemiology Unit, Ministry of Health. Retrieved January 2, 2021, from http://www.epid.gov.lk/web/index.php?lang=en

Epidemiology Unit, Ministry of Health. (2020a, October). Risk Communication and Community Engagement in COVID-19; Challenges ahead and way forward (Part 1) (Vol. 47, No.44). https://www.epid.gov.lk/web/index.php? option=com_content&view=article&id=148&Itemid=449&lang=en

Epidemiology Unit, Ministry of Health. (2020b, November). Risk Communication and Community Engagement in COVID-19: Challenges and the way forward (Part 2) (Vol. 47 No. 45). https://www.epid.gov.lk/web/index.php?option=com_content&view=article&id=148&Itemid=449&lang=en

Health Promotion Bureau. (2020). *COVID-19 Risk Communication and Community Engagement (RCCE)*. Health Promotion Bureau, Ministry of Health. https://www.hpb.health.gov.lk/media/pdf/community-engagement.pdf

Sarvodaya Shramadana Movement. (2020). *"Suwodaya" Awakening of Health*. Sarvodaya Shramadana Movement.

Wijesinghe, S., & Karunapema, P. (2020). *Strategic Directions for Community Engagement for COVID-19*. Health Promotion Bureau, Ministry of Health. https://www.hpb.health.gov.lk/media/ice-pdf/strategic-community.pdf

World Health organization. (2017). *WHO COMMUNITY ENGAGEMENT FRAMEWORK FOR QUALITY, PEOPLE-CENTRED AND RESILIENT HEALTH SERVICES*. https://apps.who.int/iris/bitstream/handle/10665/259280/WHO-HIS-SDS-2017.15-eng.pdf

World Health Organization. (2020a, April). *Practical considerations and recommendations for religious leaders and faith-based communities in the context of COVID-19*. https://www.who.int/publications/i/item/practical-considerations-and-recommendations-for-religious-leaders-and-faith-based-communities-in-the-context-of-covid-19?gclid=Cj0KCQjw16KFBhCgARIsALB0g8LOOdb2VioGP-ODIpzmRtIzaDJX0Vn8VgXSikY4PPDr3G6zTNd3AZEaAj8QEALw_wcB

World Health Organization. (2020b, December). *Role of community engagement in situations of extensive community transmission of COVID-19 Interim guidance*. World Health Organization Western Pacific Region. https://www.who.int/publications/i/item/WPR-DSE-2020-016

World Health Organization and Unicef. (1978). *Alma Ata Declaration*. World Health Organization. https://www.who.int/docs/default-source/documents/almaata-declaration-en.pdf?sfvrsn=7b3c2167_2

World Health Organization Regional Office for Europe. (2021). *Risk communication and community engagement in emergencies*. Https://Www.Euro.Who.Int. https://www.euro.who.int/en/health-topics/health-emergencies/pages/whos-work-in-emergencies/risk-communication-in-emergencies

BIBLIOGRAPHY

Gilmore, B., Ndejjo, R., Tchetchia, A., de Claro, V., Mago, E., Diallo, A. A., Lopes, C., & Bhattacharyya, S. (2020). Community engagement for COVID-19 prevention and control: a rapid evidence synthesis. *BMJ Global Health*, *5*(10), 1–11. https://gh.bmj.com/content/5/10/e003188

Hu, G., & Qiu, W. (2020). From guidance to practice: Promoting risk communication and community engagement for prevention and control of coronavirus disease (COVID-19) outbreak in China. *JOURNAL OF EVIDENCE-BASED MEDICINE*, *13*(2). https://doi.org/10.1111/jebm.12387

Lough, O., & Holloway, K. (2020, July). *Covid-19: a watershed moment for collective approaches to community engagement?* Health Policy Group. https://cdn.odi.org/media/documents/Covid-19_a_watershed_moment_for_collective_approaches_to_community_engagement.pdf

Marston, C., Renedo, A., & Miles, S. (2020). Community participation is crucial in a pandemic. *The Lancet*, *395*(May 30), 1676–1677. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7198202/

Phytochemical and pharmacological aspects of indigenous medicine‡

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ABSTRACT

The plant kingdom with estimated 500000 to 750000 species is a remarkable natural resource for biomedically important metabolites. It is estimated to harbour about 200000 different phytochemicals in a single given plant. Due to the very low exploitation rates and the presence of bioactive molecules the plant kingdom is known as a "Sleeping Giant" as well as "Natures Pharmacy".

It is reported that 28187 medicinal plant species are used in indigenous medicines worldwide. The pharmacological validations of health claims of medicinal plants using modern scientific tools remarkably justify its uses in the indigenous medicines. It is now known that various different phytochemicals belonging to a range of different phytochemical classes are responsible for the preventive and curative properties of medicinal formulations used. Of the drugs approved in the last 4 decades for instance, 75.4% of the drugs (which includes vaccines) are of natural products origin. Therefore, it is obvious that it is the phytochemicals that play the pivotal nutritive, preventive and curative role in any system of medicine in the world. In the case of polyherbal formulations, it has demonstrated that the effects exert have synergistic, additive, suppressive and ameliorative effects over a symptomatic monotherapy approach and the phytochemicals therein are able to regulate the dysregulated gene expressions during the curative process. Therefore, there is a demand now for multi targeted approach in curative processes including approaches in managing current COVID-19 global pandemic. Under this context Phytochemical and Pharmacological aspect of indigenous medicine is discussed in this review.

Keywords: Phytochemistry, Natural products, Indigenous medicine, Herbal drugs, COVID-19

1. INTRODUCTION

The plant kingdom is the largest repository of chemicals in the world. It is estimated that one single plant harbours about 200000 different phytochemicals (Pichersky & Lewinsohn, 2011) and it is the largest single source for bioactive molecules. However, it is a known fact that not even 10% of this remarkable natural resource with an estimated 500000 to 750000 species (Balandrin et al., 1985; Farnsworth & Kaas, 1981; Chapman, 2009) is exploited for potential applications and therefore the plant kingdom is considered as a "Sleeping giant" (Farnsworth & Morris, 1976). Further, considering the amazing applications of medicinal plants in traditional medical systems and being the source for ~50% of allopathic drugs, the plant kingdom is also reputed as the "Nature's Pharmacy". It is also important to note here that the plant kingdom is the largest source for aroma chemicals in the world. Figure 1 diagrammatically summarizes the position of plant kingdom in medicinal applications.

‡ **Plenary paper**

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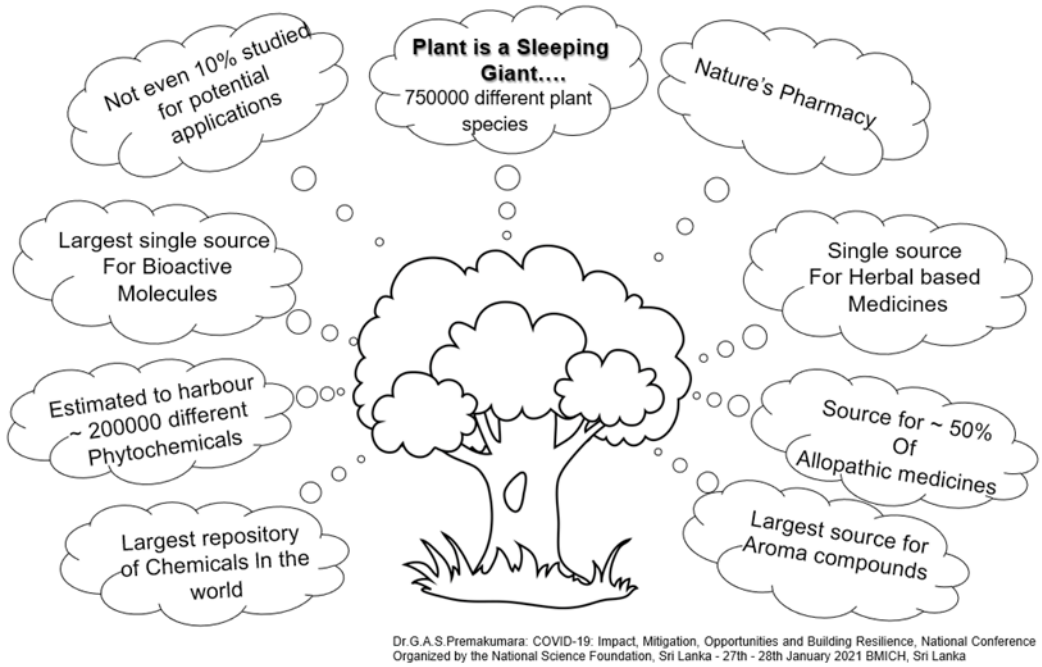


Figure 1. Diagrammatic representation of the position of plant kingdom in medicinal applications

Many natural products from the plant kingdom have been isolated, identified and introduced as pharmaceuticals to allopathic medicines over the last two centuries. Morphine, the most potent pain killer to date, is the first-ever natural product to be isolated and marketed as a pharmaceutical in the world. Starting from Morphine in 1806, a range of natural products has been introduced as pharmaceuticals chronologically as given in Figure 2 (Dias et al., 2012; Butler, 2004; Grabley & Thiericke, 2000; Siddiqui et al 2014). Figure 3 shows some pharmaceutical products available in the market derived from plant based natural products.

2. PHYTO-PHARMACEUTICALS IN MEDICAL SYSTEMS

Treatment modalities in allopathic medicine mainly depend on a single pharmaceutical drug obtained either from natural products, natural product derivatives or synthetic sources primarily addressing symptoms. In the traditional or indigenous medical systems, they mainly depend on poly-herbal formulations where many different plants and plant parts are used with specific quantities prepared according to different preparation techniques given in their systems of medicines (Ayurveda Pharmacopeia 1976). The traditional & indigenous systems expect synergistic and complementary actions from the phytochemicals present in formulations and mostly treat the route cause to cure the disease with less or no side effects.

It is claimed that 28187 medicinal plant species are used in the world in various systems of indigenous medicines (Wills, 2017). In Sri Lanka, there are 1414 medicinal plants recorded to date and about 200 medicinal plants are in use in Sri Lankan indigenous medical systems (World Bank 2004). Medicinal plant families mostly used in the traditional medical systems are as follows: Moraceae 22.5%, Apiaceae 14.4%, Lamiaceae 13.7%, Solanaceae 13.6%, Euphorbiaceae 13.5%, Apocynaceae 13.5%, Rutaceae 13.%, Ranunculaceae 11.9%, Annonaceae 11.9%, Asparagaceae 11.8%, Malvaceae 11.7%, Fabaceae 11.7% (Wills, 2017).

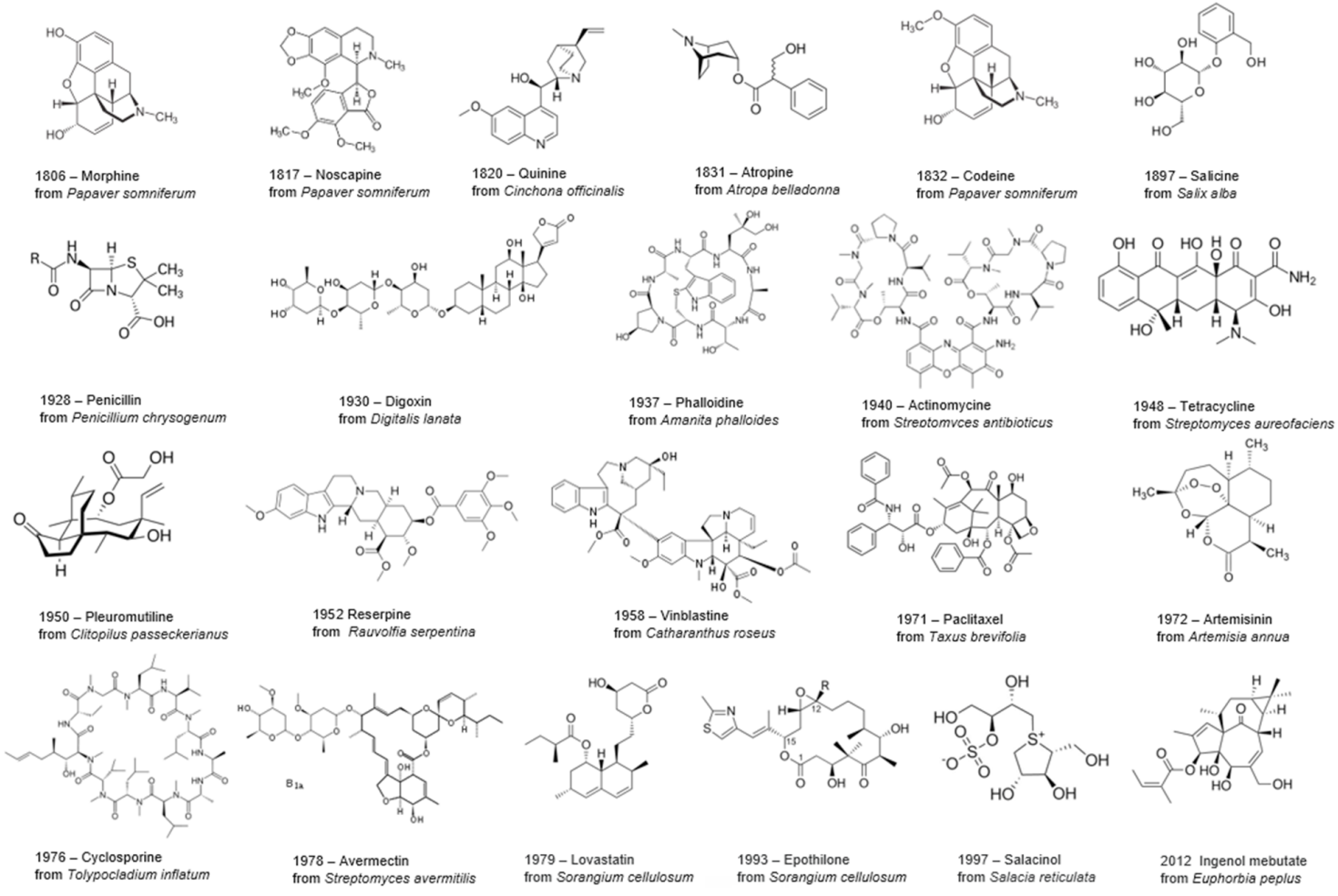


Figure 2. Some landmark pharmaceuticals of natural products origin aligned in a chronological order of discovery (Dias et al, 2012; Butler, 2004; Grabley & Thiericke, 2000; Siddiqui et al 2014)

Pictures: From Internet - downloaded by G.A.S.Premakumara for education purpose only. No commercial interest.

Figure 3. Some manufactured pharmaceutical products by various pharmaceutical companies from natural products

About half of all the drugs in the western pharmacopoeias are plant-derived and originate mainly from the medicinal plants (Newman & Cragg, 2020). For example, the anticancer drug vincristine and vinblastine are from Madagascar periwinkle, *Catharanthus roseus* in the Apocynaceae family and blood thinning drug warfarin is derived from sweet clover, *Melilotus officinalis* in the Fabaceae family1(Wills, 2017).

According to the latest review of Newman & Cragg (2020), of the drugs approved within the last four decades, 1418 (75.4%) are with natural products origin. Only 463 drugs are of pure synthetic origin (Newman & Cragg, 2020). The breakdown of the 1418 approved drugs of natural origin is as follows: natural products – 71 (5%), natural products derivatives – 356 (25%), natural products pharmacophores – 65 (4.6%), natural products mimics – 424 (32%), botanicals – 14 (1%), biologicals – 346 (24.4%), vaccines – 142 (10%) (Newman & Cragg, 2020).

These bioactive molecules can be categorized into various different chemical classes such as alkaloids, flavonoids, phenolic acids, terpenes, saponins, tannins etc. Table 1 shows some examples of pharmacologically active alkaloids exploited in modern medicine.

Table 1. Pharmacologically active natural alkaloids in modern medicine

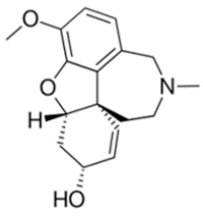
Alkaloid	Plant source	Pharmaceutical Use
Tropane & Nicotine		
Atropine	*Atropa belladonna* / other plants in Solanaceae family	Anticholinergic/ muscarinic antagonist (Hillier, 2007)
Cocaine	*Erythroxylon coca*	Cocaine possesses short-acting local anesthetic and vasoconstrictor properties (Gatley et al , 1998)/ adrenergic blocking agent; drug of abuse (Martin, 1987)
Codeine	*Papaver somniferum*	A nonaddictive analgesic and antitussive (Facchini, 1994)
Morphine	*Papaver somniferum*	Narcotic analgesic, addictive drug of abuse (Facchini, 1994)
Nicotine	*Nicotiana tabacum*	Highly toxic, causes respiratory paralysis, drug of abuse (Benowitz, 2009)
Scopolamine	*Hyoscyamu niger*	Powerful narcotic, used as a sedative for motion sickness (Kutchan, 1995)
Amaryllidaceae		
Galanthamine	*Galanthus woronowii*	Used in the treatment of Alzheimer's disease/ anti-acetylcholinesterase (Olin & Schneider, 2002)
Piperidine		
Coniine	*Conium maculatum*	An extremely toxic alkaloid, causes paralysis of motor nerve endings, used in homeopathy in minute doses (Vetter, 2004)
Terpenoid Indole Alkaloids		
Ajmaline	*Rauwolfia serpentina*	Antiarrhythmic (Rolf et al, 2003)
Quinine	*Cinchona officinalis*	Antimalarial : treat *Plasmodium falciparum* strains that are resistant to other antimalarial drugs (López-Meyer & Nessler, 1997)
Strychnine	*Strychnos nuxvomica*	Tetanic poison, rat poison, used in homeopathy (Olin & Schneider, 2002)
Vinblastine	*Catharanthus roseus*	Antineoplastic used to treat Hodgkin's disease and other lymphomas (Olin & Schneider, 2002)
Vincristine	*Catharanthus roseus*	Antitumor and chemotherapeutic agent (Olin & Schneider, 2002)
Purine		
Caffeine	*Coffea arabica*	Used as a central nervous system stimulant (Cauli & Morelli, 2005)
Pilocarpus		
Pilocarpine	*Pilocarpus jaborandi*	Peripheral stimulant of the parasympathetic system, used to treat glaucoma (Olin & Schneider, 2002)
Ipecac		
Emetine	*Uragoga ipecacuanha*	Orally active emetic, amoebicide (Olin & Schneider, 2002)
Benzophenanthridine		
Sanguinarine	*Eschscholzia californica*	Antibacterial showing antiplaque activity, used in toothpastes and oral rinses (Olin & Schneider, 2002)

Modified from Molecules 2015, 20, 12698-12731; doi:10.3390/molecules200712698 by GAS Premakumara

3. TROPANE AND NICOTINE ALKALOIDS

To date over 12000 alkaloids have been reported from nature with a range of biological activities attributed to many of them (Ncube & Staden, 2015). The tropane class of alkaloids are an important class of plant derived anti-cholinergic compounds such as hyoscyamine and scopolamine that occur mainly in the family Solanaceae. In Sri Lankan indigenous medicine 21 different species of the Solanaceae family are used in the medicinal recipes. Some important representatives of the tropane and nicotine alkaloids are given in Figure 4 (Ncube & Staden, 2015).

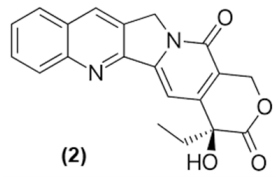
4. AMARYLLIDACEAE ALKALOIDS



(1)

The Amaryllidaceae alkaloids, represent a group of isoquinoline alkaloids, which are produced almost exclusively by members of the Amaryllidaceae family. The pharmacological effects of this group of alkaloids include potent inhibition of acetylcholinesterase, cytotoxicity, antibacterial, antiviral, anti-inflammatory, antiparasitic, antihistaminic, antiproliferative, anticancer and adrenergic activity. They are used in the treatment of lymphocytic leukaemia, mental disorders and age-related dementia. The pharmaceutical potential of the Amaryllidaceae alkaloids is recognised by Galanthamine (1), the Alzheimer's drug in use due to its potent and selective anti-acetylcholinesterase activity (Olin & Schneider, 2002).

5. TERPENOID INDOLE ALKALOIDS



(2)

Many of the terpenoid indole alkaloids are physiologically active in mammals (Ncube & Staden, 2015). Camptothecin (2), isolated from *Camptotheca acuminata* (Nyssaceae), possesses antitumour activity due to its ability to inhibit DNA topoisomerase. It also inhibits anti-retroviruses such as HIV, the equine infectious anaemia virus and parasitic trypanosomes and leishmania.

Other significant plant based terpenoid indole alkaloids in pharmacy are antimalarial drug Quinine, antihypertensive drug ajmalicine and peripheral vasodilator vincamine given in Figure 5.

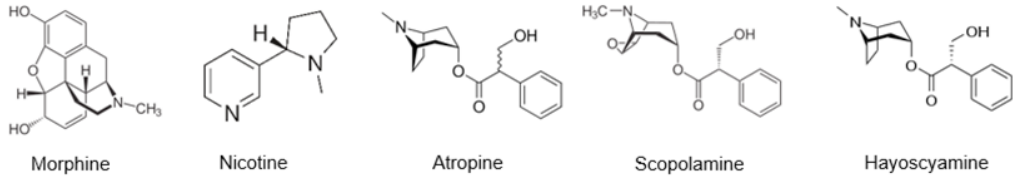


Figure 4. Some representatives of tropane and nicotine alkaloids

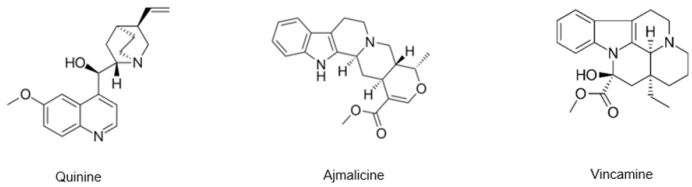


Figure 5. Some plant based terpenoid indole alkaloids in pharmacy

6. INDIGENOUS KNOWLEDGE AND SCIENTIFIC VALIDATIONS

Sri Lanka has a wealth of indigenous knowledge on the entire livelihood and sustainable living. This knowledge is mainly documented in ola leaf text. Some knowledge is in folklore and some are tacit among the rural communities. It is also noteworthy that remnants of ancient hospitals and ancient surgical tools have been excavated from archaeological sites Sri Lanka. Some of the tools show remarkable similarity in shape and dimension to the currently used surgical tools.

Some interesting indigenous knowledge based techniques, technologies and medicinal claims have been validated using modern scientific methods. Though certain factors in certain claims in the indigenous knowledge is beyond explanation from current sciences, from the available evidences, specific health benefit of a specific plant species is now proven to be due to the presence of specific phytochemical/s that can prevent/cure diseases. It has been shown that some of these phytochemicals exert curative actions by regulating respective genes. For example, our studies on effect of sesame oil on hepatic lipid metabolism have shown that specific phytochemicals in sesame oil, sesamin and episesamin regulate liver enzymes by regulating liver genes responsible for fat metabolism (Arachchige et al., 2006). See Figure 6 for hepatic gene regulation by sesame lignans in rats in our study (Arachchige et al., 2006). In the gene expression study RNA samples (30-60µg) were denatured and subjected to electrophoresis on a 1.1% agarose gel containing 0.66 mol/L formaldehyde, then transferred to a nylon membrane and fixed with UV irradiation. The RNA on the nylon membrane was hybridized with radiolabelled cDNA probes specific for mRNAs of respective proteins.

Another interesting research that we conducted provided insight to an explanation given in the 3000 year old medicinal text "*Susrutha Samghitha*" on the causation of "vitiligo" in man (see Figure 7 for a vitiligo patch in man). According to the description

Figure 7. Vitiligo in man

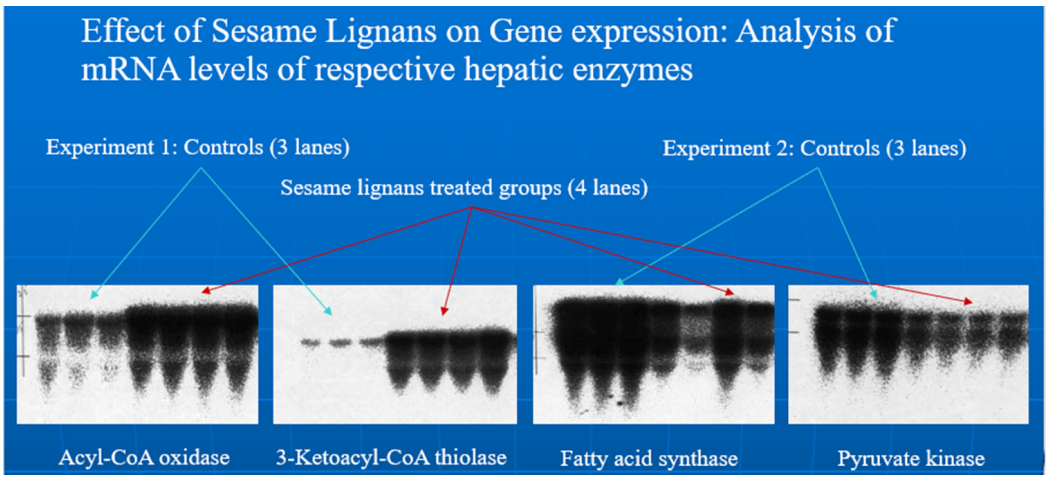


Figure 6. Northern blot analysis of mRNAs of selected enzymes involved in lipid metabolism in the liver of rats fed with experimental diet containing 0.2% Sesamin

given in this ancient text, a rat bite can lead to vitiligo and that rat should be sexually active at the time of the bite and rat's "Sukra" (Semen) has to enter the human body through that bite (Buddhadasa, 1962).

An experiment conducted at the Zoology Department of Colombo University using sexually active "Wistar" rats demonstrated that sexually active rats do have semen in their mouth (Palitharatne et al., 1998). So during a bite, rat semen can enter man's circulation. The semen so entered possibly acts as an antigen forming antibodies against melanocytes causing vitiligo (Palitharatne et al., 1998). See Figure 8 for rat mating behaviour.

7. EFFECT OF ENVIRONMENTAL FACTORS ON PHYTOCHEMISTRY

In indigenous systems of medicines, the harvesting of medicinal plants and plant parts for medicinal preparations has specific biodynamics-based protocols. For example, suppose one wishes to harvest a plant part for a medicine that should be enriched with phytochemicals produced through photo sensitive biosynthesis. In that case, one needs to harvest the plant part in the morning from the side of the plant facing the rising sun (Yang et al., 2018).

Migration of phytochemicals in a plant from one area to another and enrichment with beneficial phytochemicals based on the environmental dynamics is well established in current plant sciences (Yang et al., 2018). See Table 2, Table 3, Table 4, Table 5 & Table 6. Our ancestors must have used these dynamics to manipulate biosynthesis of interested phytochemistry, may be for better taste, aroma, to enrich nutritive components etc. in their food plants and to enrich bioactive phytochemicals in their medicinal plants. The harvesting dynamics and protocols are given in ancient texts (Buddhadasa, 1962).

These recent findings explain the vast knowledge available in traditional bio-dynamic based cultivation practices, harvesting practices, postharvest management and postharvest preparation techniques of our food and medicinal plants.

Knowledge on selecting of specific plant parts and using a specific quantity from that part into the medicinal recipe, ensures the required dose of the active ingredient/s in the formulation in order to give ultimate efficacy of the treatment. Our work on anti-diabetic plant *Kothalahimbutu* (*Salacia reticulata*) showed all plant parts contain glucosidase inhibitory activity (Figure 9) and anti-glycation activity (Figure 10) but at different levels when estimated in terms of IC50 of freeze-dried hot water extracts of different plant parts (Premakumara et al., 2017).

The use of the root of this plant in indigenous formulations for diabetes is a remarkable example to explain the richness of our indigenous medicinal knowledge. Scientific findings have evidenced possession of a multitude of diabetic control mechanisms within this single plant (Paarakh et al., 2008; Arunakumara & Subasinghe, 2010; Medagama, 2015; Katiyar & Kumar, 2017).

Figure 8. Rat mating behaviour

Table 2. Change in photoperiod on the content of various plant secondary metabolites

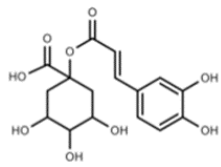
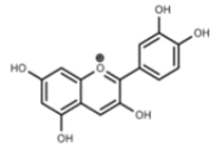
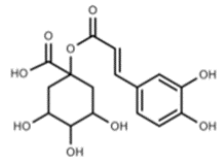
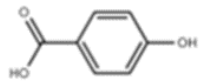
Plant	Compound class	Compound	Environmental Factor	Concentration change
Xanthium pensylvanicuim	Phenols	 Caffeoylquinicacid (Taylor, 1965)	Short day of light	Decrease
Pinus contorta	Phenols	 Pelargonidin (Camm et al, 1993)	Short day of light	Decrease
Ipomoea batatas	Phenols	 Catechins (Carvalho et al., 2010)	Long day of lights	Increase
Ipomoea batatas	Phenols	 Hydroxybenzoic acid (Carvalho et al., 2010)	Long day of lights	Increase

Table 3. Change in light intensity on the content of various plant secondary metabolites

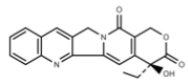
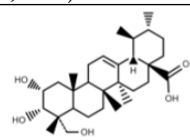
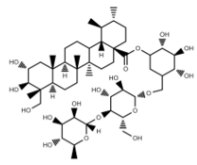
Plant	Compound class	Compound	Environmental Factor	Concentration change
Camptotheca accuminata	Alkaloids	 Camptothecin (Liu et al., 1997)	27% Full sunlight	Increase
Centella asiatica	Phenols	 Asiatic acid (Devkota et al., 2010)	70% Shade	Increase
Centella asiatica	Phenols	 Asiaticoside (Devkota et al., 2010)	Full sunlight	Increase

Table 4. Change in light quality on the content of various plant secondary metabolites

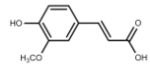
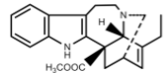
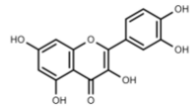
Plant	Compound class	Compound	Environmental Factor	Concentration change
Lactuca sataiva	Phenols	 Ferulic acid (Kliewer, 1977)	Increase red light	Decrease
Catharanthus roseus	Alkaloids	 Catharanthine (Ramani & Jayabaskaran, 2008)	UV-B	Increase
Fagopyrum esculentum	Phenols	 Quercetin (Regvar et al 2012)	UV	Increase

Table 5. Change in soil moisture on the content of various plant secondary metabolites

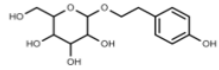
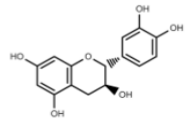
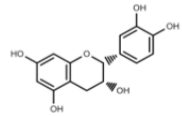
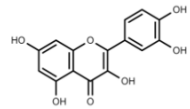
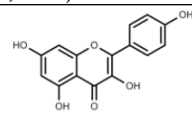
Plant	Compound class	Compound	Environmental Factor	Concentration change
Rhodiola sachalinensis	Phenols	 Salidroside (Shang et al, 2002)	Soil moisture of 55-75%	Increase
Crataegus laevigata	Phenols	 Catechins (Kirakosyan et al, 2004)	Deficit	Increase
Crataegus laevigata	Phenols	 Epicatechins (Kirakosyan et al, 2004)	Deficit	Increase

Table 6. Change in soil fertility on the content of various plant secondary metabolites

Plant	Compound class	Compound	Environmental Factor	Concentration change
Lycopersicon esculentum	Phenols	 Quercetin (Stewart et al, 2001)	Nitrogen & Phosphate	Increase
Lycopersicon esculentum	Phenols	 Kaempferol (Stewart et al, 2001)	Nitrogen & Phosphate	Increase

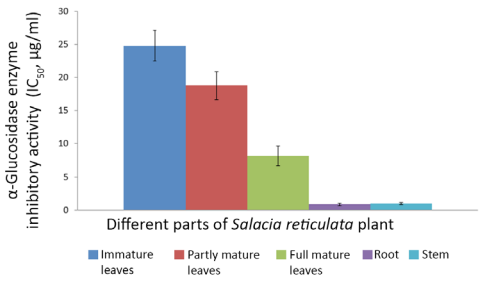


Figure 9. α-Glucosidase enzyme inhibitory activity of different parts of Kothalahimbutu (Salacia reticulata) plant. Mean±SD. (Premakumara et al, 2017)

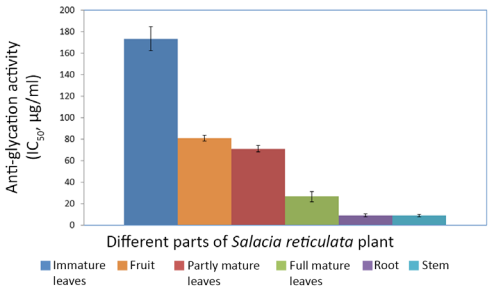
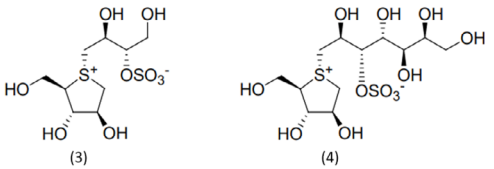


Figure 10. Anti-glycation activity of different parts of Kothalahimbutu Salacia reticulata plant. Mean±SD. (Premakumara et al, 2017).

Kothalahimbutu decoction/extract controls blood sugar by inhibiting starch breakdown enzymes in the gut thereby preventing release of glucose from starchy foods in the gut (Paarakh et al., 2008; Yoshikawa et al., 1997) It is well proved now the plant extract control blood sugar by blocking the activity of enzymes α-glucosidase, β-glucosidase and α-amylase in the gut47. Active enzyme inhibitors reported to be salacinol (3) and kotalanol(4) (Yoshikawa et al., 1997).



Further, *Kothalahimbutu* has the ability to block gluconeogenesis in the liver [the process that converts amino acids to glucose] by inhibiting the gene for gluconeogenesis rate determining enzyme in the liver (Im et al., 2009). Interestingly this remarkable plant is also able to control blood sugar by inhibiting conversion of glycogen to glucose in the liver (Paarakh et al., 2008).

Diabetic complications or pathology is mainly due to protein glycation leading to the formation of Advanced Glycation End products (AGEs) in vital organs and the cardio-vascular system (Singh et al., 2014; Negre-Salvayre et al., 2009).

Uncontrolled diabetes results in high glucose levels in the blood circulation (Fiagbe et al., 2017). High glucose concentration induces reaction of glucose with proteins and lipids in the body leading to glycation of proteins and lipids in vital tissues (Miyazawa et al., 2010). The protein glycation reaction is depicted in Figure 11. When the proteins in

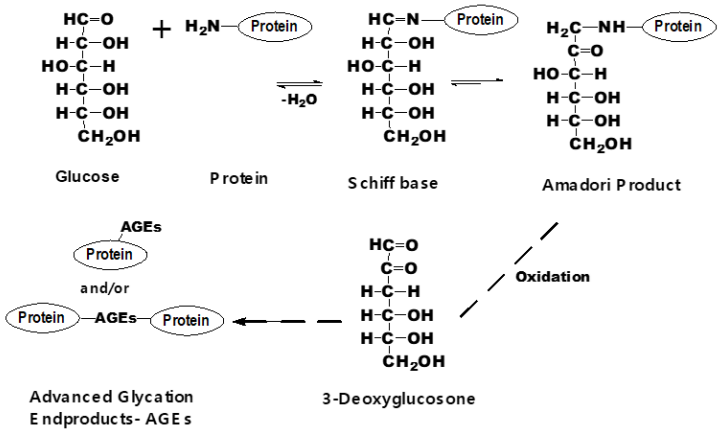


Figure 11. Protein glycation Amadori reaction in the body

vital tissues are glycated the nature and the function of those proteins change leading to pathologic conditions.

Our research with *Kothalahimbutu* demonstrated its ability to block AGE formation and also its remarkable ability in reversing or break cross links of already formed AGEs (Premakumara et al., 2017). The dual role of *Kothalahimbutu* in controlling protein glycation is diagrammatically depicted in Figure 12.

Professor Joji Yamahara's breakthrough experiment conducted in 1996 on Sri Lankan *Kothalahimbutu* (*S. reticulata*) water extract and its isolated active ingredient Salacinol on the sucrose challenge test in rat showed no significant difference in the anti-hypercalcemic activity between the traditional water extract and the isolated pure active ingredient Salacinol of *S. reticulata* (Yoshikawa et al., 1997). (see Figure 13). This experiment supports the contention that in some instances, the indigenous medicinal decoctions exert equal or superior biological effects over its isolated pure active ingredient or the western counterpart.

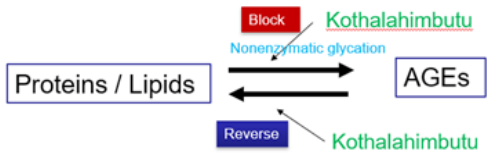


Figure 12. Dual role of *Kothalahimbutu* on management of glycation

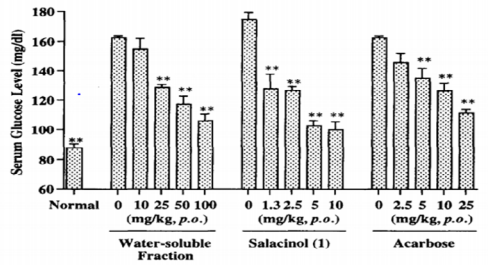


Figure 13. Effect of *Kothalahimbutu (Salacia reticulata)* water extract, it's active ingredient Salacinol and antidiabetic medication Acarbose on postprandial serum glucose levels in rats (Yoshikawa et al, 1997).

Each column represents the mean with SEM of serum glucose levels 30min after sucrose administration. **=p<0.01.

In silico experiments on phytochemicals of Sri Lankan medicinal plants

We data-mined all natural products published from Sri Lankan medicinal plants during the last two decades. From our database, over 480 different compounds were screened *in silico* for selected drug targets. Several potential drug leads were identified for further developments as given in Figure 14.

Interestingly when searched for the origin of the active compounds, the compounds retrospectively correlate with the medicinal plants that are given for hypertension, dyslipidaemia, hyperglycaemia and cardiovascular problems in our traditional medical systems.

8. INDIGENOUS KNOWLEDGE ON INFECTIOUS DISEASES

There is a wealth of knowledge in Sri Lanka on the management of infectious diseases coming from the traditional knowledge, indigenous medicine, Ayurveda and Folklore. The methods available in indigenous systems are very rational based on anti-bacterial, anti-fungal, anti-viral, immunomodulatory, anti-inflammatory and other anti-infectious properties reported from medicinal herbs and indigenous medicinal preparations (Newman & Cragg, 2020; Bylka et al., 2004, Weerakoon et al., 2020)

9. ANTIBIOTICS

All the known anti-biotics have originated from the phytochemistry of medicinal microbes. The Antibiotics discovered with the timeline is given in Figure 15. The world at present is facing the threat of antibiotics resistance for all known pathogens that were managed with these antibiotics. However, the world is still tended to rely on the phytochemistry for the next revolution of antibiotics to face the challenge (Newman & Cragg, 2020).

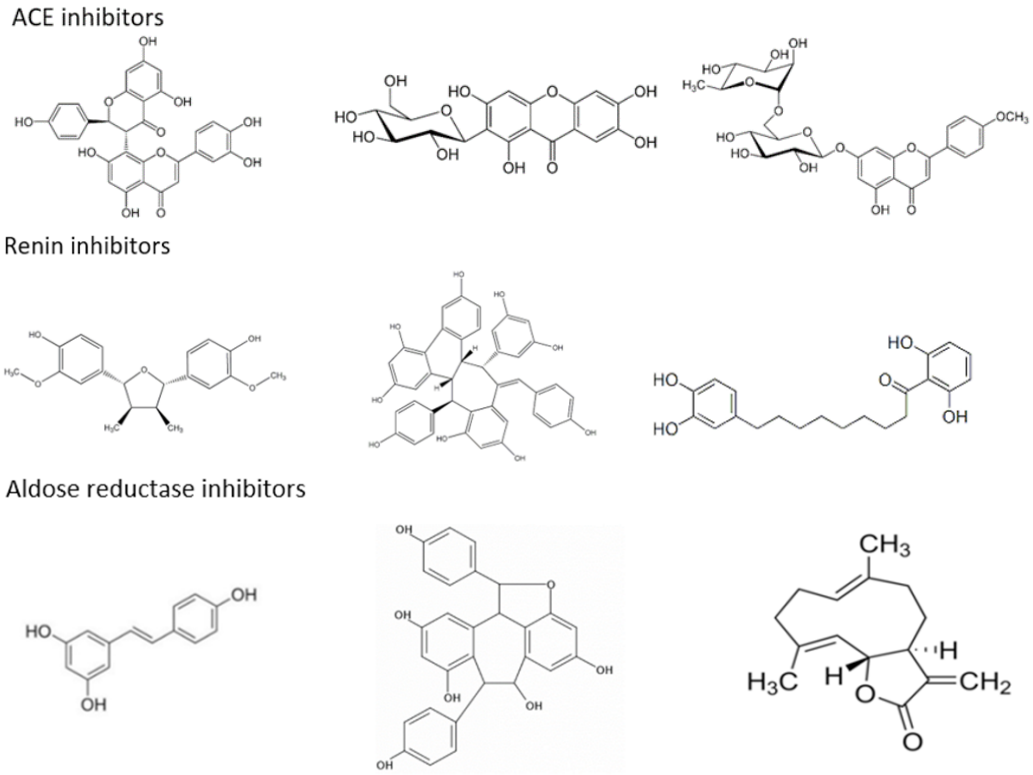


Figure 14. Phytochemicals with Angiotensin converting enzyme(ACE), Renin & Aldose reductase inhibitory activities revealed from in silico experiments.

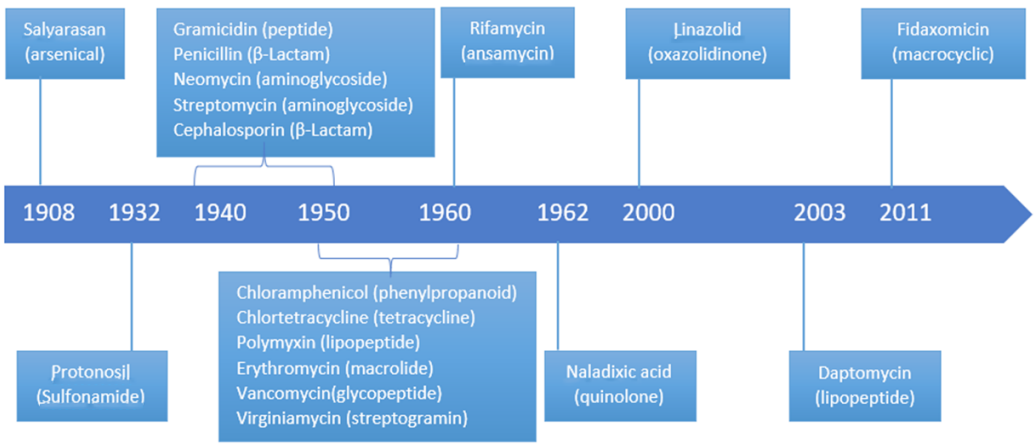
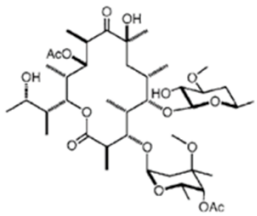
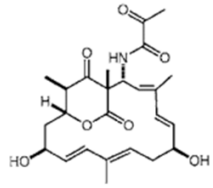


Figure 15. Antibiotic drug discovery with timeline

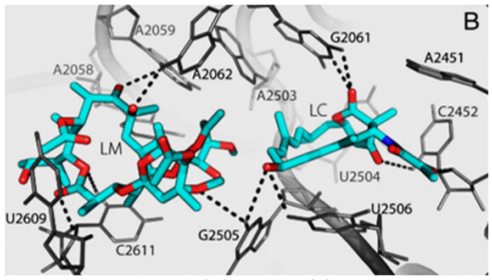
Two macrolide antibiotics originated from Sri Lankan microflora *Streptomyces violaceoniger*, namely Lankamycin (5) & Lankacidin (6) (sold as Sedamycin in Japan for Swine dysentery) are trying for the deadly MRSA infections by Prof.Ada Yonatha's team in Israel [Ada Yonatha, Nobel laureate: Nobel prize for Chemistry 2009] (Belousoffa et al., 2011).



(5)



(6)



Interaction network of Lankamycin (LM) & Lankacidin (LC) surrounding rRNA of MRSA ribosome blocking bacterial protein synthesis. Adopted from Matthew J. Belousoff et al (2011) PNAS February 2011, 108(7), 2717-2772 & modified by G.A.S.Premakumara for the present article in March 2021.

10. ANTIVIRALS OF PLANT ORIGIN

A range of antiviral compounds have been reported from medicinal plants that are been used in indigenous medical systems (Newman & Cragg, 2020). These antiviral properties are reported from almost all phytochemical classes in the plant kingdom. See Table 7.

The class of alkaloid too contains a range of different compounds with anti-viral activities. Examples are atropine, caffeine, papaverine, odorinol, colchicine and vinblastine. In the last four decades 87 biologicals, six natural products derivatives, 26 natural products pharmacophores, 30 natural products mimics and 87 vaccines have been approved as anti-virals from natural products (Newman & Cragg, 2020).

Given to the facts that a range of known medicinal herbs and microbiome carry a large number of phytochemicals with anti-infectious and curative properties, the treatment of infectious diseases using of polyherbal formulations in the indigenous systems of medicines is scientifically very rational.

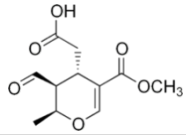
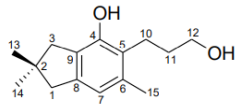
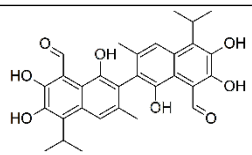
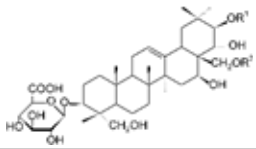
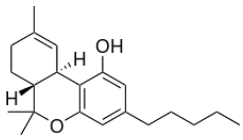
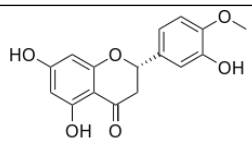
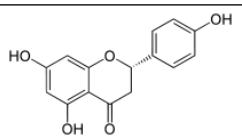
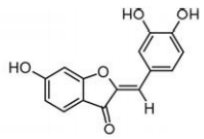
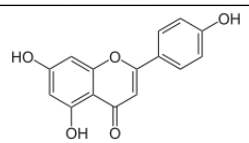
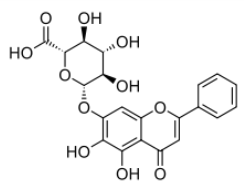
The other approach in the traditional medicine system in management of infections is strengthening of the defence mechanisms in the body which is again very rational. Approach therefore is treating to increase the immunity using herbal formulations. In our experiments on a common traditional concoction of *Koththamalli* & *Veniwelgeta* (CKV) given as a household remedy to prevent viral infections, we scientifically validated this use by showing significant enhancement of both innate & cell mediated immunity in CKV treated rats (Kothalawala et al., 2020).

There are several indigenous herbal formulations available in Sri Lankan market for immunoenhancing properties. In almost all preparations available, some common herbal ingredients can be seen. In the Department of Ayurveda recommended formulation manufactured and marketed by Ayurvedic Drug Corporation of Sri Lanka it contains four ingredients including *koththamalli* & *veniwelgeta* which we tested for immunomodulatory activity. Other two ingredients are *Heen Araththa* (*Alpenia calcarata)* and Ginger (*Zingiber officinalis*) both of which are known to have anti-inflammatory and anti-viral properties (Chandrakanthan et al., 2020; Melanathuru et al., 2017; Kaushik et al., 2020).

11. TESTING OF SRI LANKAN NATURAL PRODUCTS FOR COVID-19

We screened the 480 compounds that we data-mined for anti-COVID-19 drug target, the main protease enzyme Mpro of SARS-CoV-2 which plays a pivotal role in mediating viral replication and transcription. We also screened for ACE-1, a possible entry receptor for SARS-CoV-2 and are in the process of

Table 7. Some examples of phytochemicals with Antiviral properties

Phytochemical Class	Example	Antiviral compound
Terpenoids		
Monoterpenoids (C10)	Elenolate *From Olea europa*	
Sesquiterpenoids (C15)	Tabasesquiterpenes A *From Nicoteana tabacum*	
Diterpenoids (C20)	Gossypol *From Genus Gossypum*	
Triterpenoids (C30)	Gymnemic acid *From Gymnema syslvester*	
Mixed terpenoids	Δ9-tetrahydrocannabinol	
Flavonoids		
Flavanone	Hesperitine *From Citrus species*	
	Naringenin *From Citrus species*	
	Sulfuretin From *Rhus verniciflua*	
Flavone	Apigenin *From Chamaemelum nobile*	
Flavone glycoside	Bicalin *From Scutellaria lateriflora*	

screening for ACE-2, the SARS-CoV-2 spike receptor binding domain. From the *in silico* screening so far conducted we have uncovered 3 compounds from a culinary spice plant with strong binding energy for main protease enzyme Mpro and 3 compounds with strong binding energy for ACE-1 receptor from compounds reported from Sri Lankan anti-hypertensive medicinal herbs.

Recently there has been a plea for multitargeted interventions for sever COVID-19 (Gaborit et al., 2020). It is a joint plea by B.J.Gaborit, Department of Infectious Diseases, Nantes University Hospital, Frans, J.F.Bergmann & F. Raffi of Department of Internal Medicine, Lariboisière Hospital, France, C. Mussini of Clinic of Infectious Diseases, University of Modena and Reggio Emilia, Modena, Italy, J.R.Arribas of Infectious Diseases Unit, Internal Medicine Service, Hospital La Paz, Spain, G. Behrens of Department for Clinical Immunology and Rheumatology, Hannover Medical School, Hannover, Germany, S. Walmsley of Toronto General Hospital Research Institute, Canada, A. Pozniak of London School of Hygiene & Tropical Medicine, UK.

The key points they raised to justify a multitargeted intervention for COVID-19 given in the correspondence are: 1. Severe coronavirus disease 2019 (COVID-19) is not just a serious respiratory viral disease, as influenza is, but rather a systemic multiorgan viral invasion. 2. It is frequently complicated by overwhelming immunological reactions, with overactivation of T cells, leading to acute respiratory distress syndrome and multiorgan failure, secondary to immunopathological processes. 3. The viral load of severe acute respiratory syndrome coronavirus 2 is not correlated with worsening symptoms, but it is the host inflammatory response that is a major cause of lung damage and subsequent mortality. 4. Hyper-inflammatory responses in patients with COVID-19 are associated with a cytokine storm that is characterised by an increase in proinflammatory cytokines, including tumour necrosis factor, interleukin (IL)-1β, IL-6, and other chemokines in serum. 5. Most clinical trials to date have evaluated various strategies of antivirals, immunomodulators, host-targeted drugs, immune-based therapies, or immunosuppressive drugs, including steroids, IL-6 or IL-1 antagonists, and selinexor; all have assessed as single drugs with a clinical endpoint using the WHO seven-point ordinal scale. 6. Although some of these drugs might have a clinically meaningful effects on viral burden or some of the immune-related signs, it is highly improbable that a single drug will be enough to control and improve the most severe forms of COVID-19. 7. Without studying combinations, and their potential synergies or additive effects, potentially useful agents could be disregarded. 8. In the absence of synergistic combinations, single drugs might cause more harm, for example, mass killing of the virus might enhance inflammatory responses. 9. Because of the urgency of the current situation and, so far, an absence of clear evidence of a clinically meaningful effect of any monotherapy strategy, investigators should join their efforts in proposing, rather than adaptive or sequential studies of a single strategy, combined approaches through multifactorial designs (Gaborit et al., 2020).

Based on these nine key points they justify their plea for multitargeted intervention for management of COVID-19 patients which is very rational when study the complications and deaths due to the infection.

When we study the approach of indigenous medicines, its phytochemistry and pharmacology, approach always is using a multitargeted intervention through the polyherbal formulations to cure or prevent a disease. Thus it is pertinent and rational to test indigenous medicines for the management of the COVID-19 pandemic.

REFERENCES

Arachchige P. G., Takahashi, Y. & Ide, T. (2006). Dietary sesamin docosahexaenoic and eicosapentaenoic acids synergistically increase the gene expression of enzymes involved in hepatic peroxisomal fatty acid oxidation in rats. *Metabolism Clinical and Experimental* 55: 381-390.

Arunakumara, K.K.I.U. & Subasinghe, S. (2010). *Salacia reticulata* WIGHT: A review of botany, phytochemistry and pharmacology. *Tropical Agricultural Research* & Extension 13(2): 41-47.

Ayurvedha Pharmacopoeia (1976). Volume 1, Part 1. Department of Ayurvedha, Colombo, Sri Lanka.

Balandrin, M. F., Klocke, J. A., Wurtele, E. S. & Bollinger, W. H. (1985). Natural plant chemicals: Sources of industrial and medicinal materials. *Science* 228: 1154-1160.

Belousoffa, B.J., Shapiraa, T., Bashana, A., Zimmermana, E., Haim Rozenberga, H., Arakawab, K., Kinashib, H. & Yonatha, A. (2011). Crystal structure of the synergistic antibiotic pair, Lankamycin and Lankacidin, in complex with the large ribosomal subunit. *Proceeding of the National Academy of Science USA* 108(7), 2717-2722.

Benowitz, N.L. (2009). Pharmacology of Nicotine: Addiction, Smoking-Induced Disease, and Therapeutics. *Annual Review of Pharmacology and Toxicology* 49: 57–71. https://doi.org/10.1146/annurev.pharmtox.48.113006.094742.

Buddhadasa, R. (1962). *Susrutha Samhitha (Sinhala translation)* (pp. 66-68). Government Press, Colombo, Sri Lanka.

Butler, M. S. (2004). The Role of Natural Product Chemistry in Drug Discovery. Journal of Natural Products 67: 2141-2153.

Bylka, W., Matlawska, I., & Pilewski, N.A. (2004). Natural Flavonoids as Antimicrobial Agents. *Journal of American Nutraceutical Association* 7(2): 24-30.

Camm, E.L., McCallum, J., Leaf, E. & Koupai-abyazani, M.R. (1993). Cold-induced purpling of *Pinus contorta* seedlings depends on previous daylength treatment. *Plant Cell Environment* 16: 761–764.

Carvalho, I.S., Cavaco, T., Carvalho, L.M. & Duque, P. (2010). Effect of photoperiod on flavonoid pathway activity in sweet potato (*Ipomoea batatas* (L.) Lam.) leaves. *Food Chemistry* 118: 384–390.

Cauli, O. & Morelli, M. (2005). Caffeine and the dopaminergic system. *Behavioural Pharmacology* 16(2): 63–77.

Chandrakanthan, M., SHandunnetti, S.M., Premakumara, G.A.S. & Kathirgamanathar, S. (2020). Topical anti-Inflammatory activity of essential oils of *Alpinia calcarata* Rosc., its main constituents, and possible mechanism of action. *Evidence-Based Complementary and Alternative Medicine* 2020, Article ID 2035671, 19 pages https://doi.org/10.1155/2020/2035671

Chapman, A.D. (2009). *Number of Living Species in Australia and the World*, 2nd Edition. Department of the Environment, Water, Heritage and the Arts, Australian Government.

Devkota, A., Dall'Acqua, S., Comai, S., Innocenti, G. & Jha, P.K. (2010). *Centella asiatica* (L.) urban from Nepal: Quali-quantitative analysis of samples from several sites and selection of high terpene containing populations for cultivation. *Biochemical Systematics and Ecology* 38: 12–22.

Dias, D.A., Urban, S. & Roessner, U. (2012). A Historical Overview of Natural Products in Drug Discovery. *Metabolites* 2: 303-336. https://doi.org/10.3390/metabo2020303

Facchini, P.J. (1999). Plant secondary metabolism: Out of the evolutionary abyss. *Trends in Plant Science* 4(10): 382–384. https://doi.org/10.1016/s1360-1385(99)01476-4

Farnsworth, N. R. & Morris, R.W. (1976). Higher plants – the sleeping giant of drug development. *American Journal of Pharmacy and the Sciences Supporting Public Health* 148(2):46-52.

Farnsworth, N.R. & Kaas C.J. (1981). An approach utilizing information from traditional medicine to identify tumour-inhibiting plants. *Journal of Ethnopharmacology* 3: 85 – 99

Fiagbe, J., Bosoka, S., Opong, J., Takramah, W., Axame, W.K., Owusu, R., Parbey, P.A., Adjuik, M., Tarkang, E. & Kweku, M. (2017). Prevalence of controlled and uncontrolled diabetes mellitus and associated factors of controlled diabetes among diabetic adults in the hohoe municipality of Ghana. *Diabetes Management* 7(5): 343–354.

Gaborit, B.J., Bergmann, J.F., Mussini, C, Arribas, J.R., Behrens, G., Walmsley, S., Pozniak, A. & Raf, F. (2020). Plea for multitargeted interventions for severe COVID-19. *Lancet Infectious Diseases* 20(10): 1122-1123. https://doi.org/10.1016/ S1473-3099(20)30312-1

Gatley, S.J., Gifford, A.N., Volkow, N.D. & Fowler, J.S. (1998). Pharmacology of Cocaine. In R. E. Tarter et al. (eds.), *Handbook of Substance Abuse*. New York, NY: Springer.

Grabley, S. & Thiericke, R. (2000). *Drug Discovery from Nature.* (pp. 3-37) Berlin: Springer.

Hillier, K. (2007). Atropine. In S.J. Enna & David B. Bylund (eds.), *XPharm*: *The Comprehensive Pharmacology Reference* (pp.1-5). Elsevier Inc.

Im, R., Mano, H., Matsuura, T., Nakatani, S., Shimizu, J., & Wada, M. (2009). Mechanisms of blood glucose-lowering effect of aqueous extract from stems of *Kothala himbutu* (*Salacia reticulata*) in the mouse. *Journal of Ethnopharmacology* 121(2), 234–240. https://doi.org/10.1016/j.jep.2008.10.026

Katiyar, M. & Kumar, N. (2017). A review: pharmacological activities of *Salacia reticulata* WIGHT. *World Journal of Pharmaceutical and Medical Research* 3(6), 81-84.

Kaushik, S., Jangra, G., Kundu, V., Yadav, J.P. & Kaushik, S. (2020). Anti-viral activity of *Zingiber officinale* (Ginger) ingredients against the Chikungunya virus. Virus Diseases 31(3): 270–276. https://doi.org/10.1007/s13337-020-00584-0.

Kirakosyan, A., Kaufman, P., Warber, S., Zick, S., Aaronson, K., Bolling, S., & Chul Chang, S. (2004). Applied environmental stresses to enhance the levels of polyphenolics in leaves of hawthorn plants. *Physiologia Plantarum* 121, 182–186.

Kliewer, W.M. (1977). Influence of temperature, solar radiation and nitrogen on coloration and composition of Emperor grapes. *American Journal of Enology and Viticulture* 28: 96–103.

Kothalawala, S.D., Edward, D., Harasgama, J.C., Ranaweera, L., Weerasena, O.V.D.S.J., Niloofa, R., Ratnasooriya, W.D., Premakumar,a G.A.S. & Handunnetti, S.M. (2020). Immunomodulatory Activity of a Traditional Sri Lankan Concoction of *Coriandrum sativum* L. and *Coscinium fenestratum* G. Evidence-Based Complementary and Alternative Medicine Volume 2020, Article ID 9715060, 10 pages. https://doi.org/10.1155/2020/9715060.

Kutchan, T.M. (1995). Alkaloid Biosynthesis: The basis for metabolic engineering of medicinal plants. *Plant Cell* 7: 1059.

Liu, Z., Carpenter, S.B. & Constantin, R.J. (1997). Camptothecin production in *Camptotheca acuminata* seedlings in response to shading and flooding. *Canadian Journal of Botany* 75: 368–373.

López-Meyer, M. & Nessler, C.L. (1997). Tryptophan decarboxylase is encoded by two autonomously regulated genes in *Camptotheca acuminata* which are differentially expressed during development and stress. *Plant Journal* 11: 1167–1175.

Martin, F.S. (1987). The Amaryllidaceae Alkaloids. In A. Brossi (ed.), *The Alkaloids: Chemistry and Phamarcology* (Volume 30). London, UK: Academic Press.

Medagama, A.B. (2015). *Salacia reticulata* (Kothalahimbutu) revisited; a missed opportunity to treat diabetes and obesity?. *Nutrition Journal* 14: 21. https://doi.org/10.1186/s12937-015-0013-4

Melanathuru, V., Rengarajan, S. & Thangavel, N. (2017). Comparative study of antioxidant and anticancer activity of *Alpinia calcarata* and *Alpinia galanga*. *International Journal of Pharmacy & Pharmaceutical Science* 9(12): 186-193.

Miyazawa, T., Nakagawa, K., Shimasaki, S. & Nagai, R. (2010). Lipid glycation and protein glycation in diabetes and atherosclerosis. *Amino Acids* 42(4), 1163–1170. https://doi.org/10.1007/s00726-010-0772-3.

Ncube, B & Staden, J.V. (2015). Tilting Plant Metabolism for Improved Metabolite Biosynthesis and Enhanced Human Benefit. *Molecules* 20: 12698-12731. https://doi.org/10.3390/molecules200712698.

Negre-Salvayre, A., Salvayre, R., Augé, N., Pamplona, R. & Portero-Otín, M. (2009). Hyperglycemia and glycation in diabetic complications. *Antioxidant & Redox Signaling* 11: 3071-3109.

Newman, D.J. & Cragg, G.M. (2020). Natural Products as Sources of New Drugs over the Nearly Four Decades from 01/1981 to 09/2019. *Journal of Natural Products* 83: 770–803.

Olin, J. & Schneider, L. (2002). Galantamine for dementia due to Alzheimer's disease. *The Cochrane Database of Systematic Reviews.* https://doi.org/10.1002/ 14651858. cd001747.

Paarakh, P.M., Patil, L.J. & Thanga, S.A. (2008). Genus Salacia: A Comprehensive Review. *Journal of Natural Remedies* 8(2): 116 – 131.

Palitharatne, C.D., Vidyaratne, M.G.A. & Ratnasooriya, W.D. (1998). The presence of spermatozoa in the oral cavity of sexually active male rats. *Ceylon Journal of Science (Biological Sciences)* 25: 52-56.

Pichersky, E. & Lewinsohn, E. (2011). Convergent evolution in plant specialized metabolism. *Annual Review of Plant Biology* 62: 549–566.

Premakumara, G.A.S., Abeysekera, W.K.S.M. & Ranasinghe, P. (2017). Anti-glycation and Glycation Reversing Potential of *Salacia reticulata* L. (*Kothala Himbutu*) Root, Stem, Leaf and Twig Extracts. Chapter 7 in: Drug Discovery From Herbs - Approaches & Applications - Published by NAM S&T Centre, India.

Ramani, S. & Jayabaskaran, C. (2008). Enhanced catharanthine and vindoline production in suspension cultures of Catharanthus roseus by ultraviolet-B light. *Journal of Molecular Signalling* 3: 9.

Regvar, M., Bukovnik, U., Likar, M. & Kreft, I. (2012). UV-B radiation affects flavonoids and fungal colonisation in *Fagopyrum esculentum* and *F. tataricum*. *Open Life Science* 7: 275–283.

Rolf, S., Bruns, S.J., Wichter, T., Kirchhof, P., Ribbing, M., Wasmer, K., Paul, M., Breithardt, G., Haverkamp, W. & Eckardt, L. (2003). The

ajmaline challenge in Brugada syndrome: Diagnostic impact, safety, and recommended protocol. *European Heart Journal* 24: 1104–1112

Shang, X., Wang, Y. & Yan, X. (2002). Effect of soil moisture on growth and root-salidroside content in *Rhodiola sachalinensis*. *Plant Physiology Communications* 39: 335–336.

Siddiqui, A.A., Iram, F., Siddiqui, S. & Sahu, K. (2014). Role of Natural products in Drug Discovery Process. *International Journal of Drug Development & Research* 6 (2): 172-204.

Singh, V.P., Bali, A., Singh, N. & Jaggi, A.S. (2014). Advanced glycation end products and diabetic complications. *Korean Journal of Physiology & Pharmacology* 18(1): 1-14.

Stewart, A.J., Chapman, W., Jenkins, G.I., Graham, I., Martin, T. & Crozier, A. (2001). The effect of nitrogen and phosphorus deficiency on flavonol accumulation in plant tissues. *Plant Cell & Environment* 24, 1189–1197.

Taylor, A.O. (1965). Some effects of photoperiod on the biosynthesis of phenylpropane derivatives in Xanthium. *Plant Physiology* 40: 273.

Vetter, J. (2004). Poison hemlock (*Conium maculatum* L.). *Food and Chemical Toxicology* 42: 1373–1382. https://doi.org/10.1016/j.fct.2004.04.009

Weerakoon, W.A.S.S., Perera, P.K., Samarasinghe, K., Gunasekera, D. & Suresh, T.S. (2020). Acute and Subchronic Oral Safety Profiles of the Sudarshana Suspension. *Evidence-Based Complementary and Alternative Medicine* 2020: Article ID 2891058, 8 pages. https://doi.org/10.1155/2020/2891058

Wills, K.J. (2017). State of the World's Plants 2017. Royal Botanic Gardens, Kew, London, UK: https://stateoftheworldsplants.com/2017/useful-plants.html.

World Bank. (2004). Medicinal Plants: Conservation and Sustainable Use in Sri Lanka. Indigenous Knowledge (IK) Notes; No. 66. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/10771 License: CC BY 3.0 IGO.

Yang, L., Wen, K., Ruan, X., Zhao, Y., Wei, F., & Wang, Q. (2018). Response of Plant Secondary Metabolites to Environmental Factors. *Molecules* 23: 762. https://doi.org/10.3390/molecules23040762.

Yoshikawa, M., Murakami, T., Shimada, H., Matsuda, H., Yamahara, J., Tanabe, G., & Muraoka, O. (1997). Salacinol, potent anti-diabetic principle with unique thiosugar sulfonium sulfate structure from the Ayurvedic traditional medicine *Salacia reticulata* in Sri Lanka and India. *Tetrahedron Letters* 38: 8367-8370.

NATIONAL SCIENCE FOUNDATION

Section 2

Health

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Health: Introduction

Palitha Abeykoon and Saroj Jayasinghe

Sri Lanka detected the first case of COVID-19 in a foreign tourist on 27th of January 2020 and in a Sri Lankan on the 11th of March. Since then, the epidemic has come in three waves and there have been a total of 235413 cases who have had the infection with 2480 deaths (as of 19 June 2021).

The country has an extensive network of state health facilities that provide health services at zero user-charge. However, its health services were under-resourced compared to most countries and our critical care bed capacity was only 2·3/100,000 population, compared to the 6.6/100,000 in UK, 10.6/100,000 in South Korea, 12.6/100,000 in Italy, 34·2/100,000 in the USA. The hospitals in the early stages lacked adequate reserves of personal protection equipment, hand-wash resources and trained staff and had minimal experience in handling massive epidemics, unlike China, Singapore or Vietnam which were previously affected by the SARS. With a per-capita Gross National Income (GNI) of US $4020 it could not afford a costly epidemic that was devastating far richer economies (e.g. Italy's per-capita-GNI was US $ 34460). Sri Lanka had no option but to embark on strict public health and social prevention measures to curtail the entry of the virus and the spread of the epidemic and avail adequate time to strengthen the readiness of its health system.

The first wave included large clusters in a Navy Camp and in a rehabilitation centre in Kandakadu which were successfully crushed and from 30th of April 2020 there were no cases from Sri Lankans except those retuning from overseas. From September 2020, Sri Lanka experienced a second wave from clusters that originated in a garment factory and fish market. This was brought under control by April 2021. Unfortunately, a more devastating third wave began immediately after the New Year holidays 13-14th of April, mainly triggered by wide-ranging social mixing and extensive travel during this period.

Presently, the 3rd wave of the epidemic continues to spread especially in urban areas and has affected all the 25 administrative districts of the country, though at different intensities. This is despite severe movement restrictions that are still operative in May and June 2021. It has led to disruptions in the routine care of chronic diseases and widespread restrictions to health services. It has also had a devastating impact of the epidemic on the country's economy (especially through excessive healthcare costs, disruption earning from tourism and remittances by migrant workers), adversely affected intellectual growth of children due to school closures and has disrupted the social fabric as a result of isolation and curtailment of mobility. Other expected issues include an increase in domestic violence and the collapse of small and medium scale traders from loss of earnings.

COVID-19 has highlighted the importance of Sri Lanka improving its capacity to predict and prepare for natural disasters of this nature, enhance its resilience to mitigate, adapt and develop despite adversity. This would be possible by sharing, documenting and reflecting on our experiences and those in other countries, and learning from them to meet future challenges. This is a cyclical process that has to progress with a steady infusion of science and innovations in order to achieve an equitable, resilient and sustainable future. Such achievements will require recovery of in spheres of health, social protection, economic recovery, macroeconomy and social cohesion, and a transformative change in society. Business as usual in the post-pandemic era is not an option and the conference should be considered as the beginning of this journey towards a new normal and a better future.

The papers in the volume cover a wide range of topics, mostly based on studies from Sri Lanka. They cover the period from the origin of the global infection in early January 2020 when the World Health Organization reported a cluster of pneumonia cases in Wuhan, China, in early January 2020, through the time WHO declared COVID-19 -19 a public health emergency in January 2020

and a pandemic on 11 March 2020 until February 2021 when the Conference was held.

The presentations and communications included topics like estimation of virus reproduction rates and case-loads, guideline development for primary care, viral and immunological aspects, clinical care, knowledge of COVID-19 among future frontline healthcare workers, projecting the economic and social impact of the epidemic, and experiences in establishing new healthcare facilities. Research on functional foods and0 use of vitamin D were also presented. There were reviews on the virological and immunological aspects of COVID-19 and the physics and mechanics of spread of the virus from person to person and in clusters.

There was a wide range of discussions on control measures such as travel restrictions, and their impact on livelihoods, education and the economy. There is evidence of growing social and economic inequalities in the society as the economically and socially disadvantaged communities were more vulnerable. The health system suffered directly due to the difficulties in continuing the rest of its services. Clinics were closed and hospitals reduced their services in order to curtail spread of the disease. Telemedicine was increasingly used, and that too led to widening inequalities due to the digital gap. Repatriation of migrant workers and labour force and their management within the local health system posed fresh challenges and issues. The second and third waves have dealt serious shocks to the system. The pressure on the curative healthcare system increased drastically as increasing numbers of cases were detected. There were difficulties in coping with the situation and new facilities were required at short notice to house all persons with positive PCR test. With the availability of the vaccine, fresh challenges emerged, especially to secure vaccines in a scare international market.

Recovery period from COVID-19 will lead to fresh challenges which need to be met.

1. There is an urgent need to strategize the overall recovery of the nation and society from the pandemic.

2. The successes of the country, the experiences gained and lessons learnt should be showcased and given wider dissemination among the international community and the local population for posterity.

3. Health systems have to be made more resilient to face future pandemics and disasters.

4. Social support systems need to be strengthened to enable society to cope with crises that occur at micro and macro levels of the community.

5. Capacity has to be built to make the country more aware, informed and self-reliant in the production of diagnostic tools, essential medicines and vaccines.

Potential antiviral herbal drugs from Sri Lanka with special reference to SARS-CoV-2‡

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ABSTRACT

The search for novel and effective drugs is an important challenge, as a severe acute respiratory syndrome caused by a zoonotic coronavirus (SARS-CoV-2) is affecting the entire world population. As of 18th April 2021 there were over 140 million confirmed cases and more than 3 million deaths due to COVID-19. Natural herbal drugs are a rich resource for novel antiviral drug development. Many studies and traditional medical practices have shown their effectiveness against various human pathogens like the influenza virus, hepatitis C virus, coronavirus and the human immunodeficiency virus. Although modern synthetic drugs based on Western medicine are used in developed countries, traditional plant-based drugs are an integral part of medical treatment, including Sri Lanka. In Sri Lanka, the administration of crude herbal drug formulations dates back more than 3000 years. Numerous studies have shown that natural herbal drugs possess a wide spectrum of biological and pharmacological properties, such as anti-inflammatory, anti-angiogenic and anti-neoplastic. Accordingly, these herbs have been used for centuries in Sri Lankan traditional medicine to treat various disorders. Despite the potency, none of these herbal medicines has yet been approved as a therapeutic antiviral agent against SARS-CoV-2 due to a lack of data from clinical trials. This review summarizes the current knowledge and future perspectives of the antiviral effects of potent Sri Lankan herbal drugs as potential sources of effective anti-coronavirus therapies.

Keywords: Coronavirus, COVID-19, Plant-based drugs, Severe acute respiratory syndrome, Zoonotic disease

1. INTRODUCTION

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) originated in Wuhan, Hubei Province in China in late 2019 and rapidly spread worldwide (Di Gennaro et al., 2020, Sun et al., 2020). By 18th April 2021, the World Health Organization (WHO) estimated that over 140 million people had been infected globally with SARS-CoV-2, of which more than 3 million had died from the infection (WHO, 2021b). The novel coronavirus disease in humans (COVID-19) causes acute respiratory symptoms such as cough, fever, and lung damage (Sun et al., 2020). Other than respiratory symptoms, patients may also suffer from other conditions such as fatigue, myalgia, and diarrhea and can finally lead to pneumonia, organ failure and death (Di Gennaro et al., 2020; Sun et al., 2020). SARS-CoV-2 infection is transmitted in several ways, but most commonly through respiratory droplets of infected humans and contact with contaminated surfaces (Guo et al., 2020;

‡ **Invited Paper**

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Vellingiri et al., 2020). Accordingly, countries across the globe have implemented a range of public health and social measures, including isolation, quarantine, social distancing, partial closure or closure of public gathering areas such as educational institutes and businesses, quarantine in specific geographic regions and international travel restrictions for the prevention and management of disease transmission (Vellingiri et al., 2020).

The main management approach for prevailing COVID-19 is supportive care, accompanied by the combination of broad-spectrum antibiotics, antivirals, corticosteroids and convalescent plasma (Figure 1). The plausible antiviral drugs for SARS-CoV-2 were designed for the prevention of previous viral outbreaks such as Ebola, Middle East respiratory syndrome coronavirus (MERS-CoV) and severe acute respiratory syndrome coronavirus (SARS-CoV) viral diseases (Guo et al., 2020; Vellingiri et al., 2020). The efficacy and safety of these antiviral agents for COVID-19 is under investigation in ongoing clinical trials in different countries (Kivrak et al., 2021; Martinez, 2020; Tu et al., 2020; Williamson et al., 2020). Even though antibiotics are not effective against SARS-CoV-2, patients with COVID-19 may receive antibiotics for secondary bacterial infections (Guo et al., 2020). The blood from patients who have recovered from COVID-19, known as convalescent plasma, contains antibodies to fight off SARS-CoV-2 infections (Shen et al., 2020; Zhai et al., 2020). It is believed that convalescent plasma can be given to patients with severe COVID-19 to improve their ability to fight the virus (Shen et al., 2020). Additionally, corticosteroids such as methylprednisolone could suppress lung inflammation in patients with COVID-19 (Li et al., 2020; Ye et al., 2021), and oxygen therapy has a well-established role in the management of respiratory failure due to severe COVID-19 (Zhai et al., 2020).

Even though multiple research and development projects are underway to discover a new and efficient drug therapy, there is no specific medicine to prevent or treat SARS-CoV-2 (WHO, 2021a). The development of effective treatments against SARS-CoV-2 is further complicated by the long incubation period of the virus in humans, making source and transmission routes elusive (Vellingiri et al., 2020; Zhai et al., 2020). Moreover, antiviral drugs also exhibit adverse side effects, directly and indirectly affecting human

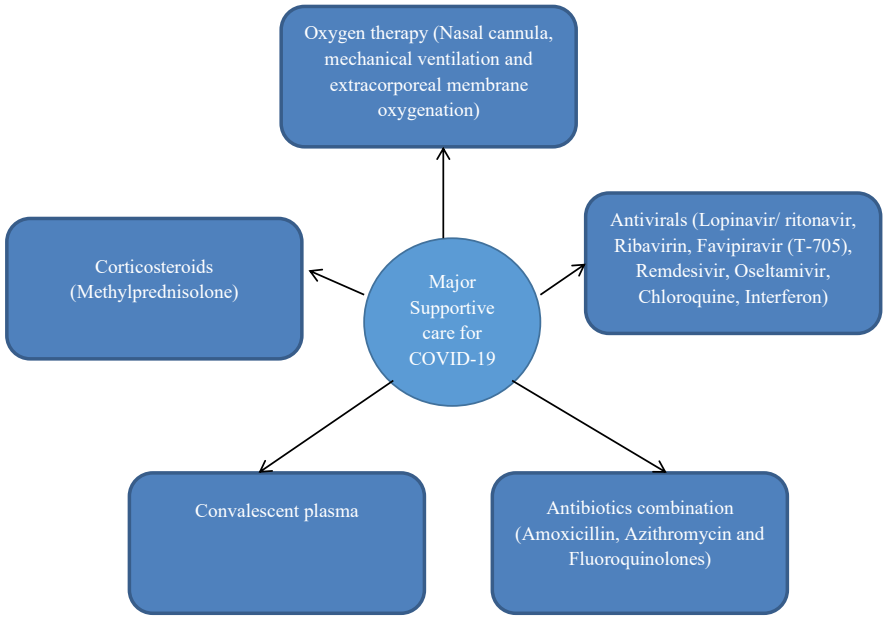

Figure 1. Major supportive treatments for patients with SARS-CoV-2 infection

health (Vellingiri et al., 2020). Therefore the development of plant-based drugs and herbal treatments with minimal side effects is of utmost importance. Recent studies from China report that, based on their experience in the treatment of previous respiratory syndromes such as SARS and MERS, both conventional medicine and traditional Chinese medicine can be used to treat COVID-19 patients (Yang et al., 2020). The limited tests of combining Chinese medicine (Shufeng Jiedu Capsule) with known antiviral drugs have shown improvement of pneumonia symptoms in COVID-19 patients (Chen et al., 2021; Wang et al., 2020).

Herbal drugs are a large group of bioactive chemical compounds derived from plants, which have potential protective effects against diseases. These chemicals can be found in different parts of plants, such as leaves, stems, flowers, roots, and seeds or combinations (Ekor, 2014; Gunawardana & Jayasuriya, 2019). Herbal drugs are available in many forms such as extracts, tablets, concoctions, dried plant parts, and contain phenolic compounds, alkaloids, colour pigments like carotenoids and anthocyanins, plant terpenes and other sulphur-containing compounds, etc. There is an increasing demand for natural herbal drugs due to safety concerns of synthetic drugs and increasing consumer preference for natural products and less usage of artificial additives (Ekor, 2014).

Sri Lanka is an island rich in biodiversity gifted with a vast repository of medicinal plants that have been used in indigenous medicine for millennia (Gunawardana & Jayasuriya, 2019). Evidence exists that Ayurveda, Siddha, Unani, and *Deshiya Chikitsa* traditional medicine systems have used Sri Lankan plants for over 3000 years as medicine, including treatment of viral infections (Kuruppu, Paranagama, & De Silva, 2019; Napagoda et al., 2019). Knowledge of traditional medicine was either verbally handed down across generations or written down in the native languages. It is estimated that plant-based drugs play a vital role in the treatment of over 70% of Sri Lankan population because they are readily available and cheaper than modern medicines (De Zoysa et al., 2017). It has been reported that there are 1430 medicinal plant species grown in Sri Lanka (Kuruppu, Paranagama, & De Silva, 2019; Kuruppu, Paranagama, & Goonasekara, 2019). Out of them, about 174 are endemic to Sri Lanka (Kuruppu, 2018). In the Sri Lankan traditional medicine practice, these plants are frequently used alone or in combination with other plant sources as polyherbal formulae to treat a myriad of diseases (Gunawardana & Jayasuriya, 2019; Napagoda et al., 2019). Moreover, Sri Lankan cuisine often incorporates herbal kanji, herbal drinks and spices. These food preparations have many health benefits, including protection from viral diseases such as influenza, dengue, malaria, chickenpox and measles (Napagoda et al., 2019). Thus, there is a clear space for using selected Sri Lankan herbal drugs in clinical trials for testing as a therapy for viral infections, including COVID-19.

Even though herbal drugs are an important source of various bioactive compounds having antiviral properties, only a few systematic research studies have been conducted on the antiviral potential of Sri Lankan herbal plants (Kankanamalage et al., 2014). Moreover, there are even fewer studies that have explored herbal drugs for the inhibition of SARS-CoV-2 (Wijayasinghe et al., 2020). The present review focuses on the Sri Lankan plant-based antiviral agents reported to inhibit viral infection and their mode of action. This review will provide baseline information to health researchers about potential antiviral herbal drugs used in Sri Lanka and will also disclose the scientific gaps in current knowledge that need to be addressed if any of these compounds are to be developed as novel drugs against SARS-CoV-2.

2. TRADITIONAL SRI LANKAN HERBAL MEDICINE AS A CONVENTIONAL TREATMENT FOR VIRAL INFECTIONS WITH SPECIAL REFERENCE TO CORONAVIRUSES

Sri Lanka has an excellent track record of using traditional plant-based formulations in successfully treating viral infections such as influenza, human immunodeficiency virus

(HIV), herpes simplex virus (HSV), dengue, malaria, SARS, hepatitis, and coxsackievirus infections (Arora et al., 2010; Jesuthasan, & Uluwaduge, 2017; Napagoda et al., 2019; Hemalika & Chandrika, 2020). Out of the four traditional medicine systems in Sri Lanka (i.e. Ayurveda, Siddha, Unani, and *Deshiya Chikitsa*), the Ayurveda and *Deshiya Chikitsa* systems principally use plant preparations for the treatment of diseases (Gunawardana & Jayasuriya, 2019). Different geographical locations have practitioner pedigrees and their unique traditional medicine systems, known as *Deshiya Chikitsa*. Traditional Sri Lankan herbal medicine therapy is either a crude extract of a single plant species or combinations of multiple species prescribed by indigenous medicine practitioners depending on the differentiation of the patient's syndrome according to ancient diagnostic patterns (i.e. inspection, listening, smelling, inquiry, palpation etc.) (Kuruppu, 2018). Most of the prescribed traditional medicines are administered as infusions, concoctions, decoctions, poultice, oil, paste, smoke, powder, porridge or kanji, juice and salad. Some medicinal preparations are administered along with honey, sugar, sugar candy, salt, coconut oil, coconut milk etc. to reduce the bitter taste, enhance the appetite and overall acceptability (Gunawardana & Jayasuriya, 2019; Napagoda et al., 2019). The primary mode of administering traditional medicinal preparations is oral, while some herbal preparations are used as an external or topical application, nasal inhalation, moxibustion, and herbal plasters (Kuruppu, Paranagama, & De Silva, 2019; Kuruppu, Paranagama, & Goonasekara, 2019). The majority of Sri Lankans resort to these herbal preparations at the initial stage of a disease before using Western medications. A lesser number simultaneously uses them with other medications. Another group tend to use herbal therapeutics as a last resort when other treatment methods have failed (Napagoda et al., 2019).

From the recently published literature, it is apparent that several medicinal plants have the potential to be used for the prevention and management of SARS-CoV-2 infection (Shawky, Nada, & Ibrahim, 2020; Yang et al., 2020; Bhattacharya, Dev, & Sourirajan, 2021). These medicinal herbs can act via two basic pathways against SARS-CoV-2 infection, namely, enhancement of overall immunity of the patient, or by acting against the virus by blocking its transcription and replication resulting in the reduction of the period of illness or by inhibiting viral signal transduction (Fuzimoto & Isidoro, 2020; Gautam et al., 2020; Nascimento Junior et al., 2020). Additionally, traditional herbal treatments are also used for symptomatic relief of fever, cough, asthma, joint pain etc. With the pandemic situation of COVID-19, traditional medicinal practices and herbal formulas have been widely accepted by Sri Lankans (Somanada, 2020; Kandewatta, Kurukulasooriya, & Keembiyahetti, 2021). Consequently, commercially available Sri Lankan herbal formulae such as Perumkayam, Instant Kanji or porridge mixers, Kasaya, Asamodgam, Peyawa and Paspanguwa have gained enormous demand in the local market. Since coronavirus primarily affects the lungs and the respiratory system, ayurvedic methods such as herbal fumigation ("dhoomayanaya") could help improve breathing and strengthen the immune system thereby improving the patient's ability to resist viral infections.

Traditionally Sri Lankans consume homemade herbal preparations such as herbal porridge, Kenji or "*Kolakenda*", coffee and tea including herbal teas regularly, often on an empty stomach. Herbal porridge is a traditional semi-solid rice-based gruel consisting also of coconut milk and the extract of different edible green leaves such as Gotukola (*Centella asiatica*), Hathavariya (*Asparagus falcatus*), Wel-penela (*Gardiospermum halicacabum*) and Karapincha (*Murraya koenigii*) (Kodikara, 2006). Most of the leaves used to prepare herbal porridge have scientifically proven antiviral effects (Murugan et al., 2011; Taj et al., 2018). Moreover, there is a broad spectrum of antiviral activity of compounds found in hot water extracts of coffee and tea (mainly green tea, black tea and herbal teas) against several influenza viruses, thus reducing lung damage by influenza viruses (Carneiro et al., 2016; Ghosh et al., 2020; Utsunomiya et al., 2008). Sri

Lankan spices widely used for daily cuisine, also exhibit a diverse array of biological activities and medicinal properties. Some of these spices have anti-influenza (Arora et al., 2010; Chen et al., 2010) and anti-hepatitis B (Kim et al., 2009) properties. Thus, bioactive chemical compounds in herbal formulas, spices, porridge, coffee and tea are promising and warrant continued investigation at *in vitro* and *in vivo* clinical level to develop pharmaceutical agents for coronaviruses, including SARS-CoV-2.

3. POTENTIAL SRI LANKAN HERBAL PLANTS AS CONVENTIONAL TREATMENT FOR CORONAVIRUSES INCLUDING COVID-19

Among the many medicinal properties that Sri Lankan plants possess, antiviral activities are documented in Table 1 and might be useful when developing novel drugs for coronaviruses, including SARS-CoV-2. The medicinal plants listed in Table 1 that have potential antiviral activity were selected from the Libraries of Ayurveda and scientific databases in Sri Lanka. Even though many herbal plants are being used for traditional treatment purposes, there is a lack of local systematic scientific research evidence to support such use for several of these species. Despite the availability of a rich reserve of indigenous knowledge of medicinal plants, the preservation and the scientific validation of these claims are still in their infancy in Sri Lanka. However, many tropical or sub-tropical plants that are naturally occurring or commercially grown in Sri Lanka have been investigated in other countries and found to have antiviral activity (Arena et al., 2008; Dhadwal et al., 2009; Hornung et al., 1994; Lieberman et al., 2006; Mhatre et al., 2020; Murck, 2020). Data on all such plants also have been included in Table 1. Most of these research studies have used *in vitro* methodologies and crude extracts of various parts of the herbal plants. Pure compounds have been tested in some cases, and *in vivo* procedures have been used in a very few cases (Wang et al., 2009). In a limited number of cases, clinical studies have also been conducted (Orozco-Topete et al., 1997; Saklani & Kutty, 2008).

Table 1. Summary of herbal plants in Sri Lanka showing antiviral activity and the reported scientific evidences

Scientific name*	**Common names***	**Part of the plant used as medicine***	**Scientific Evidence**
Zingiber officinale	English: Ginger Sinhala: *Iguru*	Rhizome	Ginger is a common Sri Lankan spice and traditional medicinal plants have important antiviral pharmacological properties. Bioactive compounds of ginger contribute to innate immunity against viral infection. It has been proved to have antiviral activity against human respiratory syncytial virus prompted plaque development *in vitro* (respiratory mucosal cell lines) by blocking viral attachment and internalization (Mao et al., 2019; San Chang et al., 2013). Using molecular docking technique Rathinavel et al. (2020) showed that 6-gingerol from ginger could act as a promising drug of choice to treat COVID-19.
Glycyrrhiza glabra	English: Licorice Sinhala: *Walmee*	Root	*In vitro* and human studies showed that Glycyrrhizin present in *G. glabra* has immunostimulatory properties and antiviral activities against several viruses including SARS-CoV, human immunodeficiency virus type 1 (HIV-1), and respiratory syncytial virus (Ali & Alharbi, 2020; Hoever et al., 2005).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Citrus aurantifolia	English: Lime Sinhala: *Dehi*	Whole plant (seeds, bark, roots, leaves and ripe and un-ripe fruit)	An aqueous extract of these plants along with lemon or lime juice and honey was found to be effective for flu and common cold virus infections (Ali & Alharbi, 2020). It has been reported that women use vaginally applied citrus juices as topical microbicides for the prevention of sexually transmitted HIV-1 infection (Lackman-Smith et al., 2010). As described earlier, citrus fruit is one of the nature's best and easily available sources of vitamin C, a key nutrient in supporting our immune system (Suchitra & Parthasarathy, 2020). Essential oils from lemon and their derivative compounds are valuable natural antiviral agents that may contribute to the prevention of the invasion of SARS-CoV-2 into the human body (Senthil Kumar et al., 2020).
Citrus limon	English: Lemon Sinhala: *Dehi*		
Cannabis sativa	English: Marijuana Sinhala: *Kansa*	Whole plant	Even though the production and sale of marijuana is illegal, some countries allow growing and possessing it for medicinal purposes. *C. sativa* can lead to psychotropic effects due to chemical compounds such as D9-Tetrahydrocannabinol and cannabidiol. They are the phytocannabinoids that have been studied the most for their medicinal properties, due to their ability to suppress lymphocyte proliferation, inflammatory cytokine production and antiviral activity (Maor et al., 2012). Chronic administration of D9-Tetrahydrocannabinol did not increase Immunodeficiency viral load in brain tissue and enhanced HIV antigen-specific immune responses. Consequently, medical marijuana is part of Acquired immunodeficiency syndrome (AIDS) adjuvant treatment in several countries (Molina et al., 2011; Oláh et al., 2017). However, effect of *c. sativa* as a treatment for viral infections is still controversial. In many clinical settings, including latent infections caused by HIV or herpes simplex virus (HSV), and persistent infection of the liver caused by hepatitis C virus, cannabinoids lead to worsened disease outcome (Reiss, 2010).
Elettaria cardamomum	English: Cardamom Sinhala: *Ensal*	Seeds and dried ripe fruits	A multi-ingredient herbal formulation with *E. cardamomum* as one of the ingredients is found to be useful in the treatment of cough and sore throat. Cardamom extract has been proved to be an effective growth inhibitor for HSV and HIV (Reichling et al., 2009). Additionally, cardamom has been shown to promote the maintenance of a healthy immune system (Majdalawieh & Carr, 2010).
Camellia sinensis	English: Tea Sinhala: *Thé*	Leaves	Tea-derived natural products assist in the prevention and treatment of various viral diseases such as dengue viruses, Chikungunya virus, Hepatitis B virus, Influenza virus, HIV and Zika virus (Carneiro et al., 2016; Xu et al., 2017). Gargling with tea or drinking hot tea may protect against the development of influenza infection (Ide et al., 2016). Recent research findings revealed that bioactive compounds isolated from the extract of black tea could act as an inhibitor of SARS-CoV 3C-like Protease (Bhardwaj et al., 2020; Ghosh et al., 2020). In addition, tea phytochemicals enhance immunity against viral infection (Ide et al., 2016).
Cinnamomum zeylanicum	English: Cinnamon, Ceylon cinnamon, true cinnamon Sinhala: *Kurudu*	Bark, leaves and oil	Along with another seven species, *C. zeylanicum* is endemic to Sri Lanka. It has inhibitory effects on RNA viral infections such as H7N3 Influenza A Virus, human respiratory syncytial virus and wild type SARS-CoV. The proposed possible antiviral mechanism was blocking cell entry via endocytosis (Polansky & Lori, 2020; Zhuang et al., 2009).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Cocos nucifera	English: Coconut Sinhala: *Pol*	Oil, kernel, young coconut water and coconut milk	HIV and AIDS patients who took coconut oil daily had substantially decreased viral loads (Nick, 2006). Moreover coconut oil demonstrated antiviral activity against visna virus, Epsteinbarr virus, influenza virus, leukemia virus, pneumono virus and hepatitis C virus. Coconut inclusion may enhance immune system activity against infections (DebMandal & Mandal, 2011).
Areca catechu	English: Arecanut Sinhala: *Puwak*	Nuts	There are some traditional medicines for several diseases which are formulated and marketed using arecanuts as one of the ingredients. Arecanut extract was found to inhibit the viral growth of the New Castle Disease Virus and Egg Drop Syndrome Virus (Anthikat & Michael, 2009). Arecanut also showed inhibitory effects on HIV-1 protease (Kusumoto et al., 1995).
Coffea arabica	English: Coffee Sinhala: *Kopi*	Seeds	Arabica and Robusta coffee varieties are commercially grown in Sri Lanka (Jeewan et al., 2020). Coffee, rich in chlorogenic acid, is used for upper respiratory tract infection treatment caused by influenza virus and respiratory syncytial virus (Ding et al., 2017; Wang et al., 2009). Moreover, coffee inhibited the multiplication of HSV-1, HIV, adenovirus, and hepatitis B virus (Chiang et al., 2002; Wang et al., 2009).
Oryza sativa	English: Rice Sinhala: *Haal*	Seeds	Rice is the dietary staple in Sri Lanka. It has been reported that red and black rice varieties with bran components such as anthocyanin, γ-oryzanol, and phenolic compounds may inhibits certain viral infections, and also provide immunity against viral diseases (Shao et al., 2014; Sompong et al., 2011).
Coriandrum sativum	English: Coriander Sinhala: *Koththamalli*	Seeds	Hot water extract of *C. sativum* is used as a traditional therapy for fever, cough and influenza conditions. Many essential oils in coriander possess antiviral properties against DNA and RNA viruses (Fayyad et al., 2017; Nurzynska-Wierdak, 2013). Research evidence also support that the major phytochemicals present in coriander seeds such as E-2-Dodecanol and Dodecanal possess high binding affinity towards structural and non-structural proteins of Dengue virus and MERS (Rao et al., 2018).
Brassica juncea	English: Mustard Sinhala: *Aba*	Seeds and leaves	*B. juncea* demonstrated antiviral effects against influenza A/H1N1 virus and also used as a treatment for lung infections (Lee et al., 2014).
Morinda citrifolia	English: Indian mulberry Sinhala: *Ahu*	Root, leaves, bark, fruits	Fruit powder of *M. citrifolia* inhibits replication of human immunodeficiency virus type-1 in MT-4 cells and Hepatitis C Virus in Huh 5.2 cells (Selvam et al., 2009).
Kalanchoe laciniata	English: Cathedral bells Sinhala: *Akkapana*	Leaves	*K. laciniata* is a succulent plant and is used as a traditional antiviral treatment. Isolated compounds from the genus *Kalanchoe* demonstrated antiviral activity against human alphaherpesvirus 1 and 2 and vaccinia virus (Cryer et al., 2017).
Acmella oleraceae Syn. *Spilanthes paniculata*	English: - Toothache plant Sinhala: *Akmella*	Whole plant	*A. oleraceae* showed inhibition of HIV replication *in vitro* and immunomodulatory effects (Prachayasittikul et al., 2009).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Gynura pseudo-china	English: China root Sinhala: *Ala beth* or *Cheena ala*	Rhizomes	The genus *Gynura* showed virucidal and antireplicative actions against HSV-1 and HSV-2 (Jarikasem et al., 2013).
Ipomoea alba	English: Moon vine Sinhala: *Alanga/ Kalu alanga*	Leaves	The genus *Ipomoea* showed antiviral activity against HSV (Meira et al., 2012).
Hyptis suaveolens	English: American mint Sinhala: *Ali thala*	Leaves and seeds	Kothandan and Swaminathan (2014) reported that aqueous and aqueous ethanolic extracts of *H. suaveolens* exhibited partial inhibition of Asian strain of chikungunya virus.
Benincasa hispida	English: Winter Melon, White gourd Sinhala: *Alu puhul*	Fruit	*B. hispida* is included in a standard formula used for the treatment of SARS-CoV in China (Chen et al., 2004).
Rhinacanthus nasutus	English: Snake jasmine Sinhala: *Aniththa*	Roots and leaves	*R. nasutus* is known as a traditional herbal drug for the treatment of herpesvirus infections. Ngoc et al. (2019) reported that bioactive naphthoquinone compounds isolated from *R. nasutus* exhibited significant antiviral activities.
Atalantia monophylla	English: - Desert lemon, wild lime Sinhala: *Apassu* or *Dodampana*	Root, leaves and bark	Pyropheophorbide isolated from the leaves of *A. monophylla* showed antiviral activity against HSV-2 (Chansakaow et al., 1996).
Terminalia chebula	English: Chebulic or black myrabalans Sinhala: *Aralu*	Fruit	Fruits of *T. chebula* showed broad-spectrum antiviral activity against HSV, human cytomegalovirus, hepatitis C virus, dengue virus, measles virus, and respiratory syncytial virus (Kesharwani et al., 2017; Lin et al., 2013).
Trachyspermum involucratum	English: Wild celery Sinhala: *Asamodagam*	Seeds	Essential oil extracted from *Trachyspermum* spp. showed *in vitro* antiviral activity against Japanese encephalitis virus. *T. involucratum* has been commonly used in traditional medicine systems for a variety of digestive tract diseases and fever (Roy et al., 2015).
Ficus racemosa	English: Cluster fig Sinhala: *Attikka*	Fruit, bark and leaves	*In vitro* studies revealed that bark extracts of *Ficus* spp inhibit Human Rhinovirus and Respiratory Syncytial Virus infection. It is also used in traditional Ayurvedic and Unani medicine to treat respiratory conditions such as cough, wheezing and asthma (Cagno et al., 2015).
Justicia adhatoda	English: Malabar Nut Sinhala: *Adathoda*	Leaves, roots, bark and stems	Herbal extract of leaves from *J. adhatoda* is a potent antiviral agent for HSV and Influenza virus which cause acute respiratory illness. Leaves have been used extensively for the treatment of respiratory disorders (Chavan & Chowdhary, 2014).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Gironniera parvifolia	English: - Sinhala: *Akmediya*	Leaves	The multiple antiviral effects of the extracts, as demonstrated in animal cell culture models are proposed to occur through several mechanisms; inhibition of cell infection by herpesviruses, interference of viral attachment and preventing viral replication of infected cells (Adnan et al., 2019).
Persea americana	English: Avocado Sinhala: *Ali geta pera*	Fruits and leaves	In Sri Lanka avocado is grown both commercially and in home gardens. According to De Almeida et al. (1998), an infusion of *P. americana* leaves strongly inhibited HSV-1, Aujeszky's disease virus and adenovirus type 3 in cell cultures. Bioactive product (2 R,4 R)-1,2,4-trihydroxyheptadec-16-yne, extracted from *P. americana* fruit can be used as a novel anti-dengue virus agent because it efficiently suppresses replication of all dengue virus serotypes (Wu et al., 2019).
Adansonia digitata	English: Monkey bread-tree, Baobab Sinhala: *Aliya gaha*	Leaves, Fruit and seeds	*A. digitata* leaf extracts have been used for a variety of traditional medicinal purposes, including fever, respiratory and intestinal symptoms. Leaf extract had the most potent antiviral properties, against influenza virus in human epithelial cell cultures (Selvarani, 2009).
Mangifera indica	English: Mango Sinhala: *Amba*	Fruits	*M. indica* extract showed the highest antiviral activity against the influenza virus H9N2 propagated on kidney cells and chicken embryo fibroblast tissue culture cells (Al Ravi et al., 2019).
Withania somnifera	English: Winter cherry Sinhala: *Amukkara*	Tuber, leaves, berries and roots	*W. somnifera* is widely claimed to have antiviral properties against different viruses such as H1N1 influenza, HSV-1, hepatitis, coxsackie virus, bursal disease virus and HIV (Mukhtar et al., 2008). *W. somnifera* can be a potential candidate for the management of COVID-19 because recent findings using *in silico* methods revealed that phytochemicals from this plant hold promise in inhibiting the SARS-CoV-2 key viral proteins (Chikhale et al., 2020).
Datura metel	English: - Indian Thornapple, Angel's trumpet Sinhala: *Kalu-attana*	Seeds, leaves and roots	*Datura* plant contains high levels of atropine which is reported to have potential *in vitro* and *in vivo* antirabies activity. Leaves are generally smoked either in a cigarette or a pipe to relieve asthma in traditional ayurvedic medicine in Sri Lanka and India (Roy et al., 2016; Roy et al., 2018).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Semecarpus acuminata Thw., S. coriacea Thw., S. gardneri Thw., S. marginata Thw., S. moonii Thw., S. nigro-viridis Thw., S. obovata Moon, S. parvifolia Thw., S. pseudo-emarginata Kosterm., S. pubescens Thw., S. subpeltata Thw and S. walkeri Hook. f.	English: - Sinhala: *Badulla* (There are 12 major species of *Semecarpus,* all of which are known as "*Badulla*")	Fruit, seed, flower and glue/exudates	The genus *Semecarpus* belongs to the family Anacardiaceae and 12 species of this genus are endemic to Sri Lanka (Jayaweera, 1981). Phenolic phytochemical in this plant showed antiviral activity and considered as having a potent herbal immunomodulatory effect. It has been used in Sri Lankan folk medicine for treating fever, cough, and asthma conditions. Extracts from nuts of *S. anacardium* was a potent antiviral agent against measles and mumps viruses (Pa et al., 2012; Panigrahi & Vyas, 2015).
Nothopegia beddomei	English: - Sinhala: *Bala*	Bark	*N. beddomei* is native to Sri Lanka. Its aqueous bark extract contains potent serine and aspartic protease inhibitors, which can act against viral infections including AIDS (Dayarathne & Rajapakse, 2019).
Ardisia elliptica	English: Shoebutton ardisia Sinhala: *Balu dan*	Fruit and leaves	*A. elliptica* is a medicinal plant traditionally used to treat herpes and measles. It is reported as having potential antiviral activities (Al-Abd et al., 2017; Chiang et al., 2003).
Ipomoea cairica	English: Coast morning glory Sinhala: *Wal Thel Kola*	Leaves	Aqueous leaf extract from *I. cairica* showed anti-respiratory syncytial virus activity *in vitro* (Ma et al., 2002). Bioactive compounds isolated from *I. cairica*, particularly lignans, are potent inhibitors of HIV-1 (Eich et al., 1996).
Hibiscus tiliaceus	English: Sea hibiscus Sinhala: *Belipatta*	Flower, Bark and leaves	*H. tiliaceus* is indigenous to Sri Lanka. The slimy sap of the bark, branches and flower buds are used to treat bronchitis, fever, cough and pulmonary diseases (Gunawardana & Jayasuriya, 2019). Oral administration of *H. tiliaceus* extract has shown immuno-modulatory effects (i.e. enhanced production of red and white blood cells and hemoglobin) in the Wistar rats (Rajeswari et al., 2013).
Euphorbia thymifolia	English: Chicken weed Sinhala: *Bin dadakiriya*	Leaves and seeds	*E. thymifolia* possesses a broad spectrum of antiviral activity including anti-HSV-2 activities (Lin et al., 2002).
Munronia pinnata	English: Ground neem Sinhala: *Bin kohomba*	Whole plant	In traditional Sri Lankan medicine, *M. pinnata* has been used in poly-herbal formulation since historic times for many ailments such as tuberculosis, cough, recurrent fever, dysentery and purification of blood (Dharmadasa et al., 2011).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Ficus religiosa	English: Sacred fig, Bodhi tree Sinhala: *Bo*	Leaves, bark, fruit	Studies showed that *F. religiosa* bark extracts inhibit Human Rhinovirus and Respiratory Syncytial Virus infection *in vitro* (Cagno et al., 2015). It is used in traditional Sri Lankan medicine to cure respiratory disorders like cough, wheezing and asthma (Kumar et al., 2018).
Derris scandens	English: Jewel vine Sinhala: *Bokala wel*	Leaves, roots, bark, fruit	Aqueous extracts of *D. scandens* showed antiviral activity against HIV-1 (Panvilai et al., 2021). Hydroalcoholic extract of *D. scandens* possesses *in vitro* immune-stimulating activity on peripheral blood mononuclear cells of both normal human individuals and HIV-infected individuals (Sriwanthana & Chavalittumrong, 2001).
Glycosmis pentaphylla	English: Orange berry, Gin berry Sinhala: *Dodanpana*	Leaves	Oral administration of tender leaf extract of *G. pentaphylla* is known to prevent the chikungunya virus infection (Brinda et al., 2019).
Phaseolus vulgaris	English: Beans Sinhala: *Bonchi*	Young fruit and seeds	The lectin of beans demonstrated inhibitory activity on HIV-1 reverse transcriptase and glucosidase (Ye et al., 2001).
Allium sativum	English: Garlic Sinhala: *Sudulunu*	Leaves and bulb	Ayurvedic medical practitioners in Sri Lanka use various preparations of garlic for different illnesses (Wolffers, 1988). The garlic extract had inhibitory effects on Infectious bronchitis coronavirus in the chicken's embryo (Shojai et al., 2016). Garlic is also considered to possess strong antiviral properties against influenza A and B viral infections, cytomegalovirus, rhinovirus, HIV, HSV-1 and HSV-2, viral pneumonia, and rotavirus (Sharma, 2019). Garlic essential oil has strong interactions with the amino acids of the Angiotensin-converting enzyme 2 (ACE2) proteins which are absolutely essential to reduce the operability of the host receptor of SARS-CoV-2 (Thuy et al., 2020).
Allium cepa	English: Red and brown onions Sinhala: *Rathu loonu, Loonu*	Leaves and bulb	*A. cepa* has been recognized for its medicinal value since ancient times. Onion extract effectively decreased the infection of enterovirus and Influenza virus (Ahmadi et al., 2018; Sharma, 2019).
Alpinia nigra	English: Black galangal Sinhala: *Kelaniya/Alan*	Rhizomes	The genus *Alpinia* has shown potential as a therapeutic against various viral diseases, including HIV and influenza virus A/PR/8/34 (H1N1) *in-vitro* (Ghule et al., 2006; Sawamura et al., 2010).
Piper betle	English: Betel Sinhala: *Bulath*	Leaves and roots	As per Ayurvedic literature, *P. betle* is used as an antioxidant, immuno-modulator and for pulmonary infection. The leaves with mustard oil is warmed and applied to the chest to relieve cough and complexity in breathing. Leaves are used in curing sore throat (Soni et al., 2020).
Pometia pinnata	English: Fijian longan Sinhala: *Bulumora / Gal mora*	Leaves and bark	*P. pinnata* leaves and bark are traditionally used for the treatment of fever and fester. The leaf extract had a strong anti-HIV-1 protease activity, which is a key enzyme involved in the replication cycle of the retrovirus (Suedee et al., 2013).
Chloroxylon swietenia	English: Satin wood Sinhala: *Burutha*	Leaves, bark and stem oil	Extracts from stem bark and leaves of *C. swietenia* showed high activity against H1N1 influenza virus (Enkhtaivan et al., 2015).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Canna indica	English: Indian shot Sinhala: *Buthsarana*	Rhizome, flowers and leaves	The pharmacological research findings showed that *C. indica* exerted antiviral activity mainly against HIV-1 (Woradulayapinij et al., 2005).
Pandanus amaryllifolius	English: Pandan Sinhala: *Rampe*	Leaves	A lectin, designated Pandanin isolated from the saline extract of the leaves of *P. amaryllifolius* showed antiviral effect against HSV-1 and influenza virus strain H1N1 (Ooi et al., 2004).
Phyllanthus urinaria	English: Chamber bitter Sinhala: *Rath pitawakka*	Roots	*P. urinaria* is a medicinal plant exhibiting potent inhibitory activity against HSV-1 and HSV-2. The antiviral activities exhibited by *P. urinaria* root extract could be due to the multiple action on the virus, such as inhibiting the viral entry and viral attachment, inhibiting the manipulation of the host actin-cytoskeleton dynamics by the virus and preventing manipulation of the host proteins by the virus (Tan et al., 2013; Yang et al., 2005).
Phyllanthus amarus	English: Niruri Sinhala: *Pitawakka*	Roots and sap	*P. amarus* has been traditionally used to reduce fever, cough and asthma and to treat tuberculosis ulcers. Potential inhibitory effect against broad spectrum of viruses, such as the hepatitis B virus, hepatitis C virus and inhibition of HIV replication both *in vitro* and *in vivo* and HSV have been demonstrated (Notka et al., 2004; Tan et al., 2013; Yeh et al., 1993).
Boehmeria nivea	English: Wild castor Sinhala: *Deththa*	Seeds, roots and whole plant	A root extract of *B. nivea* exhibited potential anti-hepatitis B virus activity in an *in vitro* and *in vivo* animal model (Chang et al., 2010; Wei et al., 2013).
Azadirachta indica	English: Neem Sinhala: *Kohomba*	Leaves and bark	The aqueous extract of neem leaves inhibited Dengue virus type-2 both *in vitro* and *in vivo* (Parida et al., 2002). Neem bark has inhibitory effect on HSV-1 proliferation (Tiwari et al., 2010). A recent study has shown the beneficial effect of Neem bark on neuro-inflammation caused by a murine coronavirus known as Mouse Hepatitis Virus (Sarkar et al., 2020). An *in silico* binding study demonstrated that neem compounds (i.e. Nimbolin A, Nimocin and Cycloartanols) may prevent assembly of SARS-CoV-2 particles, thus reducing viral propagation (Borkotoky & Banerjee, 2020). Among 19 bioactives from neem, Desacetylgedunin recorded highest molecular docking score against SARS-Cov-2 (Baildya et al., 2021)
Aloe vera	English: Aloe Sinhala: *Komarika*	Leaves	Leaf extract of *A. vera* has antiviral activity against Hemorrhagic Viral Rhobdavirus Septicaemia, HSV-1 and HSV-2, Varicella-Zoster virus, HIV, Influenza virus, poliovirus, Cytomegalovirus, Human papillomavirus including coronavirus SARS-CoV-1 through mechanisms such as interaction of virus enzyme, breakdown of the viral envelope etc. Also, the presence of minerals such as zinc, which have shown an effect on SARS-CoV-1, could be involved in the antiviral effect of *A. vera* (Mpiana et al., 2020; Sun et al., 2018).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Andrographis paniculata	English: Green chireta, Creat Sinhala: *Heen binkohomba*	Whole plant	*A. paniculata* has antiviral properties over many types of viral infections such as Chikungunya, HSV-1 ebola virus, Dengue fever and SARS-CoV through immunomodulation (Gupta et al., 2017; Iwu et al., 2020). Based on recent *in silico* studies, Andrographolide extracted from *A. paniculata* could be a potential inhibitor of SARS-CoV-2 main protease (Enmozhi et al., 2020).
Asparagus racemosus	English: Shatawari Sinhala: *Heen hathavariya*	Leaves	*A. racemosus* is widely used in Ayurveda for immunostimulation, to stimulate macrophages, the immune cells involved in controlling microorganisms and thereby improves vitality, immunity, and vigor (Anders et al., 2020). The major phytoconstituents reported in *A. racemosus* include steroidal saponins such as shatavarin which have antiviral potential. Using *in-silico* studies, Chikhale et al. (2020) reported that phytochemicals from *A. racemosus* can be used as plausible antiviral agent in COVID-19 treatment. Plaque assay using SARS-CoV-2-infected human lung epithelial cells (Calu-3) showed significant inhibition of the virus by *A. racemosus* extract and andrographolide, its major component (Sa-ngiamsuntorn et al., 2021)
Acacia nilotica	English: - Gum Arabic Tree Sinhala: *Kara wel*	Bark, leaves, fruits and gum	The methanolic extracts of *A. nilotica* showed potential to inhibit Hepatitis C virus (Hussein et al., 2000) and influenza A virus infection by interacting with the viral hemagglutinin (Sohail et al., 2011).
Boswellia carterii	English: Indian Olibanum Sinhala: *Kundirikkan*	Gum	Essential oils derived from *Boswellia* spp. possess anti-inflammatory activity and have medicinal properties including antiseptic properties. Influenza virus A/PR/8/34 (PR8) treated with *B. carterii* essential oil significantly decreased the number of released viral particles from infected Madin-Darby canine kidney (MDCK) cells (Wu et al., 2010).
Piper longum	English: Long pepper Sinhala: *Thippili*	Dried immature fruit	Ethanol extract of *P. longum* acts against Hepatitis B virus (Jiang et al., 2013).
Piper nigrum	English: Black Pepper Sinhala: *Gammiris*	Dried immature fruit	*P. nigrum* has shown antiviral properties against three viruses related to upper respiratory tract infections such as coxsackie virus type B3, human rhinovirus type 2, and influenza virus type A (Mair et al., 2016).
Syzygium aromaticum	English: Clove Sinhala: *neti Karabu*	Flower	*S. aromaticum* is a traditional spice as well as a herbal medicine. Aquous extracts of clove showed antiviral efficacy against HSV-1, hepatitis C virus and influenza A virus (Batiha et al., 2020).
Tragia involucrata	English: Singhara nut Sinhala: *Wel kahambiliya*	Roots, seeds and leaves	*T. involucrata* has been widely used in traditional systems of medicine for immunomodulatory and antivirus properties. It is among one of the 15 plants recommended by the Indian Ministry for Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy to be used for COVID-19 (Prasad et al., 2020).
Nelumbo nucifera	English: Indian lotus Sinhala: *Nelum*	Rhizome and seeds	*N. nucifera* possesses therapeutic activity against HIV, rotavirus and HSV-1 (Kashiwada et al., 2005; Knipping et al., 2012; Kuo et al., 2005).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Solanum tuberosum	English: Potato Sinhala: *Arthapal*	Tubers	Red-fleshed potatoes which are rich in anthocyanin inactivated both influenza viruses A and B (Hayashi et al., 2003). Alkaloids from potato may have an effective role against herpes viral infections (Korpan et al., 2004).
Curcuma longa	English: Turmeric Sinhala: *Kaha*	Rhizome	Turmeric exhibited antiviral properties against several viruses, including dengue virus, hepatitis C virus, HIV, Zika and chikungunya viruses (Zorofchian Moghadamtousi et al., 2014). Zahedipour et al. (2020) reported that curcumin from turmeric could be a potential treatment option for patients with coronavirus disease.
Garcinia quaesita	English: Brindle berry Sinhala: *Rath goraka*	Fruit, leaves, bark and flowers	Bioactive chemical compounds from the genus *Garcinia* showed interesting biological properties such as antiviral activity against HIV and dengue virus (Adnan et al., 2019; Lin et al., 2014). Wu et al. (2020) reported that *G. mangostana* could be a therapeutic target for SARS-CoV-2.
Garcinia zeylanica	English: - Sinhala: *Ela goraka*		
Garcinia mangostana	English: Mangosteen Sinhala: *Mangus*		
Garcinia cambogia	English: Mangosteen Sinhala: *Mangus*		
Arachis hypogaea	English: Peanut Sinhala: *Ratakaju*	Seeds	*A. hypogaea* skin extract showed antiviral properties against Human Influenza Viruses. A combination of peanut skin extract with the anti-influenza drugs (i.e. oseltamivir and amantadine), synergistically improved their antiviral activity against both influenza type A and type B viruses (Makau et al., 2018).
Strobilanthes lupulina	English: Persian shield Sinhala: *Nelu*	Whole plant	*Strobilanthes* spp. is used to treat influenza A (H5N1), viral pneumonia, mumps, and SARS (Tanaka et al., 2004).
Ficus benjamina	English: Weeping fig Sinhala: *Walu nuga*	Leaves	Yarmolinsky et al. (2012) reported that ethanol extracts from *F. benjamina* leaves strongly inhibit HSV-1 and HSV-2 as well as Varicella Zoster Virus cell infection *in vitro*.
Punica granatum	English: Pomegranate Sinhala: *Delum*	Fruit	*P. granatum* extract has shown anti-influenza properties which could be due to its bioactive polyphenolic compounds and vitamin C (Haidari et al., 2009; Mousa, 2017).
Phyllanthus emblica	English: Indian Gooseberry / Amla Sinhala: *Nelli*	Fruit	*P. emblica* plant extracts exert their anti-HIV activity via inhibition of human immunodeficiency virus reverse transcriptase activity (Estari et al., 2012). Sesquiterpenoid glycosides from *P. emblica* displayed potent activity against influenza A virus strain H3N2 (Lv et al., 2015).
Pancratium zeylanicum	English: Ceylon spider lily Sinhala: *Wal loonu*	Whole plant	*P. zeylanicum* has antiviral activities against Poliomyelitis virus and HSV, and is also effective against SARS-CoV (Li et al., 2005).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Capsicum annuum	English: Chilli Sinhala: *Miris*	Fruit	Chilli pepper is as an inhibitor of Lassa virus (LASV) and inhibits the detrimental effects of HIV protease inhibitor (Chai et al., 2005; Tang et al., 2020). Moreover, *C. annuum* methanolic extracts exhibited considerable anti-HSV-1 and HSV-2 activities (Hafiz et al., 2017).
Murraya koenigii	English: Curry leaf plant Sinhala: *Karapincha*	Leaves	The leaves of *M. koenigii* are used as a popular aromatic-spice, and in Ayurvedic medicine. Curry leaves show a strong antiviral action against Dengue and Swine flu viruses (Taj et al., 2018).
Myristica fragrans	English: Nutmeg Sinhala: *Sadikka*	Seed	*M. fragrans* contains antibacterial and antiviral properties (Gonçalves et al., 2005; Sa-nguanmoo & Poovorawan, 2007). However the mechanisms underlying those activities have not been clearly explained.
Barleria prionitis	English: Porcupine flower Sinhala: *Katu karandu*	Leaves, roots and bark	*B. prionitis* is a well-known Ayurvedic herb. Chen et al. (1998) reported that bioactive compound of *B. prionitis* showed potent activity against respiratory syncytial virus.
Caesalpinia sappan	English: - Sappanwood Sinhala: *Pathangi*	Leaves and bark	Bioactive compounds from *C. sappan* exhibited antiviral activity against respiratory syncytial virus (Ma et al., 2002).
Gardenia crameri	English: - Sinhala: *Galis*	Latex of the plant	The extract from *Gardenia* showed antiviral activity against influenza viral pneumonia in mice (Wang et al., 2006).
Nerium oleander	English: Oleander Sinhala: *Kaneru*	Leaves, roots, bark, seeds and flowers	*N. oleander* exhibited considerable antiviral activity against HSV, influenza and polio virus type 1 (Avci & Dik, 2014; Farahani, 2014; Sanna et al., 2019).
Moringa oleifera	English: Drumstick tree Sinhala: *Murunga*	Leaves	Bioactive compounds of *M. oleifera* leaves showed considerable antiviral activity against HSV-1 and Epstein-Barr virus (Imran et al., 2016).
Capparis zeylanica	English: Indian caper Sinhala: *Kalu wellangiriya*	Leaves, roots and bark	*C. zeylanica* leaves show antiviral activity (Ghule et al., 2006) and flower buds rich in flavonoids, including several quercetin and kaempferol glycosides inhibited the replication of HSV-2 in human peripheral blood mononuclear cells *in vitro* (Arena et al., 2008).
Cyperus rotundus	English: Nut grass Sinhala: *Kalanduru*	Tubers	*C. rotundus* extract has a promising antioxidant potential against HSV-1 and Hepatitis B virus (Kamala et al., 2018; Soltan & Zaki, 2009).
Diospyros malabarica	English: Gaub Sinhala: *Thimbiri*	Fruit	*D. malabarica* is used in traditional medicine for various purposes including sore throat and showed antiviral activity (Kaushik et al., 2013; Shubhra et al., 2019).
Euphorbia hirta	English: Asthma weed, Garden spurge Sinhala: *Bu dadakeeriya*	Whole plant	Extracts of *E. hirta* showed antiviral activities against HIV-1, HIV-2 and SIVmac251 SIV (mac251) reverse transcriptase (Gyuris et al., 2009).

Scientific name*	Common names*	Part of the plant used as medicine*	Scientific Evidence
Hemidesmus indicus	English: Indian sarsparilla Sinhala: *Iramusu*	Leaves	*H. indicus* decoction and its major phyto-constituents are considered as promising alternatives for the treatment of HIV-1 infections (Akram et al., 2018; Esposito et al., 2017).
Caesalpinia pulcherrima	English: Peacock flower Sinhala: *Monaramal*	Roots, seeds, leaves, flowers and bark	Antiviral activity of *C. pulcherrima* against HIV, HSV, influenza, hepatitis, and coxsackievirus have been scientifically proven through studies on experimental animal models (Akram et al., 2018).
Aegle marmelos	English: Bael fruit Sinhala: *Beli*	Fruit, flowers, bark, roots and leaves	All parts of *A. marmelos* including stem, bark, root, leaves, and fruit at all stages of maturity have been used in Ayurveda, mainly as a treatment of recurrent colds and respiratory infections. It showed *in vitro* antiviral activity on human coxsackieviruses B1-B6 (Arora et al., 2010; Badam et al., 2002).
Cassia auriculata	English: Matara tea tree Sinhala: *Ranawara*	Young Leaves & Flowers	Dried flowers and leaves of *C. auriculata* is a medicinal plant used in Ayurveda. Methanolic extract of *C. auriculata* flowers exerts antiviral activities including HSV (Arthanari et al., 2013).
Coscinium fenestratum	English: False calumba Sinhala: *Weni-Wel*	Roots and stems of the creeper	*C. fenestratum* is well-known for treatment of influenza and eye diseases and is identified as an antiviral herbal ingredient (John et al., 2015; Tushar et al., 2008).
Tinospora cordifolia	English: Heart leaved moonseed Sinhala: *Rasakinda*	Stem and roots	*T. cordifolia* demonstrated potential immunomodulatory effects against viral diseases (Sachan et al., 2019).
Aerva lanata	English: Mountain knotgrass Sinhala: *Polpala*	Leaves and young stems	*A. lanata* plant extracts have antiviral activity against HIV and immunomodulatory effect against viral diseases (Akram et al., 2018).
Scoparia dulcis	English: Sweet broom, Licorice weed Sinhala: *Wal koththamalli*	Whole plant	*S. dulcis* plant extracts have antiviral activity against the simplex virus type 1 virus and immunomodulatory effect against viral diseases (Hayashi et al., 1988).
Cuscuta reflexa	English: Dodder Sinhala: *Aga mula nethi wel*	Whole plant and seeds	*C. reflexa* is a parasitic plant which exhibited a broad spectrum of antiviral activity (Awasthi, 1981).
Cardiospermum halicacabum	English: Balloon vine Sinhala: *Wel-penela*	Whole plant	This plant is used in the traditional medicine for the treatment of rheumatism, lumbago, earache, and fever. Various pharmacological studies of *C. halicacabum* have indicated that this plant could be used to control and management of HIV coinfection with hepatitis viruses (Murugan et al., 2011).

4. PLANT-BASED ANTIVIRAL BIOACTIVE COMPOUNDS AND THEIR MODE OF ACTION AGAINST HUMAN VIRAL PATHOGENS

Ethnopharmacology has recently become an area of interest because medicinal plants' potential role against infectious viral diseases. Plant metabolites can be primary and secondary depending on their role in essential metabolic processes (Gunawardana & Jayasuriya, 2019). Carbohydrates, proteins and lipids are considered basic chemical metabolites of plants required for primary functions of growth and metabolism. Secondary metabolites are chemical compounds that are products of primary metabolism (Pagare et al., 2015; Tanaka et al., 2004). They are involved in cell pigmentation in flower and seed, which attract pollinators for plant reproduction or birds for seed dispersion. Secondary metabolites possess various biological effects and can be synthesized as defence chemicals to protect plants from pathogens, insects, herbivores (Pagare et al., 2015) as well as abiotic stresses (Akula & Ravishankar, 2011). Consequently, herbal drugs derived from natural products are mainly based on plants' secondary metabolites (Gunawardana & Jayasuriya, 2019).

Over the past decade, much attention has been placed on the study of phytochemicals from plants for their antiviral activity, especially against Influenza, HSV, Dengue, Chikungunya, Zika, Hepatitis A, Hepatitis B, Hepatitis C, SARS, MERS, ebola, rotavirus, Japanese encephalitis virus and human papillomavirus (Table 1) (Akram et al., 2018; Arora et al., 2010). In recent years, many studies have shown that secondary metabolites and their derivatives exert their antiviral activity through different mechanisms, such as damage to the viral envelope or membrane protein and suppression of the replication of viral genome or inhibit attachment of the virus to the host cellular machinery for reproduction and destroy enzymes necessary for viral encoding (Akram et al., 2018; Chen et al., 2010; Utsunomiya et al., 2008; Yang et al., 2020).

As shown in Figure 2, several antiviral agents have been isolated from Sri Lankan herbal plants listed in Table 1, due to chemical and pharmacological studies in the recent years and many have been derived from leads based on Ayurvedic and other traditional medicine principles. These bioactive chemical compounds include various phenolic compounds, alkaloids, tannins, flavonoids, glycosides, saponins etc. These secondary metabolites are possible sources of effective, low-cost and safe antiviral agents. However, much work still needs to be carried out, especially under *in vivo* conditions to ensure the selection of effective antimicrobial substances with low side effects and adverse effects. This section aims to critically review scientific reports that demonstrate the *in vitro* and *in vivo* antiviral effects of different phytochemicals belonging to different chemical classes.

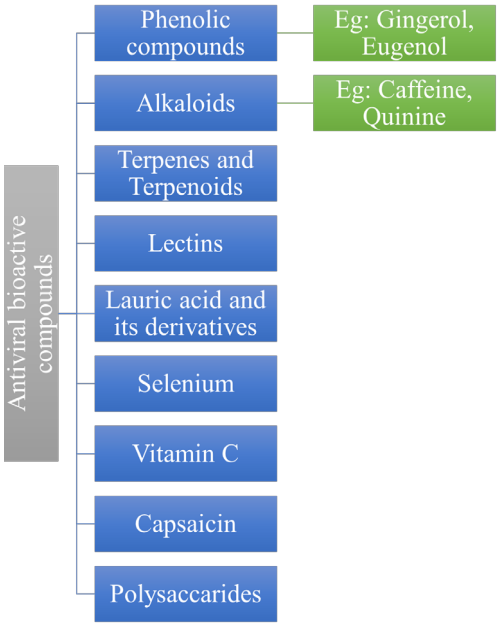

Figure 2. Bioactive chemical constituents that show antiviral activity against human pathogens

4.1. Phenolic Compounds

Bioactive phenolic compounds are highly complex polymeric substances consisting of one or more phenol groups, and they are the largest group of secondary plant metabolites (Pagare et al., 2015). According to their structure, phenolic compounds are classified into various subclasses such as simple phenolics, tannins, coumarins, flavonoids, diarylheptanoids, chromones and xanthones, stilbenes and lignans (Oliveira et al., 2014). As described below, a large number of studies demonstrated the efficacy of polyphenols against several viral pathogens, including Epstein-Barr virus, enterovirus, HSV, influenza virus, dengue virus, polio virus, and viruses causing respiratory tract-related infections.

4.1.1. Gingerol

The phenolic compounds in fresh ginger are gingerols such as 6-gingerol, 8-gingerol, and 10-gingerol that trigger spice receptors on the human tongue (Mao et al., 2019). They possess pharmacokinetic properties with the highest binding affinity with various SARS-CoV-2 viral protein targets (Rathinavel et al., 2020). Additionally, 6-gingerol is a promising drug candidate to inhibit plaque formation induced by the human respiratory syncytial virus in respiratory tract cell lines. Ginger effectively blocked human respiratory syncytial viral attachment and internalization (San Chang et al., 2013). In a clinical trial, ginger extract decreased hepatitis C virus loads, the level of α-fetoprotein, and markers relevant to liver function, such as aspartate aminotransferase and alanine aminotransferase, in Egyptian hepatitis C virus-infected patients (Abdel-Moneim et al., 2013). All these antiviral effects of gingerol could be mainly related to the suppression of viral attachment and prevention of internalization of viral particles (Abdel-Moneim et al., 2013; Mao et al., 2019).

4.1.2. Eugenol

Eugenol is found in *Cinnamomum zeylanicum* leaf oil, clove flower bud extract and clove essential oil (Polansky & Lori, 2020; Zhuang et al., 2009). It has antiviral activity against human herpesviruses because eugenol inhibits the replication of these viruses (Benencia & Courreges, 2000). Furthermore, eugenol-acyclovir combinations synergistically inhibited herpesvirus replication *in vitro* (Benencia & Courreges, 2000). Eugenol can cause damage to herpes simplex viral envelopes and can cause viral replication inhibition at the initial stage (Pramod et al., 2010). Eugenol may be potentially useful as an antiviral agent against SARS-CoV-2 (da Silva et al., 2020; Polansky & Lori, 2020; Zhuang et al., 2009).

4.1.3. Tea polyphenols

Tea polyphenols are an attractive source of bioactive molecules showing potent antiviral activity (Ghosh et al., 2020). Bioactive compounds isolated from the extract of black tea could act as a SARS-CoV 3C-like Protease Activity inhibitor (Chen et al., 2005). Clark et al. (1998) reported that theaflavins extracted from black tea were able to neutralize bovine coronavirus and rotavirus infections. Ghosh et al. (2020) and Bhardwaj et al. (2020) reported that polyphenols in green tea could be used as novel corona virus (SARS CoV-2) main protease inhibitors using *in silico* and molecular dynamics simulation study. Experimental studies have also reported that tea catechins inhibited influenza viral adsorption and suppressed replication and neuraminidase activity (Ide et al., 2016).

4.1.4. Anthocyanin

Anthocyanins and anthocyanidins are natural blue, red, or purple colored water-soluble pigments that belong to the phenolic group. Anthocyanin is a glycoside, while anthocyanidin is an aglycone (sugar free constituent) (Pour et al., 2019). They are responsible for the colors, red, purple, and blue; they are in grains, cereals, fruits and vegetables (Pour et al., 2019; Suedee et al., 2013). Cell culture studies, *in silico* studies, animal models, and human clinical trials, show that both anthocyanidins and anthocyanins possess antiviral activities. For instance, Knox et al. (2001) reported that anthocyanins prevent Infuenza A and B viral attachment and entry to cells, and their release from infected cells.

Moreover, studies report that anthocyanins could inhibit Infuenza virus adsorption on the cell surface, interfere with virus internalization and completely inhibit the growth of Infuenza A virus (Pour et al., 2019). Apart from anthocyanin, proanthocyanidin found in *Pometia pinnata* also showed *in vitro* anti-human immunodeficiency virus activity with the probable antiviral mechanism inhibiting viral RNA synthesis (Suedee et al., 2013).

4.1.5. Curcumin

Curcumin is the naturally occurring major phenolic compound present in turmeric (*Curcuma longa* L.) (Zahedipour et al., 2020). Concerning the antiviral activities studied, curcumin exhibited antiviral activity against the coxsackie virus by reducing viral RNA expression, protein synthesis, and virus titer (Zorofchian Moghadamtousi et al., 2014). Mounce et al. (2017) reported that curcumin also inhibits Zika and chikungunya virus replication in human cells. It also inhibits viral binding at the cell surface (Mounce et al., 2017). In addition, curcumin is a modest inhibitor of HIV-1 and HIV-2 proteases and thereby curcumin analogs might be formulated as anti-AIDS drugs (Praditya et al., 2019). Zahedipour et al., (2020) suggested that curcumin could have a potential inhibitory effect on SARS-CoV-2 because it could inhibit the entry of virus to the cell, inhibiting encapsulation of the virus and viral protease, and modulating various cellular signaling pathways. However, systematically designed clinical trials are required to prove the potential efficacy of curcumin against SARS-CoV-2 infection and its ensuing complications.

4.1.6. Flavonols

Flavonols are common plant-derived polyphenolic secondary plant metabolites obtained from tea, berries, fruits, vegetables, and medicinal herbs (Pagare et al., 2015). Different flavonols such as quercetin, myricetin and kaempferol have been investigated for their potential antiviral activities. Several of them exhibited significant antiviral properties in *in vitro*, *in silico* and *in vivo* studies (Ghosh et al., 2020; Zakaryan et al., 2017). Several mechanisms by which flavonol compounds inhibit viral replication have been described (Zakaryan et al., 2017). Flavanols present in onion and garlic, such as quercetin, have a strong inhibitory effect on virus multiplication (Ahmadi et al., 2018; Sharma, 2019).

Myricetin blocks herpes simplex virus binding and may possess anti-HSV-1 and HSV-2 activities (Sharma, 2019). Moreover, myricetin markedly improved survival and reduced virus titers in both lungs and spinal cord in HSV-infected mice (W. Li et al., 2020). A glycosylated derivative of myricetin inhibited HIV-1 proliferation and the HIV-1 reverse transcriptase (Ortega et al., 2017). Studies suggest that myricetin could inhibit the ATPase activity of SARS-CoV helicase nsP13 (Yu et al., 2012).

Kaempferol bearing acyl substitution was effective against human cytomegalovirus (Mitrocotsa et al., 2000). Its glucoside showed potent anti-HSV-1, anti-HSV-2 (Ürményi et al., 2016) and anti-HIV-1 activity, particularly at the early stages of infection (Behbahani et al., 2014). Kaempferol derivatives isolated from *Ficus benjamina* leaves demonstrated efficient inhibition of HSV1 and HSV-2 (Yarmolinsky et al., 2012). Kaempferol, kaempferol glycosides, and acylated kaempferol glucoside derivatives could be considered as potent inhibitors of the 3a channel proteins of coronaviruses that are involved in the mechanism of virus release (Schwarz et al., 2014).

Quercetin has been researched in different types and models of viral infection due to its promising antiviral effects in inhibiting polymerases, proteases, reverse transcriptase, suppressing DNA gyrase, and binding viral capsid proteins (Biancatelli et al., 2020). The virally encoded 3C-like protease (3CLPro) has been presumed critical for the viral replication of SARS-CoV, and as a result, 3CLPro is an attractive drug target for the treatment of SARS-CoV (Ghosh et al., 2020; Zahedipour et al., 2020). Furthermore Biancatelli et al., (2020) reported that Quercetin and Vitamin C supplementation may promote synergistic

therapy for the prevention and treatment of SARS-CoV-2.

4.1.7. Allicin

It is well known that onion and garlic are rich sources of organosulfur compounds such as allicin (Thuy et al., 2020). Allicin is associated with the inhibition of viral infection (Shojai et al., 2016). Many studies have been conducted to elucidate the mechanism of allicin action against viruses (Sharma, 2019). This compound can hinder virus attachment to host cell, alter transcription and translation of viral genome in host cell and affect viral assembly (Shubhashree et al., 2020). Moreover, it is known that allicin can pass through phospholipid membrane of cell and can further contribute to inhibiting viral multiplication (Sharma, 2019; Shubhashree et al., 2020).

4.1.8. Tannins

Tannins have been known to man for millennia, used by ancient Egyptians and Romans for tanning animal hides to leather (Nasr et al., 2013). They are also used to precipitate proteins in wine, hence the use of oak barrels. The tannins in cranberries (*Vaccinium macrocarpon*) have been medically proven to help prevent urinary tract infections by reducing the ability of *E. coli* from adhering to cells lining the urinary tract (Nowack & Schmitt, 2008). This anti-adhesive property is used to reduce the ability of *H. pylori* to cause stomach ulcers. Recent medical research has also shown that these polyphenolic compounds can also reduce LDL cholesterol and improve cardiac health. Tannic acid is a water-soluble polyphenol present mainly in tea, coffee, red wine, beer and nuts etc. (Lin et al., 2014). Lin et al., (2013) reported chebulagic acid and punicalagin, two hydrolysable tannins isolated from *Terminalia chebula*, showing broad-spectrum antiviral properties against several viruses. Specifically, chebulagic acid and punicalagin can directly inactivate free dengue particles and interfere with the attachment and fusion events during early viral entry (Kesharwani et al., 2017; Lin et al., 2013). Chebulagic acid and punicalagin also blocked HSV-1 entry, viral attachment and spread and inhibited viral glycoprotein interactions with cell surface glycosaminoglycans (Kesharwani et al., 2017; Lin et al., 2014). As a result, *T. chebula* could be a useful candidate for developing alternative therapy for the prevention of viral infections (Kesharwani et al., 2017).

4.1.9. Rhoifolin

Rhoifolin is a flavone glycoside, and recent studies showed that it has antiviral activity against some viruses, including SARS-CoV (Yang et al., 2020). Barley, wheat and soybeans are rich dietary sources of rhoifolin (Sawikowska, 2020). This chemical compound was found to efficiently block the proteins produced by all coronaviruses that harm the human immune system. More specifically, rhoifolin attaches to active protein sites and thereby inactivate them, thus neutralizing the viruses (Jo et al., 2020; Sawikowska, 2020).

4.1.10. Luteolin

Luteolin is a flavone polyphenolic compound naturally occurring in a glycosylated form (Yang et al., 2020). It is present as constituents of flowering plants, particularly in fruits and vegetables (Fan et al., 2016; Yang et al., 2020). Different luteolin compounds have been investigated for their potential antiviral activities, and several of them exhibited significant antiviral properties in *in vitro* and even *in vivo* studies. For instance, luteolin is considered an antiviral bioflavonoid with potent antiviral activity against Japanese encephalitis virus replication (Fan et al., 2016). Moreover, research evidence indicates that luteolin may serve as a base flavonoid to develop potent anti– HIV-1 derivatives (Mehla et al., 2011).

4.1.11. Chlorogenic acid

Chlorogenic acid is a caffeoylquinic acid and is the major polyphenolic compound in coffee (Guo et al., 2015). It has antiviral effects against several viruses, including HIV, adenovirus, hepatitis B virus and HSV in both cell culture and *in vivo* animal trials (Ding et al., 2017; Wang et al., 2009). Results from molecular docking trials indicated that

chlorogenic acid could be a potential drug for influenza virus H1N123, H5N124 and H7N925 (Chiang et al., 2002; Ding et al., 2017). However, evidence for the antiviral mechanisms of chlorogenic acid is minimal. Nevertheless, it has been shown that chlorogenic acid acts as a neuraminidase blocker to inhibit influenza A virus, both in cellular and animal models (Ding et al., 2017). It also decreased virus titres and alleviated inflammation in infected mouse lung tissues (Ding et al., 2017; Wang et al., 2009). Furthermore, chlorogenic acid also inhibited inflammation caused by viral infection (Guo et al., 2015). The action of chlorogenic acid to inhibit inflammation in lung tissue caused by viral infection also requires future investigations.

4.1.12. Diarylheptanoids

Diarylheptanoids are secondary plant metabolites belonging to the broad class of plant phenolic compounds (Dinić et al., 2014). They are bioactive natural products mainly derived from the genus *Alpinia* (e.g. *A. officinarum*) which has been used as a folk medicine in Sri Lanka (Konno et al., 2011; Sun et al., 2016). Even though the antiviral activities of diarylheptanoids are less elucidated, *in vitro* assays revealed the antiviral activities of diarylheptanoids isolated from *A. officinarum* against the respiratory syncytial virus, poliovirus, measles virus, influenza virus, respiratory syncytial virus and HSV-1 (Konno et al., 2011; Sun et al., 2016). According to Konno et al. (2011), diarylheptanoids were effective in reducing virus titers in the lungs of respiratory syncytial virus-infected mice. In the histopathological analysis, the oral administration of diarylheptanoids significantly reduced the interferon-γ level of respiratory syncytial virus-infected lungs, which is considered as a marker of severe pneumonia due to the virus infection (Konno et al., 2011).

4.1.13. Lignans

Lignans are a group of phenolic secondary metabolites in plants that have antiviral activity (Epifano et al., 2007). Many lignan compounds in *Strobilanthes* spp. and *Ipomoea cairica* have antiviral effects against influenza and respiratory syncytial viruses (Ma et al., 2002; Tanaka et al., 2004). Arctigenin is a lignan compound that inhibits the replication of HIV (Eich et al., 1996). Moreover, specific plant lignans derivatives possess potent antiviral activities against SARS-CoV (Cui et al., 2020; Wen et al., 2007).

4.1.14. Stilbenes

Stilbenes are low-molecular-weight chemical constituents that are found in a wide range of plants. Resveratrol is a stilbenoid found in the skins of grapes, berries, and peanuts (Abba et al., 2015; Makau et al., 2018). It has antiviral properties of inhibition of viral replication, protein production, gene expression, and nucleic acid production (Abba et al., 2015). They significantly inhibited MERS-CoV infection and prolonged cellular survival after virus infection. Furthermore, the expression of nucleocapsid protein critical for MERS-CoV replication was diminished after administration of resveratrol (Lin et al., 2017).

4.1.15. Gallic acid

Gallic acid is a phenolic acid and one of the major polyphenolic compounds in tea (Govea-Salas et al., 2016). It has been demonstrated that gallic acid exerted anti-hepatitis C virus, anti-HSV-1, anti-influenza virus, anti-human rhinovirus and anti-HIV activity (Choi et al., 2010; Govea-Salas et al., 2016; Lee et al., 2016). Govea-Salas et al. (2016) reported that gallic acid could effectively involve in the downregulation of Hepatitis C virus replication in hepatoma cells. Viral infections frequently result in the production of reactive oxygen species in infected cells. Gallic acid has been found to exert antiviral activities against viruses by alleviating the oxidative stress generated by the viruses (Choi et al., 2010; Govea-Salas et al., 2016).

4.1.16. Cinnamaldehyde

Cinnamaldehyde is a bioactive chemical compound that occurs naturally in the bark of cinnamon trees and other species of the genus *Cinnamomum* such as camphor and cassia

(Polansky & Lori, 2020; Zhuang et al., 2009). Sri Lanka is home to eight endemic *Cinnamomum* species, including *C. zeylanicum*, and all these species have more than 50% cinnamaldehyde in bark oil (Paranagama et al., 2001). Cinnamaldehyde inhibited the influenza A/PR/8 virus growth and inhibited viral protein synthesis, *in vitro* and *in vivo* (Hayashi et al., 2007).

4.1.17. Coumarins

First isolated from tonka beans (*Dipteryx odorata* (Aubl.) Willd. - Fabaceae) in 1822 and chemically synthesized in 1868, coumarin (2H-1-benzopyran-2-one) was a popular flavouring agent in the food industry due to its pleasant spicy odor of fresh hay, woodruff or vanilla. After a century of use, it was found that coumarin has hepatotoxic effects in laboratory animals, and its use as a flavouring agent was banned in the USA in 1954 by the US Food & Drug Administration, including the use of tonka beans and its extract as a food (Pathirana & Senaratne, 2020). European Food Safety Authority has set a limit of 2 mg/kg coumarin in food derived from natural spices and herbs (Abraham et al., 2010). Nevertheless, this natural polyphenolic compound has shown potential antiviral activity against several pathogenic human viruses (i.e. HIV, Influenza, Hepatitis virus, Dengue virus, Chikungunya virus, Enterovirus 71 and coxsackievirus A16) (Mishra et al., 2020; Moore & Stevenson, 2000). The possible antiviral mechanisms involve either inhibition of proteins essential for viral entry, inhibition of proteins related to polymerase responsible for viral replication and infection, or regulation of cellular pathways, and anti-oxidative pathway (Hassan et al., 2016). Coumarin derivatives such as 4-Hydroxycoumarins, Pyranocoumarins, Furanocoumarin, 3-Phenylcoumarins, 4-Phenylcoumarins, Hybrid coumarin analogue Toddacoumaquinone have all shown potent antiviral effect against HIV infection because they inhibit HIV protease, integrase, reverse transcriptase and viral DNA replication (Hassan et al., 2016; Moore & Stevenson, 2000). A major limitation of the literature on the antiviral effects of coumarins is that these studies have been performed mainly *in silico* and *in vitro.* Only a few studies have been done on animal models (Liu et al., 2019).

4.2. Alkaloids

Bioactive alkaloids are a group of secondary plant metabolites containing a nitrogen atom in its ring structure (Korpan et al., 2004). The growing evidence from research demonstrates that plant alkaloids exhibit activity against human viral pathogens. Alkaloids inhibit the viral infection at different stages of replication and also inhibit the synthesis of viral proteins (Malakar et al., 2018). Antiviral alkaloids are classified into a number of classes, including methyl-xanthine, pyrrolizidines, pyrrolidines, quinolizidines, indoles, tropanes, piperidines, purines, imidazoles, and isoquinolines which are described below.

4.2.1. Caffeine

Caffeine is a methyl-xanthine alkaloid naturally occurring in coffee, tea and kolanuts (Murayama et al., 2008). It is attracting attention due to various physiological and pharmacological activities (Yamazaki & Tagaya, 1980). Among the bioactive components of coffee extracts, caffeine has been reported to show antiviral activity against influenza virus, vaccinia virus, HSV-1 and poliovirus (Murayama et al., 2008; Yamazaki & Tagaya, 1980). Caffeine inhibits the multiplication of RNA (e.g. poliovirus) and DNA (e.g. HSV-1) viruses, inhibited viral protein synthesis and suppressed the plaque formation of the virus (Murayama et al., 2008; Utsunomiya et al., 2008).

4.2.2. Quinine

Quinine is a natural alkaloid compound extracted from the bark of the *Cinchona officinalis*. It has been used in the treatment of malaria since the 1960s (Malakar et al., 2018). Quinine inhibits dengue virus replication by reducing dengue RNA and viral protein synthesis (D'Alessandro et al., 2020). Quinine and its derivatives appear as versatile bioactive agents, and reported to possess antiviral activity against RNA viruses as diverse as rabies virus,

poliovirus, HIV, hepatitis A virus, hepatitis C virus, influenza A and B viruses, influenza A H5N1 virus, Chikungunya virus, Dengue virus, Zika virus and Ebola virus, as well as various DNA viruses such as hepatitis B virus and HSV (D'Alessandro et al., 2020; Devaux et al., 2020; Malakar et al., 2018). Chloroquine and hydroxychloroquine are structural analogs of quinine, which have been described as potent inhibitors of most coronaviruses, including SARS-CoV-1 and MERS-CoV (Wang et al., 2020). Moreover, hydroxychloroquine combined with azithromycin is found to be more effective in reducing the SARS-CoV-2 viral load (Devaux et al., 2020). Even though chloroquine and hydroxychloroquine were reported to be active against respiratory syndrome coronavirus, all these observations remain controversial and merit future investigations.

4.2.3. Lycorine

Lycorine is a natural alkaloid extracted from the Amaryllidaceae plant family (e.g. *Lycoris radiata* and *Pancratium zeylanicum* – the latter endemic to Sri Lanka) (Hu et al., 2015). Lycorine has been reported to exhibit a wide range of antiviral effects, including HIV-1, SARS-CoV, poliovirus, coxsackie virus, human enterovirus 71, measles virus, and HSV-1 (Li et al., 2005; Lin et al., 2014). However, the mechanism of antiviral activity against SARS-CoV-2 of this active compound is not very clear. It is believed that lycorine interferes with expressed viral proteins and antigens (Zarrinhaghighi & Dehshahri, 2020).

4.2.4. Tropane

Tropane alkaloids are valuable secondary plant metabolites that occur naturally in high concentrations in the Solanaceae and Erythroxylaceae plant families (Kohnen-Johannsen & Kayser, 2019). As reported in Table 1, *Datura metel* contains high levels of tropane alkaloids such as atropine, hyoscyamine, and scopolamine (Roy et al., 2015; Roy et al., 2016; Roy et al., 2018). Atropine is reported to have an antiviral activity, which inhibits the growth of enveloped viruses such as HSV, influenza virus, new castle disease virus, sindbis, vaccinia, adenovirus, and Japanese encephalitis virus (Yamazaki & Tagaya, 1980). Additionally, atropine blocks the glycosylation process of viral proteins of herpesvirus, and thereby limits the synthesis of new infectious virus particles. Even though new virus particles are formed in the presence of atropine, they are non-infectious (Alarcón et al., 1984).

4.2.5. Piperine

Piperine is the bioactive alkaloid compound mainly responsible for the pungency of black pepper (*Piper nigrum*) and long pepper (*Piper longum*) belonging to the family Piperaceae (Tiwari et al., 2010). Though black pepper is the most commonly consumed spice in the world, it has also been used in some forms of traditional medicine to treat pain management, chills, rheumatism, arthritis, strep throat, influenza, and fever (Jiang et al., 2013; Tiwari et al., 2010). Piperines extracted from both species showed potent antiviral activity against Vesicular stomatitis Indiana virus and Human parainfluenza virus (Jiang et al., 2013; Priya & Kumari, 2017). However, possible mechanisms underlying viral inhibitory effects are not yet clear that merits future investigations. Interestingly, piperine has been identified as one of the potential lead molecules possessing the ability to interact with the components that block the replication of SARS-CoV-2 (Rout, Swain, & Tripathy, 2020). Moreover, piperine may establish natural resistance to alleviate the SARS-CoV-2 viral infection by boosting the human immune system (Alagu Lakshmi et al., 2020).

4.2.6. Terpenes and Terpenoids

Terpenes consist of five-carbon isoprene units with simple hydrocarbons, whereas terpenoids are the modified forms of terpenes with different functional groups at different positions (Chiang et al., 2003; Tanaka et al., 2004). These natural compounds present in plants have significant antiviral properties. Cannabis is one of the most common plant sources for medicinal terpene which shows several antiviral properties (Maor et al., 2012). Terpenes such as carvone, carveol limonene, alpha- and beta-pinene, caryophylene,

camphor, beta-ocimene, and germacreneform are major constituents of essential oils in plants that play a major role in the inactivation of HSV-1, dengue virus type 2, and Junin virus (Cox-Georgian et al., 2019). β-amyrin is a pentacyclic triterpenoid that efficiently acts against influenza A, HSV, HIV and hepatitis B viruses (Al-Abd et al., 2017; Chiang et al., 2003; Tanaka et al., 2004). As reported in Table 1, the antiviral activity of both leaf and fruit extracts of *Ardisia elliptica* may be attributed to their high β-amyrin contents (Al-Abd et al., 2017). Andrographolide is a terpenoid extracted from the stems and leaves of *Andrographis paniculata* (Pongtuluran & Rofaani, 2015). Andrographolide was found to have broad-spectrum antiviral properties over many types of viral infections, including H1N1, H9N2, or H5N1 influenza viruses, HIV, Chikungunya and HSV-1 (Gupta et al., 2017; Pongtuluran & Rofaani, 2015). Thus, andrographolide can inhibit viral load and induce lymphocyte cell proliferation, thereby acting as an immune booster (Enmozhi et al., 2020). Additionally, Wen et al. (2007) reported that terpenoids possess potent inhibitory action on SARS-CoV replication. Further studies are warranted to elucidate the mechanism of action of terpinoids against SARS-CoV-2.

4.3. L-ascorbate

Emerging literature suggests that L-ascorbate (vitamin C) may play an adjunctive role in treating a variety of DNA and RNA virus diseases including SARS-CoV-2 (Biancatelli et al., 2020; Jariwalla & Harakeh, 1996). In general, yellow and red-coloured fruits and green-leafy vegetables have high vitamin C content (i.e. orange, lemon, guava, pomegranate, nelli etc.). Chemically, vitamin C is known as L-ascorbic acid or L-ascorbate, and it is one of the well-known anti-influenza viral agents (Kim et al., 2013). It has been reported that vitamin C shows *in vivo* antiviral immune responses at the early stage of Influenza A virus infection, and sufficiently high vitamin C content at the initial stage of viral infection prevents the replication of influenza viruses (Jariwalla & Harakeh, 1996; Kim et al., 2013). Additionally, vitamin C may effectively inhibit severe or fatal damages in humans by the infection of influenza virus. Vitamin C also appears to have clinical benefits in patients with infections because it has beneficial immunomodulating properties (Biancatelli et al., 2020). Despite the *in vitro* and *in vivo* biological plausibility that vitamin C may be beneficial in viral infections; there is limited evidence from well-designed clinical trials to support this contention which merits future investigations.

4.4. Saponins

Saponins are a class of bioorganic glycosides found in particular abundance in the plant kingdom. Glycyrrhizin, a saponin isolated from liquorice (*Glycyrrhiza glabra*) roots can bind with important proteins of SARS-CoV which are essential for viral infection and replication (Cinatl et al., 2003; Li et al., 2005). It has been further reported that glycyrrhizin was the most active in inhibiting replication of the SARS-associated virus in two clinical isolates of coronavirus (FFM-1 and FFM-2) from patients with SARS-CoV admitted to the Clinical Centre of Frankfurt University, Germany (Cinatl et al., 2003). It will be interesting to see if glycyrrhizin will be equally effective against SARS-CoV-2 considering its pharmacological action, including binding ACE2, downregulating proinflammatory cytokines, inhibiting the accumulation of intracellular reactive oxygen species, inhibiting thrombin, inhibiting the hyperproduction of airway exudates, and inducing endogenous interferon (Dabaghian et al., 2020; Luo et al., 2020).

4.5. Lectins

Lectins are natural proteins or glycoproteins that bind to carbohydrates, and they are found in almost all foods, particularly legumes and grains (Mitchell et al., 2017). Many natural lectins have been reported to have antiviral activity. For instance, the leaves of *Pandanus amaryllifolius* is a rich source of a lectin, designated Pandanin, which shows potent antiviral activity against HSV-1 and influenza virus (H1N1) (Ooi et al., 2004). Many lectins can block viral replication by interacting with viral envelope glycoproteins and reducing

the severity of illness and preventing death in virus-infected host (Mitchell et al., 2017). Keyaerts et al. (2007) reported a variety of plant lectins as antiviral compounds against both SARS-CoV and Feline coronavirus both of which are associated with serious lower respiratory diseases. The lectins demonstrated antiviral activity because they could interfere with the glycans on the spike protein during SARS-CoV virus entry and virus release. Mannose-binding lectins showed the most pronounced anti-coronavirus activity by targeting the entry and the release of virus particles (Keyaerts et al., 2007).

4.6. Selenium

Pathogenesis of viral infections is frequently associated with deficiencies in macronutrients and micronutrients, including the essential trace element selenium found in plants, fruits and seeds (Gill & Walker, 2008; Kieliszek & Lipinski, 2020). For example, selenium deficiency is related to disease progression in HIV-infected patients and hepatitis C virus-induced liver cancers (Steinbrenner et al., 2015). It has been further reported that selenium deficiency leads to mutation of Coxsackie and influenza viruses to highly pathogenic strains (Beck, 1999; Steinbrenner et al., 2015). Additionally, selenium-deficient animals infected with a viral pathogen exhibited poor immunity to protect the host against viral infection (Gill & Walker, 2008). Therefore, adequate dietary intake of selenium has been advised to maintain the health status of patients with HIV and influenza A virus infections (Steinbrenner et al., 2015). Kieliszek and Lipinski (2020) reported that supplementation of selenium could inhibit the entrance of viruses into healthy cells, disrupting their infectivity. Methylated amino acid derivative of selenium methylselenocystaine found in species such as garlic has antitumorigenic activity (Brummell et al., 2011; McKenzie et al., 2008)

4.7. Capsaicin

Capsaicin (8-methyl-N-vanillyl-6-nonenamide) is a major bioactive compound of plants found in the genus *Capsicum* such as chilli peppers (Dhadwal et al., 2009). It can cause a burning sensation in the mucous membranes of humans (Hafiz et al., 2017). It is widely used as a culinary ingredient in Asian cuisine. It has been a traditional component of ancient herbal remedies for several disease conditions (Dhadwal et al., 2009). Capsaicin has gained considerable attention because of its antiviral activity. Capsaicin inhibits the entry of enveloped single negative-strand RNA Lassa virus that causes Lassa hemorrhagic fever (Tang et al., 2020). Additionally, capsaicin effectively inhibits the detrimental effects of HIV protease inhibitor and thereby has significantly prolonged the functional immune system (Dhadwal et al., 2009).

4.8. Polysaccharides

Polymeric carbohydrate molecules comprised of long chains of monosaccharide units are known as polysaccharides (Wang et al., 2016). Plant-derived polysaccharides have antiviral activities (Sun et al., 2018; Yu et al., 2018). Plant-origin polysaccharides may directly interfere with viral infection in host cells and induce host antiviral proteins (Sun et al., 2018; Vlietinck et al., 1998). Additionally, polysaccharides have immunity-enhancing functions against viral infections (Wang et al., 2014). Aloe polysaccharides, active ingredient isolated from *Aloe vera* gel are used as an approved treatment of AIDS in humans because of its effect on viral replication (Radha & Laxmipriya, 2015). Additionally, aloe polysaccharides could inhibit the replication of H1N1 influenza virus mainly during the viral adsorption period (Sun et al., 2018). An inulin-type fructan polysaccharide can be extracted from the genus *Allium*. This polysaccharide possessed anti-influenza A virus activity in an animal model (Lee et al., 2012) and immunomodulatory effects *in vitro* (Chandrashekar et al., 2011).

4.9. Lauric acid and its derivatives

Lauric acid is a medium-chain (C12) free fatty acid which has been known for many years to have significant antiviral activity. It has a broad spectrum of antimicrobial activity against several enveloped viruses similar to

SARS-CoV-2 (Grant et al., 2012; Thormar et al., 1987). Medium-chain free fatty acids have been shown to reduce the viral load of AIDS patients, indicating that they have an antiviral effect against HIV (Enig, 1998). It has been reported that the medium-chain free fatty acids in coconut oil destroy viruses by disrupting their membranes, interfering virus assembly and maturation (Hornung et al., 1994; Thormar et al., 1987). In addition to lauric acid, monolaurin is a chemical derivative of lauric acid, found in coconut milk and human colostrum. It is used in a wide range of products for its strong antiviral properties, mainly against enveloped human viruses such as HIV, measles virus, HSV, vesicular stomatitis virus, visna virus, and cytomegalovirus (Thormar et al., 2013). Monolaurin acts as an antiviral agent because it can solubilize the lipids and phospholipids in the envelope of the virus, resulting in the destruction of the virus envelope (Lieberman et al., 2006). Thus, these research findings support the premise that coconut oil, lauric acid and its derivatives can be effective and safe herbal drugs against the prevailing SARS-CoV-2.

5. CONCLUSIONS AND FUTURE PROSPECTS

A new Severe Acute Respiratory Syndrome caused by SARS-CoV-2 was identified in 2019, causing the disease COVID-19 in humans. There have been some significant advances in vaccine development, treatment, control, and prevention of SARS-CoV-2 infection. This virus causes acute symptoms that include fever, headache, sore throat, sneezing, and abdominal pain, and can develop into more severe and potentially fatal conditions such as pneumonia. Currently, immunization against SARS-CoV-2 is available. Since SARS-CoV viruses keep appearing more frequently, including mutant strains of existing SARS-CoV-2, eradicating these viral diseases appears difficult. Efforts have been made at identifying natural products that inhibit SARS-CoV and include a number of Asian traditional medicines.

Traditional herbal drugs have been continuously used in the field of traditional medicine for the treatment of various viral infections. Therapies based on natural phytochemicals are generally less toxic and have minimal side effects. Thus, researchers are focusing on elucidating new plant-based compounds for the treatment of many diseases including coronaviruses. Secondary plant metabolites have proven successful in boosting immunity and providing tolerance to virus infections because they possess broad-spectrum antiviral activity. This article reviewed potential antiviral properties of medicinal plants used in Sri Lanka and their bioactive secondary metabolites against a diverse group of viruses. The review highlights the potential of plants possessing broad-spectrum antiviral effects against emerging coronavirus infections.

Sri Lanka has a variety of medicinal plants traditionally being used to treat viral infections. However, literature is scanty regarding formulations, effective dosage and side effects of these medicinal plants with potential for treating COVID-19. Among all the phytochemicals of herbal plants in Sri Lanka, phenolic compounds, alkaloids, terpenoids have been widely explored and studied for the treatment of influenza, dengue, chikungunya, and other viruses. All these herbal drugs are potential candidates that can be processed further to the development of antiviral agents. Moreover, the combination of phytochemicals with synthetic compounds or drugs can also have potential applications as antiviral therapies. Particularly, the synergistic effect of these molecules coupled with synthetic drugs should be tested as studies have shown higher efficiency of this combination in reducing the viral load. Such work will not only prove effective against the ongoing pandemic but also serve as a roadmap for any future encounters with different viral strains.

Unfortunately, in-depth clinical studies exploring the bioactive compounds of plant origin and their mechanism of action are rare. Therefore, it is necessary to conduct ethnomedicinal studies to understand their mechanism of action. Scientific publications on the antiviral activity of medicinal plants should be encouraged and incorporated

into a universal database system. Moreover, randomized, double-blind, placebo-controlled multicenter clinical trials should be conducted before herbal remedies are used for treatment of viral diseases. Policy support and collaboration between academic institutions and industries are important for such ventures and to facilitate large-scale production of plant-based antiviral molecules and vaccines. In addition, more focus should be given to widely distributed plant species enabling extraction of novel compounds on a large scale. Very few plant products have been screened *in vitro* and *in vivo* against SARS-CoV-2. It is imperative to screen unexplored plants in detail not only for their *in-vitro* and *in-vivo* activity but also for their phytochemistry, toxicology and mechanisms of action. Synergistic studies employing phytochemicals combined with approved drugs or inhibitors could be explored in the future. Furthermore, biodiversity-rich regions in Sri Lanka could be explored to identify more potent phytochemicals and metabolites as antiviral agents. In addition, identified antiviral phytochemicals can be nanoencapsulated for better delivery, prolonged action, and enhanced bioavailability. The use of *in silico* information systems provide further avenues that might involve databases to relate constituents to their network profile to integrate networks and decrease the exploitation of plants. Such strategies may also permit new drug discovery from plants that have ubiquitous existence on earth.

ACKNOWLEDGEMENT

The authors express their gratitude to Professor Shanthi Mendis for critical review of the manuscript.

REFERENCES

Abba, Y., Hassim, H., Hamzah, H., & Noordin, M. M. (2015). Antiviral activity of resveratrol against human and animal viruses. *Advances in Virology*, *2015*(184241). https://doi.org/10.1155/2015/184241.

Abdel-Moneim, A., Morsy, B. M., Mahmoud, A. M., Abo-Seif, M. A., & Zanaty, M. I. (2013). Beneficial therapeutic effects of *Nigella sativa* and/or *Zingiber officinale* in HCV patients in Egypt. *EXCLI Journal*, *12*, 943-955.

Abraham, K., Wohrlin, F., Lindtner, O., Heinemeyer, G., & Lampen, A. (2010). Toxicology and risk assessment of coumarin: focus on human data. *Mol Nutr Food Res*, *54*(2), 228-239. https://doi.org/10.1002/mnfr.200900281.

Adnan, A., Allaudin, Z. N., Hani, H., Loh, H.-S., Khoo, T.-J., Ting, K. N., & Abdullah, R. (2019a). Virucidal activity of *Garcinia parvifolia* leaf extracts in animal cell culture. *BMC Complementary and Alternative Medicine*, *19*(1), 169. https://doi.org/10.1186/s12906-019-2586-5.

Ahmadi, S., Rajabi, Z., & Vasfi-Marandi, M. (2018). Evaluation of the antiviral effects of aqueous extracts of red and yellow onions (*Allium cepa*) against avian influenza virus subtype H9N2. *Iranian Journal of Veterinary Science and Technology*, *10*(2), 23-27. https://doi.org/10.22067/VETERINARY.V2I10.74060.

Akram, M., Tahir, I. M., Shah, S. M. A., Mahmood, Z., Altaf, A., Ahmad, K., Munir, N., Daniyal, M., Nasir, S., & Mehboob, H. (2018). Antiviral potential of medicinal plants against HIV, HSV, influenza, hepatitis, and coxsackievirus: A systematic review. *Phytotherapy Research*, *32*(5), 811-822. https://doi.org/10.1002/ptr.6024.

Akula, R., & Ravishankar, G. A. (2011). Influence of abiotic stress signals on secondary metabolites in plants. *Plant Signaling & Behavior*, *6*(11), 1720-1731. https://doi.org/10.4161/psb.6.11.17613.

Al-Abd, N. M., Nor, Z. M., Mansor, M., Zajmi, A., Hasan, M. S., Azhar, F., & Kassim, M. (2017). Phytochemical constituents, antioxidant and antibacterial activities of methanolic extract of *Ardisia elliptica*. *Asian Pacific Journal of Tropical Biomedicine*, *7*(6), 569-576.

Al Ravi, A. A. S., AL Dulaimi, H. S. H., & Al Ravi, M. A. A. (2019). Antiviral activity of *Mangifera* extract on Influenza Virus cultivated in different cell cultures. *J Pure Appl Microbiol*, *13*(1), 455-458.

Alagu Lakshmi, S., Shafreen, R. M. B., Priya, A., & Shunmugiah, K. P. (2020). Ethnomedicines of Indian origin for combating COVID-19 infection by hampering the viral replication: using structure-based drug discovery approach. *Journal of Biomolecular Structure and Dynamics*, 1-16. https://doi.org/10.1080/07391102.2020.1778537.

Alarcón, B., González, M. E., & Carrasco, L. (1984). Antiherpesvirus action of atropine. *Antimicrobial Agents and Chemotherapy*, *26*(5), 702-706. https://aac.asm.org/content/aac/26/5/702.full.pdf.

Ali, I., & Alharbi, O. M. (2020). COVID-19: Disease, management, treatment, and social impact. *Science of The Total Environment*, *728*, 138861. https://doi.org/10.1016/j.scitotenv.2020.138861.

Anders, J. P. V., Keller, J. L., Smith, C. M., Hill, E. C., Housh, T. J., Schmidt, R. J., & Johnson, G. O. (2020). The Effects of *Asparagus racemosus* supplementation plus 8 weeks of resistance training on muscular strength and endurance. *Journal of Functional Morphology and Kinesiology*, *5*(1), 4.

Anthikat, R. R. N., & Michael, A. (2009). Study on the areca nut for its antimicrobial properties. *Journal of Young Pharmacists*, *1*(1), 42.

Arena, A., Bisignano, G., Pavone, B., Tomaino, A., Bonina, F. P., Saija, A., Cristani, M., D'Arrigo, M., & Trombetta, D. (2008). Antiviral and immunomodulatory effect of a lyophilized extract of *Capparis spinosa* L. buds. *Phytotherapy Research*, *22*(3), 313-317. https://doi.org/10.1002/ptr.2313.

Arora, R., Chawla, R., Marwah, R., Arora, P., Sharma, R., Kaushik, V., Goel, R., Kaur, A., Silambarasan, M., & Tripathi, R. (2010). Potential of complementary and alternative medicine in preventive management of novel H1N1 flu (Swine flu) pandemic: thwarting potential disasters in the bud. *Evidence-Based Complementary and Alternative Medicine*, *586506*. https://doi.org/10.1155/2011/586506.

Arthanari, S., Vanitha, J., Krishnaswami, V., Renukadevi, P., Deivasigamani, K., & De Clercq, E. (2013). In vitro antiviral and cytotoxic screening of methanolic extract of *Cassia auriculata* flowers in HeLa, Vero, CRFK and HEL cell lines. *Drug Invention Today*, *5*(1), 28-31.

Avci, O., & Dik, B. (2014). Determination of *in vitro* antiviral activity of *Nerium oleander* distillate against to parainfluenza-3 virus. *Anim. Vet. Sci*, *2*(5), 150-153.

Awasthi, L. (1981). The purification and nature of an antiviral protein from *Cuscuta reflexa* plants. *Archives of Virology*, *70*(3), 215-223.

Badam, L., Bedekar, S., Sonavane, K. B., & Joshi, S. P. (2002). *In vitro* antiviral activity of bael (*Aegle marmelos* Corr) upon Human Coxsackieviruses B1-B6. *Journal of Communicable Diseases*, *34*(2), 88-99.

Baildya, N., Khan, A. A., Ghosh, N. N., Dutta, T., & Chattopadhyay, A. P. (2021). Screening of potential drug from *Azadirachta Indica* (Neem) extracts for SARS-CoV-2: An insight from molecular docking and MD-simulation studies. *Journal of Molecular Structure*, *1227*, 129390. https://doi.org/https://doi.org/10.1016/j.molstruc.2020.129390.

Batiha, G. E.-S., Alkazmi, L. M., Wasef, L. G., Beshbishy, A. M., Nadwa, E. H., & Rashwan, E. K. (2020). *Syzygium aromaticum* L.(Myrtaceae): Traditional uses, bioactive chemical constituents, pharmacological and toxicological activities. *Biomolecules*, *10*(3), 352, https://doi.org/10.3390/biom10030352.

Beck, M. A. (1999). Selenium and host defence towards viruses. *Proceedings of the Nutrition Society*, *58*(3), 707-711. https://doi.org/10.1017/S0029665199000920.

Behbahani, M., Sayedipour, S., Pourazar, A., & Shanehsazzadeh, M. (2014). In vitro anti-HIV-1 activities of kaempferol and kaempferol-7-O-glucoside isolated from *Securigera securidaca*. *Research in Pharmaceutical Sciences*, *9*(6), 463-469.

Benencia, F., & Courreges, M. (2000). *In vitro* and *in vivo* activity of eugenol on human herpesvirus. *Phytotherapy Research*, *14*(7), 495-500. https://doi.org/10.1002/1099-1573(200011)14:7<495::AID-PTR650>3.0.CO;2-8.

Bhardwaj, V. K., Singh, R., Sharma, J., Rajendran, V., Purohit, R., & Kumar, S. (2020). Identification of bioactive molecules from tea plant as SARS-CoV-2 main protease inhibitors. *Journal of Biomolecular Structure and Dynamics*, 1-13. https://doi.org/10.1080/07391102.2020.1766572.

Bhattacharya, R., Dev, K., & Sourirajan, A. (2021). Antiviral activity of bioactive phytocompounds against coronavirus: An update. *Journal of Virological Methods*, *290*:114070. https://doi.org/10.1016/j.jviromet.2021.114070.

Biancatelli, R. M. L. C., Berrill, M., Catravas, J. D., & Marik, P. E. (2020). Quercetin and vitamin C: an experimental, synergistic therapy for the prevention and treatment of SARS-CoV-2 related disease (COVID-19). *Frontiers in Immunology*, *11*, 1451. https://doi.org/10.3389/fimmu.2020.01451.

Borkotoky, S., & Banerjee, M. (2020). A computational prediction of SARS-CoV-2 structural protein inhibitors from *Azadirachta indica* (Neem). *Journal of Biomolecular Structure and Dynamics*, 1-17. https://doi.org/10.1080/07391102.2020.1774419.

Brinda, O., Mathew, D., Shylaja, M., Davis, P. S., Cherian, K. A., & Valsala, P. (2019). Isovaleric acid and avicequinone-C are Chikungunya virus resistance principles in *Glycosmis pentaphylla* (Retz.) Correa. *Journal of Vector*

Borne Diseases, *56*(2), 111. https://doi.org/10.4103/0972-9062.263719.

Brummell, D. A., Watson, L. M., Pathirana, R., Joyce, N. I., West, P. J., Hunter, D. A., & McKenzie, M. J. (2011). Biofortification of tomato (*Solanum lycopersicum*) fruit with the anticancer compound methylselenocysteine using a selenocysteine methyltransferase from a selenium hyperaccumulator. *Journal of Agricultural and Food Chemistry*, *59*(20), 10987-10994. https://doi.org/10.1021/jf202583f.

Cagno, V., Civra, A., Kumar, R., Pradhan, S., Donalisio, M., Sinha, B. N., Ghosh, M., & Lembo, D. (2015). *Ficus religiosa* L. bark extracts inhibit human rhinovirus and respiratory syncytial virus infection in vitro. *Journal of Ethnopharmacology*, *176*, 252-257. https://doi.org/10.1016/j.jep.2015.10.042.

Carneiro, B. M., Batista, M. N., Braga, A. C. S., Nogueira, M. L., & Rahal, P. (2016). The green tea molecule EGCG inhibits Zika virus entry. *Virology*, *496*, 215-218.

Chai, H., Yan, S., Lin, P., Lumsden, A. B., Yao, Q., & Chen, C. (2005). Curcumin blocks HIV protease inhibitor ritonavir-induced vascular dysfunction in porcine coronary arteries. *Journal of the American College of Surgeons*, *200*(6), 820-830.

Chandrashekar, P. M., Prashanth, K. V. H., & Venkatesh, Y. P. (2011). Isolation, structural elucidation and immunomodulatory activity of fructans from aged garlic extract. *Phytochemistry*, *72*(2-3), 255-264.

Chang, J.-M., Huang, K.-L., Yuan, T. T.-T., Lai, Y.-K., & Hung, L.-M. (2010). The anti-hepatitis B virus activity of *Boehmeria nivea* extract in HBV-viremia SCID mice. *Evidence-Based Complementary and Alternative Medicine*, *7*(930105). https://doi.org/10.1093/ecam/nem180.

Chansakaow, S., Ruangrungsi, N., & Ishikawa, T. (1996). Isolation of pyropheophorbide a from the leaves of *Atalantia monophylla* (ROXB.) CORR. (Rutaceae) as a possible antiviral active principle against herpes simplex virus type 2. *Chemical and Pharmaceutical Bulletin*, *44*(7), 1415-1417. https://doi.org/10.1248/cpb.44.1415.

Chavan, R., & Chowdhary, A. (2014). In vitro inhibitory activity of Justicia adhatoda extracts against influenza virus infection and hemagglutination. *Int. J. Pharm. Sci. Rev. Res*, *25*(2), 231-236.

Chen, C.-N., Lin, C. P., Huang, K.-K., Chen, W.-C., Hsieh, H.-P., Liang, P.-H., & Hsu, J. T.-A. (2005). Inhibition of SARS-CoV 3C-like protease activity by theaflavin-3, 3'-digallate (TF3). *Evidence-Based Complementary and Alternative Medicine*, *2*.

Chen, D.-Y., Shien, J.-H., Tiley, L., Chiou, S.-S., Wang, S.-Y., Chang, T.-J., Lee, Y.-J., Chan, K.-W., & Hsu, W.-L. (2010). Curcumin inhibits influenza virus infection and haemagglutination activity. *Food Chemistry*, *119*(4), 1346-1351.

Chen, F., Chan, K., Jiang, Y., Kao, R., Lu, H., Fan, K., Cheng, V., Tsui, W., Hung, I., & Lee, T. (2004). *In vitro* susceptibility of 10 clinical isolates of SARS coronavirus to selected antiviral compounds. *Journal of Clinical Virology*, *31*(1), 69-75. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7128415/pdf/main.pdf.

Chen, J., Lin, S., Niu, C., & Xiao, Q. (2021). Clinical evaluation of Shufeng Jiedu Capsules combined with umifenovir (Arbidol) in the treatment of common-type COVID-19: a retrospective study. *Expert Review of Respiratory Medicine*, *15*(2), 257-265. https://doi.org/10.1080/17476348.2020.1822741.

Chen, J. L., Blanc, P., Stoddart, C. A., Bogan, M., Rozhon, E. J., Parkinson, N., Ye, Z., Cooper, R., Balick, M., & Nanakorn, W. (1998). New iridoids from the medicinal plant *Barleria prionitis* with potent activity against respiratory syncytial virus. *Journal of Natural Products*, *61*(10), 1295-1297. https://pubs.acs.org/doi/10.1021/np980086y.

Chiang, L.-C., Cheng, H.-Y., Liu, M.-C., Chiang, W., & Lin, C.-C. (2003). In vitro anti-herpes simplex viruses and anti-adenoviruses activity of twelve traditionally used medicinal plants in Taiwan. *Biological and Pharmaceutical Bulletin*, *26*(11), 1600-1604. https://doi.org/10.1248/bpb.26.1600.

Chiang, L., Chiang, W., Chang, M., Ng, L., & Lin, C. (2002). Antiviral activity of *Plantago major* extracts and related compounds *in vitro*. *Antiviral Research*, *55*(1), 53-62. https://doi.org/10.1016/S0166-3542(02)00007-4.

Chikhale, R. V., Sinha, S. K., Patil, R. B., Prasad, S. K., Shakya, A., Gurav, N., Prasad, R., Dhaswadikar, S. R., Wanjari, M., & Gurav, S. S. (2020). *In-silico* investigation of phytochemicals from *Asparagus racemosus* as plausible antiviral agent in COVID-19. *Journal of Biomolecular Structure and Dynamics*, 1-15. https://doi.org/10.1080/07391102.2020.1784289.

Choi, H. J., Song, J. H., Bhatt, L. R., & Baek, S. H. (2010). Anti-human rhinovirus activity of gallic acid possessing antioxidant capacity. *Phytotherapy Research*, *24*(9), 1292-1296. https://doi.org/10.1002/ptr.3101.

Cinatl, J., Morgenstern, B., Bauer, G., Chandra, P., Rabenau, H., & Doerr, H. (2003). Glycyrrhizin, an active component of liquorice roots, and replication of SARS-associated coronavirus. *The Lancet*, *361*(9374), 2045-2046.

Clark, K., Grant, P., Sarr, A., Belakere, J., Swaggerty, C., Phillips, T., & Woode, G. (1998). An *in vitro* study of theaflavins extracted from black tea to neutralize bovine rotavirus and bovine coronavirus infections. *Veterinary Microbiology*, *63*(2-4), 147-157.

Cox-Georgian, D., Ramadoss, N., Dona, C., & Basu, C. (2019). Therapeutic and medicinal uses of terpenes. In *Medicinal Plants* (pp. 333-359). Springer. https://doi.org/10.1007/978-3-030-31269-5_15.

Cryer, M., Lane, K., Greer, M., Cates, R., Burt, S., Andrus, M., Zou, J., Rogers, P., Hansen, M. D., & Burgado, J. (2017). Isolation and identification of compounds from *Kalanchoe pinnata* having human alphaherpesvirus and vaccinia virus antiviral activity. *Pharmaceutical Biology*, *55*(1), 1586-1591. https://doi.org/10.1080/13880209.2017.1310907.

Cui, Q., Du, R., Liu, M., & Rong, L. (2020). Lignans and their derivatives from plants as antivirals. *Molecules*, *25*(1), 183. https://doi.org/10.3390/molecules25010183.

D'Alessandro, S., Scaccabarozzi, D., Signorini, L., Perego, F., Ilboudo, D. P., Ferrante, P., & Delbue, S. (2020). The use of antimalarial drugs against viral infection. *Microorganisms*, *8*(1), 85. https://doi.org/10.3390/microorganisms8010085.

da Silva, J. K. R., Figueiredo, P. L. B., Byler, K. G., & Setzer, W. N. (2020). Essential oils as antiviral agents, potential of essential oils to treat SARS-CoV-2 infection: An in-silico investigation. *International Journal of Molecular Sciences*, *21*(10), 3426.

Dabaghian, F., Khanavi, M., & Zarshenas, M. M. (2020). Bioactive compounds with possible inhibitory activity of Angiotensin-Converting Enzyme-II; a gate to manage and prevent COVID-19. *Medical Hypotheses*, *143*, 109841-109841. https://doi.org/10.1016/j.mehy.2020.109841.

Dayarathne, M., & Rajapakse, S. (2019). Preliminary investigations on the serine and aspartic protease inhibitors from *Nothopegia beddomei*. *Ceylon Journal of Science*, *48*(2), 185-189.

De Almeida, A., Miranda, M., Simoni, I., Wigg, M., Lagrota, M., & Costa, S. (1998). Flavonol monoglycosides isolated from the antiviral fractions of *Persea americana* (Lauraceae) leaf infusion. *Phytotherapy Research*, *12*(8), 562-567.

DebMandal, M., & Mandal, S. (2011). Coconut (*Cocos nucifera* L.: Arecaceae): in health promotion and disease prevention. *Asian Pacific Journal of Tropical Medicine*, *4*(3), 241-247.

Devaux, C. A., Rolain, J.-M., Colson, P., & Raoult, D. (2020). New insights on the antiviral effects of chloroquine against coronavirus: what to expect for COVID-19? *International Journal of Antimicrobial Agents*, 105938. https://doi.org/10.1016/j.ijantimicag.2020.105938.

Dhadwal, A. K., Wang, X., Annambhotla, S., Lin, P. H., Yao, Q., & Chen, C. (2009). Capsaicin blocks HIV protease inhibitor ritonavir-induced vascular dysfunction in porcine pulmonary arteries. *Medical Science Monitor: International Medical Journal of Experimental and Clinical Research*, *15*(1), BR1-5.

Dharmadasa, R., Hettiarachchi, P., & Premakumara, G. (2011). Geographical distribution and conservation of a rare medicinal plant *Munronia pinnata* (Wall.) Theob.(Meliaceae) in Sri Lanka. *Bangladesh Journal of Plant Taxonomy*, *18*(1), 39-49.

Di Gennaro, F., Pizzol, D., Marotta, C., Antunes, M., Racalbuto, V., Veronese, N., & Smith, L. (2020). Coronavirus diseases (COVID-19) current status and future perspectives: a narrative review. *International Journal of Environmental Research and Public Health*, *17*(8), 2690.

Ding, Y., Cao, Z., Cao, L., Ding, G., Wang, Z., & Xiao, W. (2017). Antiviral activity of chlorogenic acid against influenza A (H1N1/H3N2) virus and its inhibition of neuraminidase. *Scientific Reports*, *7*, 45723. https://doi.org/10.1038/srep45723

Dinić, J., Novaković, M., Podolski-Renić, A., Stojković, S., Mandić, B., Tešević, V., Vajs, V., Isaković, A., & Pešić, M. (2014). Antioxidative activity of diarylheptanoids from the bark of black alder (*Alnus glutinosa*) and their interaction with anticancer drugs. *Planta Medica*, *80*(13), 1088-1096.

Eich, E., Pertz, H., Kaloga, M., Schulz, J., Fesen, M. R., Mazumder, A., & Pommier, Y. (1996). (−)-Arctigenin as a lead structure for inhibitors of human immunodeficiency virus type-1 integrase. *Journal of Medicinal Chemistry*, *39*(1), 86-95. https://doi.org/10.1021/jm950387u.

Ekor, M. (2014). The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. *Frontiers in Pharmacology*, *4*, 177. https://doi.org/10.3389/fphar.2013.00177.

Enig, M. G. (1998). Lauricoils as antimicrobial agents: theory of effect, scientific rationale. *Nutrients and Foods in AIDS*, *17*, 21-100.

Enkhtaivan, G., John, K. M., Ayyanar, M., Sekar, T., Jin, K.-J., & Kim, D. H. (2015). Anti-influenza (H1N1) potential of leaf and stem bark extracts of selected medicinal plants of South India. *Saudi Journal of Biological Sciences*, *22*(5), 532-538. https://doi.org/10.1016/j.sjbs.2015.01.011.

Enmozhi, S. K., Raja, K., Sebastine, I., & Joseph, J. (2020). Andrographolide as a potential inhibitor of SARS-CoV-2 main protease: an *in silico* approach. *Journal of Biomolecular Structure and Dynamics*, 1-7. https://doi.org/10.1080/07391102.2020.1760136

Epifano, F., Genovese, S., Menghini, L., & Curini, M. (2007). Chemistry and pharmacology of oxyprenylated secondary plant metabolites. *Phytochemistry*, *68*(7), 939-953. https://doi.org/10.1016/j.phytochem.2007.01.019.

Esposito, F., Mandrone, M., Del Vecchio, C., Carli, I., Distinto, S., Corona, A., Lianza, M., Piano, D., Tacchini, M., & Maccioni, E. (2017). Multi-target activity of *Hemidesmus indicus* decoction against innovative HIV-1 drug targets and characterization of Lupeol mode of action. *Pathogens and Disease*, *75*(6), ftx065.

Estari, M., Venkanna, L., Sripriya, D., & Lalitha, R. (2012). Human Immunodeficiency Virus (HIV-1) reverse transcriptase inhibitory activity of *Phyllanthus emblica* plant extract. *Biology and Medicine*, *4*(4), 178.

Fan, W., Qian, S., Qian, P., & Li, X. (2016). Antiviral activity of luteolin against Japanese encephalitis virus. *Virus Research*, *220*, 112-116.

Farahani, M. (2014). Anti-Herpes Simplex Virus Effect of *Camellia sinesis*, *Echiumamoenum* and *Nerium oleander*. *Journal of Applied & Environtal Microbiology*, *2*, 102-105. https://doi.org/10.12691/jaem-2-4-3.

Fayyad, G., Ibrahim, N., & Yaakob, A. (2017). Evaluation of biological activities of seeds of *Coriandrum sativum*. *International Journal of Scientific and Engineering Research*, *8*(7), 1058-1063.

Fuzimoto, A. D., & Isidoro, C. (2020). The antiviral and coronavirus-host protein pathways inhibiting properties of herbs and natural compounds - Additional weapons in the fight against the COVID-19 pandemic? *Journal of Traditional and Complementary Medicine*, *10*(4), 405-419. https://doi.org/https://doi.org/10.1016/j.jtcme.2020.05.003.

Gautam, S., Gautam, A., Chhetri, S., & Bhattarai, U. (2020). Immunity against COVID-19: Potential role of Ayush Kwath. *Journal of Ayurveda and Integrative Medicine*. (In press) https://doi.org/https://doi.org/10.1016/j.jaim.2020.08.003.

Ghosh, R., Chakraborty, A., Biswas, A., & Chowdhuri, S. (2020). Evaluation of green tea polyphenols as novel corona virus (SARS CoV-2) main protease (Mpro) inhibitors–an in silico docking and molecular dynamics simulation study. *Journal of Biomolecular Structure and Dynamics*, 1-13. https://doi.org/10.1080/07391102.2020.1779818.

Ghule, B., Murugananthan, G., Nakhat, P., & Yeole, P. (2006). Immunostimulant effects of *Capparis zeylanica* Linn. leaves. *Journal of Ethnopharmacology*, *108*(2), 311-315. https://doi.org/10.1016/j.jep.2006.03.041.

Gill, H., & Walker, G. (2008). Selenium, immune function and resistance to viral infections. *Nutrition & Dietetics*, *65*, S41-S47.

Gonçalves, J., Lopes, R., Oliveira, D., Costa, S., Miranda, M., Romanos, M., Santos, N., & Wigg, M. (2005). In vitro anti-rotavirus activity of some medicinal plants used in Brazil against diarrhea. *Journal of Ethnopharmacology*, *99*(3), 403-407. https://doi.org/10.1016/j.jep.2005.01.032.

Govea-Salas, M., Rivas-Estilla, A. M., Rodríguez-Herrera, R., Lozano-Sepúlveda, S. A., Aguilar-Gonzalez, C. N., Zugasti-Cruz, A., Salas-Villalobos, T. B., & Morlett-Chávez, J. A. (2016). Gallic acid decreases hepatitis C virus expression through its antioxidant capacity. *Experimental and Therapeutic Medicine*, *11*(2), 619-624. https://doi.org/10.3892/etm.2015.2923.

Grant, A., Seregin, A., Huang, C., Kolokoltsova, O., Brasier, A., Peters, C., & Paessler, S. (2012). Junin virus pathogenesis and virus replication. *Viruses*, *4*(10), 2317-2339. https://doi.org/10.3390/v4102317.

Gunawardana, S., & Jayasuriya, W. (2019). Medicinally important herbal flowers in Sri Lanka. *Evidence-Based Complementary and Alternative Medicine*, *2019*(Article ID 2321961). https://doi.org/10.1155/2019/2321961.

Guo, Y.-J., Luo, T., Wu, F., Mei, Y.-W., Peng, J., Liu, H., Li, H.-R., Zhang, S.-L., Dong, J.-H., & Fang, Y. (2015). Involvement of TLR2 and TLR9 in the anti-inflammatory effects of chlorogenic acid in HSV-1-infected microglia. *Life Sciences*, *127*, 12-18. https://doi.org/10.1016/j.lfs.2015.01.036.

Guo, Y.-R., Cao, Q.-D., Hong, Z.-S., Tan, Y.-Y., Chen, S.-D., Jin, H.-J., Tan, K.-S., Wang, D.-Y., & Yan, Y. (2020). The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak–an update on the status. *Military Medical Research*, *7*, 11. https://doi.org/10.1186/s40779-020-00240-0.

Gupta, S., Mishra, K., & Ganju, L. (2017). Broad-spectrum antiviral properties of andrographolide. *Archives of Virology*, *162*(3), 611-623. https://doi.org/10.1007/s00705-016-3166-3.

Gyuris, A., Szlavik, L., Minarovits, J., Vasas, A., Molnar, J., & Hohmann, J. (2009). Antiviral activities of extracts of *Euphorbia hirta* L. against HIV-1, HIV-2 and SIVmac251. *In Vivo*, *23*(3), 429-432. http://iv.iiarjournals.org/content/23/3/429.full.pdf.

Hafiz, T. A., Mubaraki, M. A., Dkhil, M. A., & Al-Quraishy, S. (2017). Antiviral activities of *Capsicum annuum* methanolic extract against herpes simplex virus 1 and 2. *Pak. J. Zool*, *49*, 251-255.

Haidari, M., Ali, M., Casscells III, S. W., & Madjid, M. (2009). Pomegranate (*Punica granatum*) purified polyphenol extract inhibits influenza virus and has a synergistic effect with oseltamivir. *Phytomedicine*, *16*(12), 1127-1136. https://doi.org/10.1016/j.phymed.2009.06.002.

Hassan, M. Z., Osman, H., Ali, M. A., & Ahsan, M. J. (2016). Therapeutic potential of coumarins as antiviral agents. *European Journal of Medicinal Chemistry*, *123*, 236-255. https://doi.org/10.1016/j.ejmech.2016.07.056.

Hayashi, K., Imanishi, N., Kashiwayama, Y., Kawano, A., Terasawa, K., Shimada, Y., & Ochiai, H. (2007). Inhibitory effect of cinnamaldehyde, derived from Cinnamomi cortex, on the growth of influenza A/PR/8 virus *in vitro* and *in vivo*. *Antiviral Research*, *74*(1), 1-8. https://doi.org/10.1016/j.antiviral.2007.01.003.

Hayashi, K., Mori, M., Knox, Y. M., Suzutan, T., Ogasawara, M., Yoshida, I., Hosokawa, K., Tsukui, A., & Azuma, M. (2003). Anti influenza virus activity of a red-fleshed potato anthocyanin. *Food Science and Technology Research*, *9*(3), 242-244. https://doi.org/10.3136/fstr.9.242.

Hayashi, K., Niwayama, S., Hayashi, T., Nago, R., Ochiai, H., & Morita, N. (1988). *In vitro* and *in vivo* antiviral activity of scopadulcic acid B from *Scoparia dulcis*, Scrophulariaceae, against herpes simplex virus type 1. *Antiviral Research*, *9*(6), 345-354. https://doi.org/10.1016/0166-3542(88)90036-8.

Hemalika, D. V. D., & Chandrika, U. G. (2020). Anti-dengue effects of medicinal plants: A review. *International Journal of Herbal Medicine, 8*(6):50-56,

Hoever, G., Baltina, L., Michaelis, M., Kondratenko, R., Baltina, L., Tolstikov, G. A., Doerr, H. W., & Cinatl, J. (2005). Antiviral activity of Glycyrrhizic acid derivatives against SARS–Coronavirus. *Journal of Medicinal Chemistry*, *48*(4), 1256-1259. https://doi.org/10.1021/jm0493008.

Hornung, B., Amtmann, E., & Sauer, G. (1994). Lauric acid inhibits the maturation of vesicular stomatitis virus. *Journal of General Virology*, *75*(2), 353-361.

Hu, M., Peng, S., He, Y., Qin, M., Cong, X., Xing, Y., Liu, M., & Yi, Z. (2015). Lycorine is a novel inhibitor of the growth and metastasis of hormone-refractory prostate cancer. *Oncotarget*, *6*(17), 15348. https://doi.org/10.18632/oncotarget.3610.

Hussein, G., Miyashiro, H., Nakamura, N., Hattori, M., Kakiuchi, N., & Shimotohno, K. (2000). Inhibitory effects of Sudanese medicinal plant extracts on hepatitis C virus (HCV) protease. *Phytotherapy Research*, *14*(7), 510-516. https://doi.org/10.1002/1099-1573(200011)14:7<510::AID-PTR646>3.0.CO;2-B.

Ide, K., Kawasaki, Y., Kawakami, K., & Yamada, H. (2016). Anti-influenza virus effects of catechins: A molecular and clinical review. *Current Medicinal Chemistry*, *23*(42), 4773-4783.

Imran, I., Altaf, I., Ashraf, M., Javeed, A., Munir, N., & Bashir, R. (2016). In vitro evaluation of antiviral activity of leaf extracts of *Azadirachta indica*, *Moringa oleifera*, and *Morus alba* against the foot and mouth disease virus on BHK-21 cell line. *Science Asia*, *42*(6), 392-396. https://doi.org/10.2306/scienceasia1513-1874.2016.42.392.

Iwu, M. M., Okunji, C. O., Tchimene, M., & Sokomba, E. (2020). Antiviral activity of Andrographolide against Ebola virus, Dengue fever and SARS coronavirus. *Research Square*, *PrePrint*. https://doi.org/10.21203/rs.3.rs-24311/v1.

Jarikasem, S., Charuwichitratana, S., Siritantikorn, S., Chantratita, W., Iskander, M., Frahm, A. W., & Jiratchariyakul, W. (2013). Antiherpetic effects of *Gynura procumbens*. *Evidence-Based Complementary and Alternative Medicine*, *2013*, Article 394865. https://doi.org/10.1155/2013/394865.

Jariwalla, R. J., & Harakeh, S. (1996). Antiviral and immunomodulatory activities of ascorbic acid. In *Subcellular Biochemistry* (pp. 215-231). Springer. https://doi.org/10.1007/978-1-4613-0325-1_11.

Jayaweera, D. (1981). *A revised handbook to the flora of Ceylon. Vol. 2*. Balkema.

Jeewan, M., Liyanage, T., Roshana, M., & Mahendran, T. (2020). Determination and comparison of caffeine and other chemical constituents in

Coffea arabica varieties grown in Sri Lanka. *Ceylon Journal of Science*, *49*(1), 151-158. https://doi.org/10.4038/cjs.v49i2.7735.

Jesuthasan, A. S., & Uluwaduge, D. I. (2017). Ethnobotanics used in folk medicine of Tamil culture in Sri Lanka: a scientific review. *Journal of Integrative Medicine, 15*(1), 19-26. http://dx.doi.org/10.1016/S2095-4964(17)60317-0.

Jiang, Z.-Y., Liu, W.-F., Zhang, X.-M., Luo, J., Ma, Y.-B., & Chen, J.-J. (2013). Anti-HBV active constituents from *Piper longum*. *Bioorganic & Medicinal Chemistry Letters*, *23*(7), 2123-2127.

Jo, S., Kim, S., Shin, D. H., & Kim, M.-S. (2020). Inhibition of SARS-CoV 3CL protease by flavonoids. *Journal of Enzyme Inhibition and Medicinal Chemistry*, *35*(1), 145-151. https://doi.org/10.1080/14756366.2019.1690480.

John, K. M., Enkhtaivan, G., Ayyanar, M., Jin, K., Yeon, J. B., & Kim, D. H. (2015). Screening of ethnic medicinal plants of South India against influenza (H1N1) and their antioxidant activity. *Saudi Journal of Biological Sciences*, *22*(2), 191-197.

Kamala, A., Middha, S. K., & Karigar, C. S. (2018). Plants in traditional medicine with special reference to *Cyperus rotundus* L.: a review. *3 Biotech*, *8*(7), 309. https://doi.org/10.1007/s13205-018-1328-6.

Kandewatta, K., Kurukulasooriya, N., & Keembiyahetti, N. (2021). COVID-19: The Socio-Economic Impact on Sri Lanka. Proc. Sri Lanka Economic Research Conference 2020, Sri Lanka Forum of University Economists, Uva Wellassa University of Sri Lanka, Badulla, Sri Lanka. Volume IX, Pp. 28-37. http://slfue.org/images/SLFUE_2020/SLERC_2020_Proceedings_2021_01_21.pdf#page=44.

Kankanamalage, T. N. M., Dharmadasa, R. M., Abeysinghe, D. C., & Wijesekara, R. G. S. (2014). A survey on medicinal materials used in traditional systems of medicine in Sri Lanka. *Journal of Ethnopharmacology*, *155*(1), 679-691. https://doi.org/https://doi.org/10.1016/j.jep.2014.06.016.

Kashiwada, Y., Aoshima, A., Ikeshiro, Y., Chen, Y.-P., Furukawa, H., Itoigawa, M., Fujioka, T., Mihashi, K., Cosentino, L. M., & Morris-Natschke, S. L. (2005). Anti-HIV benzylisoquinoline alkaloids and flavonoids from the leaves of *Nelumbo nucifera*, and structure–activity correlations with related alkaloids. *Bioorganic & Medicinal Chemistry*, *13*(2), 443-448.

Kaushik, V., Saini, V., Pandurangan, A., Khosa, R. L., & Parcha, V. (2013). A review of phytochemical and biological studies of *Diospyros malabarica*. *Int J Pharm Sci Let*, *2*(6), 167-169.

Kesharwani, A., Polachira, S. K., Nair, R., Agarwal, A., Mishra, N. N., & Gupta, S. K. (2017). Anti-HSV-2 activity of *Terminalia chebula* Retz extract and its constituents, chebulagic and chebulinic acids. *BMC Complementary and Alternative Medicine*, *17*(1), 110. https://doi.org/10.1186/s12906-017-1620-8.

Keyaerts, E., Vijgen, L., Pannecouque, C., Van Damme, E., Peumans, W., Egberink, H., Balzarini, J., & Van Ranst, M. (2007). Plant lectins are potent inhibitors of coronaviruses by interfering with two targets in the viral replication cycle. *Antiviral Research*, *75*(3), 179-187. https://doi.org/10.1016/j.antiviral.2007.03.003.

Kieliszek, M., & Lipinski, B. (2020). Selenium supplementation in the prevention of coronavirus infections (COVID-19). *Medical Hypotheses*, *143*, 109878. https://doi.org/10.1016/j.mehy.2020.109878.

Kim, H. J., Yoo, H. S., Kim, J. C., Park, C. S., Choi, M. S., Kim, M., Choi, H., Min, J. S., Kim, Y. S., Yoon, S. W., & Ahn, J. K. (2009). Antiviral effect of *Curcuma longa* Linn extract against hepatitis B virus replication. *Journal of Ethnopharmacology*, *124*(2), 189-196. https://doi.org/10.1016/j.jep.2009.04.046.

Kim, Y., Kim, H., Bae, S., Choi, J., Lim, S. Y., Lee, N., Kong, J. M., Hwang, Y.-i., Kang, J. S., & Lee, W. J. (2013). Vitamin C is an essential factor on the anti-viral immune responses through the production of interferon-α/β at the initial stage of influenza A virus (H3N2) infection. *Immune Network*, *13*(2), 70-74. https://doi.org/10.4110/in.2013.13.2.70.

Kivrak, A., Ulaş, B., & Kivrak, H. (2021). A comparative analysis for anti-viral drugs: Their efficiency against SARS-CoV-2. *International Immunopharmacology*, *90*, 107232. https://doi.org/10.1016/j.intimp.2020.107232.

Knipping, K., Garssen, J., & van't Land, B. (2012). An evaluation of the inhibitory effects against rotavirus infection of edible plant extracts. *Virology Journal*, *9*(1), 1-8.

Knox, Y., Hayashi, K., Suzutani, T., Ogasawara, M., Yoshida, I., Shiina, R., Tsukui, A., Terahara, N., & Azuma, M. (2001). Activity of anthocyanins from fruit extract of *Ribes nigrum* L. against influenza A and B viruses. *Acta Virologica*, *45*(4), 209-215.

Kodikara, H. N. (2006). *Studies on gelled, pasteurized & sterilized Kolakenda (Ayurvedic Herbal Porridge)* University of Sri Jayewardenepura, Nugegoda.

Kohnen-Johannsen, K. L., & Kayser, O. (2019). Tropane alkaloids: Chemistry, pharmacology,

biosynthesis and production. *Molecules*, *24*(4), 796.

Konno, K., Sawamura, R., Sun, Y., Yasukawa, K., Shimizu, T., Watanabe, W., Kato, M., Yamamoto, R., & Kurokawa, M. (2011). Antiviral activities of diarylheptanoids isolated from *Alpinia officinarum* against respiratory syncytial virus, poliovirus, measles virus, and herpes simplex virus type 1 in vitro. *Natural Product Communications*, *6*(12). https://doi.org/10.1177/1934578X1100601222.

Korpan, Y. I., Nazarenko, E. A., Skryshevskaya, I. V., Martelet, C., Jaffrezic-Renault, N., & Anna, V. (2004). Potato glycoalkaloids: true safety or false sense of security? *Trends in Biotechnology*, *22*(3), 147-151. https://doi.org/10.1016/j.tibtech.2004.01.009.

Kothandan, S., & Swaminathan, R. (2014). Evaluation of *in vitro* antiviral activity of *Vitex negundo* L., *Hyptis suaveolens* (L) poit., *Decalepis hamiltonii* Wight & Arn., to Chikungunya virus. *Asian Pacific Journal of Tropical Disease*, *4*, S111-S115. https://doi.org/10.1016/S2222-1808(14)60424-2.

Kumar, A., Sandeep, D., Tomer, V., Gat, Y., & Kumar, V. (2018). *Ficus religiosa*: A wholesome medicinal tree. *Journal of Pharmacognosy and Phytochemistry*, *7*(4), 32-37.

Kumar, S. V., Kumar, S. P., Rupesh, D., & Nitin, K. (2011). Immunomodulatory effects of some traditional medicinal plants. *J Chem Pharm Res*, *3*(1), 675-684.

Kuo, Y.-C., Lin, Y.-L., Liu, C.-P., & Tsai, W.-J. (2005). Herpes simplex virus type 1 propagation in HeLa cells interrupted by *Nelumbo nucifera*. *Journal of Biomedical Science*, *12*(6), 1021-1034. https://link.springer.com/article/10.1007%2Fs11373-005-9001-6.

Kuruppu, A. (2018). *In vitro* anti-cancer analyses of selected Apocynaceae family species from Sri Lanka. *Journal of Global Oncology*, *4*(Supplement 2). https://doi.org/10.1200/jgo.18.54500.

Kuruppu, A., Paranagama, P., & De Silva, R. (2019). Anticancer potential of natural products: a review focusing on Sri Lankan plants. *Frontiers in Bioscience (Scholar edition)*, *11*, 161-177.

Kuruppu, A., Paranagama, P., & Goonasekara, C. (2019). Medicinal plants commonly used against cancer in traditional medicine formulae in Sri Lanka. *Saudi Pharmaceutical Journal*, *27*(4), 565-573. https://doi.org/10.1016/j.jsps.2019.02.004.

Kusumoto, I. T., Nakabayashi, T., Kida, H., Miyashiro, H., Hattori, M., Namba, T., & Shimotohno, K. (1995). Screening of various plant extracts used in ayurvedic medicine for inhibitory effects on human immunodeficiency virus type 1 (HIV-1) protease. *Phytotherapy Research*, *9*(3), 180-184.

Lackman-Smith, C. S., Snyder, B. A., Marotte, K. M., Osterling, M. C., Mankowski, M. K., Jones, M., Nieves-Duran, L., Richardson-Harman, N., Cummins, J. E., & Sanders-Beer, B. E. (2010). Safety and anti-HIV assessments of natural vaginal cleansing products in an established topical microbicides *in vitro* testing algorithm. *AIDS Research and Therapy*, *7*(1), 22.

Lee, J.-B., Miyake, S., Umetsu, R., Hayashi, K., Chijimatsu, T., & Hayashi, T. (2012). Anti-influenza A virus effects of fructan from Welsh onion (*Allium fistulosum* L.). *Food Chemistry*, *134*(4), 2164-2168. https://doi.org/10.1016/j.foodchem.2012.04.016.

Lee, J.-H., Oh, M., Seok, J. H., Kim, S., Lee, D. B., Bae, G., Bae, H.-I., Bae, S. Y., Hong, Y.-M., & Kwon, S.-O. (2016). Antiviral effects of black raspberry (*Rubus coreanus*) seed and its gallic acid against influenza virus infection. *Viruses*, *8*(6), 157.

Lee, N.-K., Lee, J.-H., Lim, S.-M., Lee, K., Kim, Y., Chang, P.-S., & Paik, H.-D. (2014). Antiviral activity of subcritical water extract of *Brassica juncea* against influenza virus A/H1N1 in nonfat milk. *Journal of Dairy Science*, *97*(9), 5383-5386. https://doi.org/10.3168/jds.2014-8016.

Li, H., Chen, C., Hu, F., Wang, J., Zhao, Q., Gale, R. P., & Liang, Y. (2020). Impact of corticosteroid therapy on outcomes of persons with SARS-CoV-2, SARS-CoV, or MERS-CoV infection: a systematic review and meta-analysis. *Leukemia*, *34*(6), 1503-1511. https://doi.org/10.1038/s41375-020-0848-3.

Li, S.-y., Chen, C., Zhang, H.-q., Guo, H.-y., Wang, H., Wang, L., Zhang, X., Hua, S.-n., Yu, J., & Xiao, P.-g. (2005). Identification of natural compounds with antiviral activities against SARS-associated coronavirus. *Antiviral Research*, *67*(1), 18-23. https://doi.org/10.1016/j.antiviral.2005.02.007.

Li, W., Xu, C., Hao, C., Zhang, Y., Wang, Z., Wang, S., & Wang, W. (2020). Inhibition of herpes simplex virus by myricetin through targeting viral gD protein and cellular EGFR/PI3K/Akt pathway. *Antiviral Research*, 104714.

Lieberman, S., Enig, M. G., & Preuss, H. G. (2006). A review of monolaurin and lauric acid: natural virucidal and bactericidal agents. *Alternative & Complementary Therapies*, *12*(6), 310-314.

Lin, C.-C., Cheng, H.-Y., Yang, C.-M., & Lin, T.-C. (2002). Antioxidant and antiviral activities of

Euphorbia thymifolia L. *Journal of Biomedical Science*, *9*(6), 656-664.

Lin, L.-T., Chen, T.-Y., Lin, S.-C., Chung, C.-Y., Lin, T.-C., Wang, G.-H., Anderson, R., Lin, C.-C., & Richardson, C. D. (2013). Broad-spectrum antiviral activity of chebulagic acid and punicalagin against viruses that use glycosaminoglycans for entry. *BMC Microbiology*, *13*(1), 187.

Lin, L.-T., Hsu, W.-C., & Lin, C.-C. (2014). Antiviral natural products and herbal medicines. *Journal of Traditional and Complementary Medicine*, *4*(1), 24-35.

Lin, S.-C., Ho, C.-T., Chuo, W.-H., Li, S., Wang, T. T., & Lin, C.-C. (2017). Effective inhibition of MERS-CoV infection by resveratrol. *BMC Infectious Diseases*, *17*(1), 1-10. https://doi.org/10.1186/s12879-017-2253-8.

Luo, P., Liu, D., & Li, J. (2020). Pharmacological perspective: glycyrrhizin may be an efficacious therapeutic agent for COVID-19. *International Journal of Antimicrobial Agents*, *55*(6), 105995. https://doi.org/10.1016/j.ijantimicag.2020.105995.

Liu, G., Wang, C., Wang, H., Zhu, L., Zhang, H., Wang, Y., Pei, C., & Liu, L. (2019). Antiviral efficiency of a coumarin derivative on spring viremia of carp virus *in vivo*. *Virus Research*, *268*, 11-17. https://doi.org/https://doi.org/10.1016/j.virusres.2019.05.007.

Lv, J.-J., Yu, S., Xin, Y., Cheng, R.-R., Zhu, H.-T., Wang, D., Yang, C.-R., Xu, M., & Zhang, Y.-J. (2015). Anti-viral and cytotoxic norbisabolane sesquiterpenoid glycosides from *Phyllanthus emblica* and their absolute configurations. *Phytochemistry*, *117*, 123-134. https://doi.org/10.1016/j.phytochem.2015.06.001.

Ma, S.-C., Du, J., But, P. P.-H., Deng, X.-L., Zhang, Y.-W., Ooi, V. E.-C., Xu, H.-X., Lee, S. H.-S., & Lee, S. F. (2002). Antiviral Chinese medicinal herbs against respiratory syncytial virus. *Journal of Ethnopharmacology*, *79*(2), 205-211. https://doi.org/10.1016/S0378-8741(01)00389-0.

Mair, C., Liu, R., Atanasov, A., Schmidtke, M., Dirsch, V., & Rollinger, J. (2016). Antiviral and anti-proliferative *in vitro* activities of piperamides from black pepper. *Planta Medica*, *82*(S 01), P807.

Majdalawieh, A. F., & Carr, R. I. (2010). In vitro investigation of the potential immunomodulatory and anti-cancer activities of black pepper (*Piper nigrum*) and cardamom (*Elettaria cardamomum*). *Journal of Medicinal Food*, *13*(2), 371-381. https://doi.org/10.1089/jmf.2009.1131.

Makau, J. N., Watanabe, K., Mohammed, M. M., & Nishida, N. (2018). Antiviral activity of peanut (*Arachis hypogaea* L.) skin extract against human influenza viruses. *Journal of Medicinal Food*, *21*(8), 777-784. https://doi.org/10.1089/jmf.2017.4121

Malakar, S., Sreelatha, L., Dechtawewat, T., Noisakran, S., Yenchitsomanus, P.-t., Chu, J. J. H., & Limjindaporn, T. (2018). Drug repurposing of quinine as antiviral against dengue virus infection. *Virus Research*, *255*, 171-178. https://doi.org/10.1016/j.virusres.2018.07.018 .

Mao, Q.-Q., Xu, X.-Y., Cao, S.-Y., Gan, R.-Y., Corke, H., & Li, H.-B. (2019). Bioactive compounds and bioactivities of ginger (*Zingiber officinale* Roscoe). *Foods*, *8*(6), 185.

Maor, Y., Yu, J., Kuzontkoski, P. M., Dezube, B. J., Zhang, X., & Groopman, J. E. (2012). Cannabidiol inhibits growth and induces programmed cell death in kaposi sarcoma–associated herpesvirus-infected endothelium. *Genes & Cancer*, *3*(7-8), 512-520.

Martinez, M. A. (2020). Clinical Trials of Repurposed Antivirals for SARS-CoV-2. *Antimicrobial Agents and Chemotherapy*, *64*(9), e01101-01120. https://doi.org/10.1128/aac.01101-20.

McKenzie, M. J., Hunter, D. A., Pathirana, R., Watson, L. M., Joyce, N. I., Matich, A. J., Rowan, D. D., & Brummell, D. A. (2008). Accumulation of an organic anticancer selenium compound in a transgenic Solanaceous species shows wider applicability of the selenocysteine methyltransferase transgene from selenium hyperaccumulators. *Transgenic Research*, *18*(3), 407. https://doi.org/10.1007/s11248-008-9233-0.

Mehla, R., Bivalkar-Mehla, S., & Chauhan, A. (2011). A flavonoid, luteolin, cripples HIV-1 by abrogation of tat function. *Plos One*, *6*(11), e27915.

Meira, M., Silva, E. P. d., David, J. M., & David, J. P. (2012). Review of the genus *Ipomoea*: traditional uses, chemistry and biological activities. *Revista Brasileira de Farmacognosia*, *22*(3), 682-713.

Mhatre, S., Srivastava, T., Naik, S., & Patravale, V. (2020). Antiviral activity of green tea and black tea polyphenols in prophylaxis and treatment of COVID-19: A review. *Phytomedicine*, 153286. https://doi.org/10.1016/j.phymed.2020.153286.

Mishra, S., Pandey, A., & Manvati, S. (2020). Coumarin: An emerging antiviral agent. *Heliyon*, *6*(1), e03217. https://doi.org/10.1016/j.heliyon.2020.e03217

Mitchell, C. A., Ramessar, K., & O'Keefe, B. R. (2017). Antiviral lectins: Selective inhibitors of viral entry. *Antiviral Research*, *142*, 37-54. https://doi.org/10.1016/j.antiviral.2017.03.007.

Mitrocotsa, D., Mitaku, S., Axarlis, S., Harvala, C., & Malamas, M. (2000). Evaluation of the antiviral activity of kaempferol and its glycosides against human cytomegalovirus. *Planta Med*, *66*(4), 377-379. https://doi.org/10.1055/s-2000-8550.

Molina, P. E., Amedee, A., LeCapitaine, N. J., Zabaleta, J., Mohan, M., Winsauer, P., & Stouwe, C. V. (2011). Cannabinoid neuroimmune modulation of SIV disease. *Journal of Neuroimmune Pharmacology*, *6*(4), 516. https://doi.org/10.1007/s11481-011-9301-8.

Moore, J. P., & Stevenson, M. (2000). New targets for inhibitors of HIV-1 replication. *Nature Reviews Molecular Cell Biology*, *1*(1), 40-49. https://www.nature.com/articles/35036060.

Mounce, B. C., Cesaro, T., Carrau, L., Vallet, T., & Vignuzzi, M. (2017). Curcumin inhibits Zika and chikungunya virus infection by inhibiting cell binding. *Antiviral Research*, *142*, 148-157.

Mousa, H. A.-L. (2017). Prevention and treatment of influenza, influenza-like illness, and common cold by herbal, complementary, and natural therapies. *Journal of Evidence-based Complementary & Alternative Medicine*, *22*(1), 166-174.

Mpiana, P. T., Tshibangu, D. S., Kilembe, J. T., Gbolo, B. Z., Mwanangombo, D. T., Inkoto, C. L., Lengbiye, E. M., Mbadiko, C. M., Matondo, A., & Bongo, G. N. (2020). *Aloe vera* (L.) Burm. F. as a potential anti-COVID-19 plant: a mini-review of Its antiviral activity. *European Journal of Medicinal Plants*, *31*(8), 86-93. https://doi.org/10.9734/ejmp/2020/v31i830261.

Mukhtar, M., Arshad, M., Ahmad, M., Pomerantz, R. J., Wigdahl, B., & Parveen, Z. (2008). Antiviral potentials of medicinal plants. *Virus Research*, *131*(2), 111-120.

Murck, H. (2020). Symptomatic protective action of glycyrrhizin (licorice) in COVID-19 infection? *Front Immunol*, *11*, 1239. https://doi.org/10.3389/fimmu.2020.01239.

Murayama, M., Tsujimoto, K., Uozaki, M., Katsuyama, Y., Yamasaki, H., Utsunomiya, H., & Koyama, A. H. (2008). Effect of caffeine on the multiplication of DNA and RNA viruses. *Molecular Medicine Reports*, *1*(2), 251-255.

Murugan, K., Prabu, R. V., Sangeetha, S., & Al-Sohaibani, S. (2011). Antiviral activity of *Cardiospermum halicacabum* L. extract against coinfecting agents HIV and HBV. *Journal of Herbs, Spices & Medicinal Plants*, *17*(4), 403-418.

Napagoda, M. T., Sundarapperuma, T., Fonseka, D., Amarasiri, S., & Gunaratna, P. (2019). Traditional uses of medicinal plants in Polonnaruwa district in North Central Province of Sri Lanka. *Scientifica*, *2019*, 9737302. https://doi.org/10.1155/2019/9737302.

Nascimento Junior, J. A. C., Santos, A. M., Quintans-Júnior, L. J., Walker, C. I. B., Borges, L. P., & Serafini, M. R. (2020). SARS, MERS and SARS-CoV-2 (COVID-19) treatment: a patent review. *Expert Opinion on Therapeutic Patents*, *30*(8), 567-579. https://doi.org/10.1080/13543776.2020.1772231.

Nasr, A., Abdelsalam, M., & Azzam, A. (2013). Effect of tanning method and region on physical and chemical properties of barki sheep leather. *Egyptian Journal of Sheep and Goat Sciences*, *65*(1242), 1-16.

Ngoc, T. M., Phuong, N. T. T., Khoi, N. M., Park, S., Kwak, H. J., Nhiem, N. X., Trang, B. T. T., Tai, B. H., Song, J.-H., & Ko, H.-J. (2019). A new naphthoquinone analogue and antiviral constituents from the root of *Rhinacanthus nasutus*. *Natural product research*, *33*(3), 360-366. https://doi.org/10.1080/14786419.2018.1452004.

Nick, G. L. (2006). Coconuts as a functional food in the prevention and treatment of AIDS. *Townsend Letter: The Examiner of Alternative Medicine*(275), 52-55.

Notka, F., Meier, G., & Wagner, R. (2004). Concerted inhibitory activities of *Phyllanthus amarus* on HIV replication *in vitro* and *ex vivo*. *Antiviral Research*, *64*(2), 93-102. https://doi.org/10.1016/j.antiviral.2004.06.010.

Nowack, R., & Schmitt, W. (2008). Cranberry juice for prophylaxis of urinary tract infections–Conclusions from clinical experience and research. *Phytomedicine*, *15*(9), 653-667. https://doi.org/10.1016/j.phymed.2008.07.009.

Nurzynska-Wierdak, R. (2013). Essential oil composition of the coriander (*Coriandrum sativum* L.) herb depending on the development stage. *Acta Agrobotanica*, *66*(1):53-60.

Oláh, A., Szekanecz, Z., & Bíró, T. (2017). Targeting cannabinoid signaling in the immune system:"High"-ly exciting questions, possibilities, and challenges. *Frontiers in Immunology*, *8*, 1487. https://doi.org/10.3389/fimmu.2017.01487.

Oliveira, L. d. L. d., Carvalho, M. V. d., & Melo, L. (2014). Health promoting and sensory properties of phenolic compounds in food. *Revista Ceres*, *61*, 764-779. https://doi.org/10.1590/0034-737x201461000002.

Ooi, L. S., Sun, S. S., & Ooi, V. E. (2004). Purification and characterization of a new antiviral protein from the leaves of *Pandanus amaryllifolius* (Pandanaceae). *The International Journal of Biochemistry & Cell Biology*, *36*(8), 1440-1446.

Orozco-Topete, R., Sierra-Madero, J., Cano-Dominguez, C., Kershenovich, J., Ortiz-Pedroza, G., Vazquez-Valls, E., Garcia-Cosio, C., Soria-Cordoba, A., Armendariz, A. M., Teran-Toledo, X., Romo-Garcia, J., Fernandez, H., & Rozhon, E. J. (1997). Safety and efficacy of Virend for topical treatment of genital and anal herpes simplex lesions in patients with AIDS. *Antiviral Res*, *35*(2), 91-103. https://doi.org/10.1016/s0166-3542(97)00015-6.

Ortega, J. T., Suárez, A. I., Serrano, M. L., Baptista, J., Pujol, F. H., & Rangel, H. R. (2017). The role of the glycosyl moiety of myricetin derivatives in anti-HIV-1 activity *in vitro*. *AIDS research and therapy*, *14*(1), 57. https://doi.org/10.1186/s12981-017-0183-6.

Pa, S., Mangalaa, S. D., Sophiea, A., & Lathab, C. P. (2012). Antiviral and antioxidant activities of two medicinal plants. *Int J Curr Sci*, 256-261.

Pagare, S., Bhatia, M., Tripathi, N., Pagare, S., & Bansal, Y. (2015). Secondary metabolites of plants and their role: Overview. *Current Trends in Biotechnology and Pharmacy*, *9*(3), 293-304.

Panigrahi, B., & Vyas, M. (2015). *Semecarpus ancardium* Linn.: A potent herbal immunomodulator. *International Journal of Pharma and Bio Sciences*, *6*(4),155-167.

Panvilai, S., Napaswad, C., Limthongkul, J., & Akkarawongsapat, R. (2021). Aqueous extracts of Thai medicinal plants possess anti-HIV-1 activity. *Journal of Herbs, Spices & Medicinal Plants*, *27*(1):1-10. https://doi.org/10.1080/10496475.2020.1753276.

Paranagama, P., Wimalasena, S., Jayatilake, G., Jayawardena, A., Senanayake, U., & Mubarak, A. (2001). A comparison of essential oil constituents of bark, leaf, root and fruit of cinnamon (*Cinnamomum zeylanicum* Blum) grown in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka*, *29*(3-4), 147-153.

Parida, M., Upadhyay, C., Pandya, G., & Jana, A. (2002). Inhibitory potential of neem (*Azadirachta indica* Juss) leaves on dengue virus type-2 replication. *Journal of Ethnopharmacology*, *79*(2), 273-278. https://doi.org/10.1016/S0378-8741(01)00395-6.

Pathirana, R., & Senaratne, R. (2020). An introduction to Sri Lanka and its cinnamon industry In R. Senaratne & R. Pathirana (Eds.), *Cinnamon: Botany, Agronomy, Chemistry and Industrial Applications* (pp. 1-38). Springer Nature. https://doi.org/https://doi.org/10.1007/978-3-030-54426-3_1.

Polansky, H., & Lori, G. (2020). Effects of Gene-Eden-VIR and Novirin on SARS-CoV: Implications for COVID-19. *Journal of Evidence-based Integrative Medicine*, *25*, 1-4. https://doi.org/10.1177/2515690X20932523.

Pongtuluran, O. B., & Rofaani, E. (2015). Antiviral and immunostimulant activities of *Andrographis paniculata*. *HAYATI Journal of Biosciences*, *22*(2), 67-72.

Pour, P. M., Fakhri, S., Asgary, S., Farzaei, M. H., & Echeverria, J. (2019). The signaling pathways, and therapeutic targets of antiviral agents: focusing on the antiviral approaches and clinical perspectives of anthocyanins in the management of viral diseases. *Frontiers in Pharmacology*, *10*. https://doi.org/10.3389/fphar.2019.01207.

Prachayasittikul, S., Suphapong, S., Worachartcheewan, A., Lawung, R., Ruchirawat, S., & Prachayasittikul, V. (2009). Bioactive metabolites from *Spilanthes acmella* Murr. *Molecules*, *14*(2), 850-867. https://doi.org/10.3390/molecules14020850.

Praditya, D., Kirchhoff, L., Brüning, J., Rachmawati, H., Steinmann, J., & Steinmann, E. (2019). Anti-infective properties of the golden spice curcumin. *Frontiers in Microbiology*, *10*, 912. https://doi.org/10.3389/fmicb.2019.00912.

Pramod, K., Ansari, S. H., & Ali, J. (2010). Eugenol: a natural compound with versatile pharmacological actions. *Natural Product Communications*, *5*(12), 1999 - 2006. https://doi.org/10.1177/1934578X1000501236.

Prasad, A., Muthamilarasan, M., & Prasad, M. (2020). Synergistic antiviral effects against SARS-CoV-2 by plant-based molecules. *Plant Cell Reports*, *39*(9), 1109-1114. https://doi.org/10.1007/s00299-020-02560-w.

Priya, N., & Kumari, P. (2017). Antiviral activities and cytotoxicity assay of seed extracts of *Piper longum* and *Piper nigrum* on human cell lines. *Int J Pharma Sci Rev Res*, *44*, 197-202.

Radha, M. H., & Laxmipriya, N. P. (2015). Evaluation of biological properties and clinical effectiveness of *Aloe vera*: A systematic review. *Journal of Traditional and Complementary Medicine*, *5*(1), 21-26.

Rajeswari, G., Priyanka, B., Amrutha, R., Rajaram, C., Kanhere, R. S., & Kumar, S. N. (2013). *Hibiscus tiliaceus*: a possible immunomodulatory agent. *Journal of Pharmacy Research*, *6*(7), 742-747.

Rao, S. V., Tulasi, D., Pavithra, K., Nisha, R., & Taj, R. (2018). In silico studies on dengue and MERS

coronavirus proteins with selected *Coriandrum sativum* L. herb constituents. *World Journal of Pharmacy and Pharmaceutical Science*, *7*(12), 970-989.

Rathinavel, T., Palanisamy, M., Palanisamy, S., Subramanian, A., & hangaswamy, S. (2020). Phytochemical 6-Gingerol-A promising drug of choice for COVID-19. *International Journal of Advanced Science and Engineering*, *6*, 1482-1489.

Reichling, J., Schnitzler, P., Suschke, U., & Saller, R. (2009). Essential oils of aromatic plants with antibacterial, antifungal, antiviral, and cytotoxic properties–an overview. *Complementary Medicine Research*, *16*(2), 79-90.

Reiss, C. S. (2010). Cannabinoids and viral infections. *Pharmaceuticals*, *3*(6), 1873-1886.

Rout, J., Swain, B. C., & Tripathy, U. (2020). In silico investigation of spice molecules as potent inhibitor of SARS-CoV-2. *Journal of Biomolecular Structure and Dynamics*, 1-15.

Roy, S., Chaurvedi, P., & Chowdhary, A. (2015). Evaluation of antiviral activity of essential oil of *Trachyspermum ammi* against Japanese encephalitis virus. *Pharmacognosy Research*, *7*(3), :263-267.

Roy, S., Mukherjee, S., Pawar, S., & Chowdhary, A. (2016). Evaluation of in vitro antiviral activity of *Datura metel* Linn. against Rabies virus. *Pharmacognosy Research*, *8*(4), 265-269. https://doi.org/10.4103/0974-8490.188874.

Roy, S., Samant, L., Ganjhu, R., Mukherjee, S., & Chowdhary, A. (2018). Assessment of *in vivo* antiviral potential of *Datura metel* Linn. extracts against Rabies virus. *Pharmacognosy Research*, *10*(1), 109-112. https://doi.org/10.4103/pr.pr_121_17.

Sa-ngiamsuntorn, K., Suksatu, A., Pewkliang, Y., Thongsri, P., Kanjanasirirat, P., Manopwisedjaroen, S., Charoensutthivarakul, S., Wongtrakoongate, P., Pitiporn, S., Chaopreecha, J., Kongsomros, S., Jearawuttanakul, K., Wannalo, W., Khemawoot, P., Chutipongtanate, S., Borwornpinyo, S., Thitithanyanont, A., & Hongeng, S. (2021). Anti-SARS-CoV-2 Activity of *Andrographis paniculata* extract and its major component Andrographolide in human lung epithelial cells and cytotoxicity evaluation in major organ cell representatives. *Journal of Natural Products*. (In press). https://doi.org/10.1021/acs.jnatprod.0c01324.

Sa-nguanmoo, P., & Poovorawan, Y. (2007). *Myristica fragrans* Houtt. methanolic extract induces apoptosis in a human leukemia cell line through SIRT1 mRNA downregulation. *J Med Assoc Thai*, *90*(11), 2422-2428.

Sachan, S., Dhama, K., Latheef, S. K., Samad, H. A., Mariappan, A. K., Munuswamy, P., Singh, R., Singh, K. P., Malik, Y. S., & Singh, R. K. (2019). Immunomodulatory potential of *Tinospora cordifolia* and CpG ODN (TLR21 Agonist) against the very virulent, infectious bursal disease virus in SPF chicks. *Vaccines*, *7*(3), 106. https://doi.org/10.3390/vaccines7030106.

Saklani, A., & Kutty, S. K. (2008). Plant-derived compounds in clinical trials. *Drug Discovery Today*, *13*(3), 161-171. https://doi.org/https://doi.org/10.1016/j.drudis.2007.10.010.

San Chang, J., Wang, K. C., Yeh, C. F., Shieh, D. E., & Chiang, L. C. (2013). Fresh ginger (*Zingiber officinale*) has anti-viral activity against human respiratory syncytial virus in human respiratory tract cell lines. *Journal of Ethnopharmacology*, *145*(1), 146-151.

Sanna, G., Madeddu, S., Serra, A., Collu, D., Efferth, T., Hakkim, F. L., & Rashan, L. (2019). Anti-poliovirus activity of *Nerium oleander* aqueous extract. *Natural Product Research*, 1-4. https://doi.org/10.1080/14786419.2019.1582046.

Sarkar, L., Putchala, R. K., Safiriyu, A. A., & Das Sarma, J. (2020). *Azadirachta indica* A. Juss ameliorates Mouse Hepatitis virus-induced neuroinflammatory demyelination by modulating cell-to-cell fusion in an experimental animal model of Multiple Sclerosis. *Frontiers in Cellular Neuroscience*, *14*, 116. https://doi.org/10.3389/fncel.2020.00116.

Sawamura, R., Sun, Y., Yasukawa, K., Shimizu, T., Watanabe, W., & Kurokawa, M. (2010). Antiviral activities of diarylheptanoids against influenza virus *in vitro*. *Journal of Natural Medicines*, *64*(1), 117-120.

Sawikowska, A. (2020). Meta-analysis of flavonoids with antiviral potential against coronavirus. *Biometrical Letters*, *57*(1), 13-22. https://doi.org/10.2478/bile-2020-0002.

Schwarz, S., Sauter, D., Wang, K., Zhang, R., Sun, B., Karioti, A., Bilia, A. R., Efferth, T., & Schwarz, W. (2014). Kaempferol derivatives as antiviral drugs against the 3a channel protein of coronavirus. *Planta Medica*, *80*(2-3), 177-182. https://doi.org/10.1055/s-0033-1360277.

Selvam, P., Murugesh, N., Witvrouw, M., Keyaerts, E., & Neyts, J. (2009). Studies of antiviral activity and cytotoxicity of *Wrightia tinctoria* and *Morinda citrifolia*. *Indian Journal of Pharmaceutical Sciences*, *71*(6), 670.

Selvarani, V. (2009). Multiple inflammatory and antiviral activities in *Adansonia digitata*

(Baobab) leaves, fruits and seeds. *Journal of Medicinal Plants Research*, *3*(8), 576-582.

Senthil Kumar, K., Gokila Vani, M., Wang, C.-S., Chen, C.-C., Chen, Y.-C., Lu, L.-P., Huang, C.-H., Lai, C.-S., & Wang, S.-Y. (2020). Geranium and lemon essential oils and their active compounds downregulate angiotensin-converting enzyme 2 (ACE2), a SARS-CoV-2 spike receptor-binding domain, in epithelial cells. *Plants*, *9*(6), 770.

Shao, Y., Xu, F., Sun, X., Bao, J., & Beta, T. (2014). Phenolic acids, anthocyanins, and antioxidant capacity in rice (*Oryza sativa* L.) grains at four stages of development after flowering. *Food Chemistry*, *143*, 90-96.

Sharma, N. (2019). Efficacy of Garlic and Onion against virus. *International Journal of Research in Pharmaceutical Sciences*, *10*(4), 3578-3586.

Shen, C., Wang, Z., Zhao, F., Yang, Y., Li, J., Yuan, J., Wang, F., Li, D., Yang, M., & Xing, L. (2020). Treatment of 5 critically ill patients with COVID-19 with convalescent plasma. *Jama*, *323*(16), 1582-1589. https://doi.org/10.1001/jama.2020.4783.

Shojai, T. M., Langeroudi, A. G., Karimi, V., Barin, A., & Sadri, N. (2016). The effect of *Allium sativum* (Garlic) extract on infectious bronchitis virus in specific pathogen free embryonic egg. *Avicenna Journal of Phytomedicine*, *6*(4), 458.

Shubhashree, M., Naik, R., & Doddamani, S. (2020). Preventive strategies to combat infections–a review of traditional practices and Ayurveda concepts. *Int J Complement Alt Med*, *13*(3), 125-129.

Shubhra, R. D., Polash, S. A., Saha, T., Hasan, A., Hossain, S., Islam, Z., & Sarker, S. R. (2019). Investigation of the phytoconstituents and antioxidant activity of *Diospyros malabarica* fruit extracts. *Advances in Bioscience and Biotechnology*, *10*(12), 431-454.

Sohail, M. N., Rasul, F., Karim, A., Kanwal, U., & Attitalla, I. H. (2011). Plant as a source of natural antiviral agents. *Asian Journal of Animal and Veterinary Advances*, *6*(12), 1125-1152.

Soltan, M. M., & Zaki, A. K. (2009). Antiviral screening of forty-two Egyptian medicinal plants. *Journal of Ethnopharmacology*, *126*(1), 102-107. https://doi.org/10.1016/j.jep.2009.08.001.

Somanada, O. (2020). Relationships between Sri Lankan culture, diets and COVID-19 disease control. *Eubios Journal of Asian and International Bioethics, 30*(4):143-147.

Sompong, R., Siebenhandl-Ehn, S., Linsberger-Martin, G., & Berghofer, E. (2011). Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. *Food Chemistry*, *124*(1), 132-140.

Soni, H., Sharma, S., & Malik, J. K. (2020). Synergistic Prophylaxis on COVID-19 by Nature Golden Heart (*Piper betle*) & Swarna Bhasma. *Asian Journal of Research in Dermatological Science*, *3*(2), 21-27.

Sriwanthana, B., & Chavalittumrong, P. (2001). *In vitro* effect of *Derris scandens* on normal lymphocyte proliferation and its activities on natural killer cells in normals and HIV-1 infected patients. *Journal of Ethnopharmacology*, *76*(1), 125-129. https://doi.org/10.1016/S0378-8741(01)00223-9.

Steinbrenner, H., Al-Quraishy, S., Dkhil, M. A., Wunderlich, F., & Sies, H. (2015). Dietary selenium in adjuvant therapy of viral and bacterial infections. *Advances in Nutrition*, *6*(1), 73-82. https://doi.org/10.3945/an.114.007575.

Suchitra, M., & Parthasarathy, S. (2020). Nutrition and corona virus: Plan a diet in a pandemic. *International Journal of Research in Pharmaceutical Sciences*, *11*(SPL1), 110-114.

Suedee, A., Tewtrakul, S., & Panichayupakaranant, P. (2013). Anti-HIV-1 integrase compound from *Pometia pinnata* leaves. *Pharmaceutical Biology*, *51*(10), 1256-1261. https://doi.org/10.3109/13880209.2013.786098.

Sun, P., Lu, X., Xu, C., Sun, W., & Pan, B. (2020). Understanding of COVID-19 based on current evidence. *Journal of Medical Virology*, *92*(6), 548-551.

Sun, Y., Kurokawa, M., Miura, M., Kakegawa, T., Motohashi, S., & Yasukawa, K. (2016). Bioactivity and synthesis of diarylheptanoids from *Alpinia officinarum*. *Studies in Natural Products Chemistry*, *49*, 157-187. https://doi.org/10.1016/B978-0-444-63601-0.00004-1.

Sun, Z., Yu, C., Wang, W., Yu, G., Zhang, T., Zhang, L., Zhang, J., & Wei, K. (2018). Aloe polysaccharides inhibit influenza A virus infection—A promising natural anti-flu drug. *Frontiers in Microbiology*, *9*, 2338. https://doi.org/i10.3389/fmicb.2018.02338.

Taj, R., Rao, S. V., Tulasi, D., Nisha, R., & Pavithra, K. (2018). In silico studies on Dengue and Marburg viral proteins with selected *Murraya Koenigii* leaves constituents. *World Journal of Pharmacy and Pharmaceutical Sciences*, *7*(12), 820-841.

Tan, W. C., Jaganath, I. B., Manikam, R., & Sekaran, S. D. (2013). Evaluation of antiviral activities of four local Malaysian *Phyllanthus* species against herpes simplex viruses and possible antiviral target. *International Journal of Medical Sciences*,

10(13), 1817-1829. https://doi.org/10.7150/ijms.6902.

Tanaka, T., Ikeda, T., Kaku, M., Zhu, X.-H., Okawa, M., Yokomizo, K., Uyeda, M., & Nohara, T. (2004). A new lignan glycoside and phenylethanoid glycosides from *Strobilanthes cusia* B REMEK. *Chemical and Pharmaceutical Bulletin*, *52*(10), 1242-1245.

Tang, K., Zhang, X., & Guo, Y. (2020). Identification of the dietary supplement capsaicin as an inhibitor of Lassa virus entry. *Acta Pharmaceutica Sinica B*, *10*(5), 789-798. https://doi.org/10.1016/j.apsb.2020.02.014.

Thormar, H., Hilmarsson, H., & Bergsson, G. (2013). Antimicrobial lipids: role in innate immunity and potential use in prevention and treatment of infections. In A. Méndez-Vilas (Ed.), *Microbial Pathogens and Strategies for Combating Them: Science, Technology and Education, 3*: 1474-1488. Formatex.

Thormar, H., Isaacs, C. E., Brown, H. R., Barshatzky, M. R., & Pessolano, T. (1987). Inactivation of enveloped viruses and killing of cells by fatty acids and monoglycerides. *Antimicrobial Agents and Chemotherapy*, *31*(1), 27-31.

Thuy, B. T. P., My, T. T. A., Hai, N. T. T., Hieu, L. T., Hoa, T. T., Thi Phuong Loan, H., Triet, N. T., Anh, T. T. V., Quy, P. T., & Tat, P. V. (2020). Investigation into SARS-CoV-2 resistance of compounds in garlic essential oil. *ACS Omega*, *5*, 8312-8320. https://doi.org/10.1021/acsomega.0c00772.

Tiwari, V., Darmani, N. A., Yue, B. Y., & Shukla, D. (2010). In vitro antiviral activity of neem (*Azardirachta indica* L.) bark extract against herpes simplex virus type-1 infection. *Phytotherapy Research*, *24*(8), 1132-1140.

Tu, Y.-F., Chien, C.-S., Yarmishyn, A. A., Lin, Y.-Y., Luo, Y.-H., Lin, Y.-T., Lai, W.-Y., Yang, D.-M., Chou, S.-J., Yang, Y.-P., Wang, M.-L., & Chiou, S.-H. (2020). A review of SARS-CoV-2 and the ongoing clinical trials. *International Journal of Molecular Sciences*, *21*(7), 2657. https://www.mdpi.com/1422-0067/21/7/2657.

Tushar, K., George, S., Remashree, A., & Balachandran, I. (2008). *Coscinium fenestratum* (Gaertn.) Colebr.-A review on this rare, critically endangered and highly-traded medicinal species. *Journal of Plant Sciences*, *3*(2), 133-145.

Ürményi, F. G. G., Saraiva, G. d. N., Casanova, L. M., Matos, A. d. S., de Magalhães Camargo, L. M., Romanos, M. T. V., & Costa, S. S. (2016). Anti-HSV-1 and HSV-2 flavonoids and a new kaempferol triglycoside from the medicinal plant *Kalanchoe daigremontiana*. *Chemistry & Biodiversity*, *13*(12), 1707-1714. https://doi.org/10.1002/cbdv.201600127.

Utsunomiya, H., Ichinose, M., Uozaki, M., Tsujimoto, K., Yamasaki, H., & Koyama, A. H. (2008). Antiviral activities of coffee extracts *in vitro*. *Food and Chemical Toxicology*, *46*(6), 1919-1924. https://doi.org/10.1016/j.fct.2008.01.031.

Vellingiri, B., Jayaramayya, K., Iyer, M., Narayanasamy, A., Govindasamy, V., Giridharan, B., Ganesan, S., Venugopal, A., Venkatesan, D., & Ganesan, H. (2020). COVID-19: A promising cure for the global panic. *Science of The Total Environment*, 138277. https://doi.org/10.1016/j.scitotenv.2020.138277.

Vlietinck, A., De Bruyne, T., Apers, S., & Pieters, L. (1998). Plant-derived leading compounds for chemotherapy of human immunodeficiency virus (HIV) infection. *Planta Medica*, *64*(02), 97-109.

Wang, C., Liu, J., Huang, Y., & Zhang, X. (2016). *In vitro* polysaccharide extraction from *Cipangopaludina cathayensis* and its pharmacological potential. *Journal of Environmental Biology*, *37*(5), 1069.

Wang, G.-F., Shi, L.-P., Ren, Y.-D., Liu, Q.-F., Liu, H.-F., Zhang, R.-J., Li, Z., Zhu, F.-H., He, P.-L., & Tang, W. (2009). Anti-hepatitis B virus activity of chlorogenic acid, quinic acid and caffeic acid *in vivo* and *in vitro*. *Antiviral Research*, *83*(2), 186-190. https://doi.org/10.1016/j.antiviral.2009.05.002.

Wang, N., Yang, J., Lu, J., Qiao, Q., Wu, T., Du, X., Bao, G., & He, X. (2014). A polysaccharide from *Salvia miltiorrhiza* Bunge improves immune function in gastric cancer rats. *Carbohydrate Polymers*, *111*, 47-55. https://doi.org/10.1016/j.carbpol.2014.04.061.

Wang, Y. Z., Cui, X., Gao, Y., Guo, S. S., Wang, X., Huang, Y., Zhao, Y., & Gong, W. (2006). Antivirus effects of extract from gardenia. *China Journal of Chinese Materia Medica*, *31*(14), 1176-1178.

Wang, Z., Chen, X., Lu, Y., Chen, F., & Zhang, W. (2020). Clinical characteristics and therapeutic procedure for four cases with 2019 novel coronavirus pneumonia receiving combined Chinese and Western medicine treatment. *Bioscience Trends*, *14*(1), 64-68. https://doi.org/10.5582/bst.2020.01030.

Wei, J., Lin, L., Su, X., Qin, S., Xu, Q., Tang, Z., Deng, Y., Zhou, Y., & He, S. (2013). Anti-hepatitis B virus activity of *Boehmeria nivea* leaf extracts in human HepG2. 2.15 cells. *Biomedical reports*, *2*(1), 147-151. https://doi.org/10.3892/br.2013.205.

Wen, C.-C., Kuo, Y.-H., Jan, J.-T., Liang, P.-H., Wang, S.-Y., Liu, H.-G., Lee, C.-K., Chang, S.-T., Kuo, C.-J., Lee, S.-S., Hou, C.-C., Hsiao, P.-W., Chien, S.-C., Shyur, L.-F., & Yang, N.-S. (2007). Specific plant terpenoids and lignoids possess potent antiviral activities against Severe Acute Respiratory Syndrome Coronavirus. *Journal of Medicinal Chemistry*, *50*(17), 4087-4095. https://doi.org/10.1021/jm070295s.

WHO. (2021a). *Technical Guidance Publications*. World Health Organization. Retrieved 14 January 2021 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance-publications?publicationtypes=d198f134-5eed-400d-922e-1ac06462e676.

WHO. (2021b, 2 April 2021). *WHO Coronavirus Disease (COVID-19) Dashboard, World Health Organization*. Retrieved 20 April 2021 from https://covid19.who.int/.

Wijayasinghe, Y. S., Bhansali, P., Viola, R. E., Kamal, M. A., & Poddar, N. K. (2020). Natural products: A rich source of antiviral drug lead candidates for the management of COVID-19. *Current Pharmaceutical Design*, 26*:1-25*. http://dx.doi.org/10.2174/1381612826666201118111151.

Williamson, B. N., Feldmann, F., Schwarz, B., Meade-White, K., Porter, D. P., Schulz, J., van Doremalen, N., Leighton, I., Yinda, C. K., Pérez-Pérez, L., Okumura, A., Lovaglio, J., Hanley, P. W., Saturday, G., Bosio, C. M., Anzick, S., Barbian, K., Cihlar, T., Martens, C., Scott, D. P., Munster, V. J., & de Wit, E. (2020). Clinical benefit of remdesivir in rhesus macaques infected with SARS-CoV-2. *Nature*, *585*(7824), 273-276. https://doi.org/10.1038/s41586-020-2423-5.

Wolffers, I. (1988). Illness behaviour in Sri Lanka: results of a survey in two Sinhalese communities. *Social Science & Medicine*, *27*(5), 545-552.

Woradulayapinij, W., Soonthornchareonnon, N., & Wiwat, C. (2005). *In vitro* HIV type 1 reverse transcriptase inhibitory activities of Thai medicinal plants and *Canna indica* L. rhizomes. *Journal of Ethnopharmacology*, *101*(1-3), 84-89. https://doi.org/10.1016/j.jep.2005.03.030.

Wu, C., Liu, Y., Yang, Y., Zhang, P., Zhong, W., Wang, Y., Wang, Q., Xu, Y., Li, M., & Li, X. (2020). Analysis of therapeutic targets for SARS-CoV-2 and discovery of potential drugs by computational methods. *Acta Pharmaceutica Sinica B*, *10*, 766-788. https://doi.org/10.1016/j.apsb.2020.02.008.

Wu, S., Patel, K. B., Booth, L. J., Metcalf, J. P., Lin, H.-K., & Wu, W. (2010). Protective essential oil attenuates influenza virus infection: an *in vitro* study in MDCK cells. *BMC Complementary and Alternative Medicine*, *10*(1), 1-13.

Wu, Y.-H., Tseng, C.-K., Wu, H.-C., Wei, C.-K., Lin, C.-K., Chen, I.-S., Chang, H.-S., & Lee, J.-C. (2019). Avocado (*Persea americana*) fruit extract (2 R, 4 R)-1, 2, 4-trihydroxyheptadec-16-yne inhibits dengue virus replication via upregulation of NF-κB–dependent induction of antiviral interferon responses. *Scientific Reports*, *9*(1), 1-10.

Xu, J., Xu, Z., & Zheng, W. (2017). A review of the antiviral role of green tea catechins. *Molecules*, *22*(8), 1337.

Yamazaki, Z., & Tagaya, I. (1980). Antiviral effects of atropine and caffeine. *Journal of General Virology*, *50*(2), 429-431. https://doi.org/10.1099/0022-1317-50-2-429.

Yang, C.-M., Cheng, H.-Y., Lin, T.-C., Chiang, L.-C., & Lin, C.-C. (2005). Acetone, ethanol and methanol extracts of *Phyllanthus urinaria* inhibit HSV-2 infection *in vitro*. *Antiviral Research*, *67*(1), 24-30. https://doi.org/10.1016/j.antiviral.2005.02.008.

Yang, Y., Islam, M. S., Wang, J., Li, Y., & Chen, X. (2020). Traditional Chinese medicine in the treatment of patients infected with 2019-new coronavirus (SARS-CoV-2): a review and perspective. *International Journal of Biological Sciences*, *16*(10), 1708-1718. https://doi.org/10.1016/j.antiviral.2005.02.008.

Yarmolinsky, L., Huleihel, M., Zaccai, M., & Ben-Shabat, S. (2012). Potent antiviral flavone glycosides from *Ficus benjamina* leaves. *Fitoterapia*, *83*(2), 362-367. https://doi.org/10.1016/j.fitote.2011.11.014.

Ye, X., Ng, T., Tsang, P. W., & Wang, J. (2001). Isolation of a homodimeric lectin with antifungal and antiviral activities from red kidney bean (*Phaseolus vulgaris*) seeds. *Journal of Protein Chemistry*, *20*(5), 367-375.

Ye, Z.-W., Yuan, S., Chan, J. F.-W., Zhang, A. J., Yu, C.-Y., Ong, C. P., Yang, D., Chan, C. C.-Y., Tang, K., Cao, J., Poon, V. K.-M., Chan, C. C.-S., Cai, J.-P., Chu, H., Yuen, K.-Y., & Jin, D.-Y. (2021). Beneficial effect of combinational methylprednisolone and remdesivir in hamster model of SARS-CoV-2 infection. *Emerging Microbes & Infections*, *10*(1), 291-304. https://doi.org/10.1080/22221751.2021.1885998.

Yeh, S.-F., Hong, C.-Y., Huang, Y.-L., Liu, T.-Y., Choo, K.-B., & Chou, C.-K. (1993). Effect of an extract from *Phyllanthus amarus* on hepatitis B surface antigen gene expression in human hepatoma cells. *Antiviral Research*, *20*(3), 185-192. https://doi.org/10.1016/0166-3542(93)90019-F.

Yu, M.-S., Lee, J., Lee, J. M., Kim, Y., Chin, Y.-W., Jee, J.-G., Keum, Y.-S., & Jeong, Y.-J. (2012). Identification of myricetin and scutellarein as novel chemical inhibitors of the SARS coronavirus helicase, nsP13. *Bioorganic & Medicinal Chemistry Letters*, *22*(12), 4049-4054.

Yu, Y., Shen, M., Song, Q., & Xie, J. (2018). Biological activities and pharmaceutical applications of polysaccharide from natural resources: A review. *Carbohydrate polymers*, *183*, 91-101. https://doi.org/10.1016/j.carbpol.2017.12.009.

Zahedipour, F., Hosseini, S. A., Sathyapalan, T., Majeed, M., Jamialahmadi, T., Al-Rasadi, K., Banach, M., & Sahebkar, A. (2020). Potential effects of curcumin in the treatment of COVID-19 infection. *Phytotherapy Research*, *34*, 2911–2920. https://doi.org/10.1002/ptr.6738.

Zakaryan, H., Arabyan, E., Oo, A., & Zandi, K. (2017). Flavonoids: promising natural compounds against viral infections. *Archives of Virology*, *162*(9), 2539-2551. https://doi.org/10.1007/s00705-017-3417-y.

Zarrinhaghighi, A., & Dehshahri, A. (2020). An *in silico* approach to find the molecular targets and potential candidates for SARS-CoV-2. *Trends in Pharmaceutical Sciences*, *6*(1), 11-20.

Zhai, P., Ding, Y., Wu, X., Long, J., Zhong, Y., & Li, Y. (2020). The epidemiology, diagnosis and treatment of COVID-19. *International Journal of Antimicrobial Agents*, *55*(5), 105955. https://doi.org/10.1016/j.ijantimicag.2020.105955.

Zhuang, M., Jiang, H., Suzuki, Y., Li, X., Xiao, P., Tanaka, T., Ling, H., Yang, B., Saitoh, H., & Zhang, L. (2009). Procyanidins and butanol extract of Cinnamomi Cortex inhibit SARS-CoV infection. *Antiviral Research*, *82*(1), 73-81. https://doi.org/10.1016/j.antiviral.2009.02.001.

Zorofchian Moghadamtousi, S., Abdul Kadir, H., Hassandarvish, P., Tajik, H., Abubakar, S., & Zandi, K. (2014). A review on antibacterial, antiviral, and antifungal activity of curcumin. *BioMed Research International*, *2014*(186864). https://doi.org/10.1155/2014/186864.

Estimation of the basic reproduction number (R0) for the novel coronavirus disease in Sri Lanka using a cluster in a navy base

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ABSTRACT

The Basic Reproduction Number (R0) is defined as the average number of secondary infections which can be caused by a patient, throughout his infectious period, in a completely susceptible population. We aimed to calculate R0 using the Welisara Naval base cluster in Sri Lanka. The total number of confirmed COVID-19 patients belonging to this cluster, was extracted daily from the situation reports of the Epidemiology Unit, Ministry of Health, Sri Lanka. The R0 was calculated using the exponential growth rate method and the maximum likelihood estimation method. R0 can be calculated by the exponential growth rate of the observed epidemic curve using the moment generating function of the assumed generation time distribution. The maximum likelihood estimation method assumes that the number of secondary cases caused by an index case is Poisson distributed, and the expected value (R0) can be estimated by maximizing the log-likelihood for the observation of incident cases. The analysis was done using the R language for statistical computing. The exponential growth rate method calculated an R0 of 1.69 (Confidence Interval (CI): 1.47-1.93) with a root mean squared error (RMSE) of 15.77. The R0 estimated using the maximum likelihood method was 1.89 (CI: 1.59- 2.23) with an RMSE of 30.13. The R0 calculated using the two different methods were comparable, with overlapping confidence intervals and reflects a lesser ability of the virus to spread within Sri Lanka in comparison to worldwide estimates.

Key words: Basic reproduction number, Coronavirus, R0

1. INTRODUCTION

The Basic Reproduction Number (R0) is defined as the average number of secondary infections which can be caused by a patient, throughout his infectious period, in a completely susceptible population. It is therefore a dimensionless number and is indicative of the contagiousness of a pathogen (Hethcote, 2000). Environmental conditions affect the virulence of the organism and the human interaction patterns of a particular population affects the transmission of disease, and thereby both affect the R0. Therefore, the R0 is not a constant for a pathogen itself, but a constant for a pathogen in a specific population (Delamater et al., 2019).

It is utilized to assess the ability of an infectious disease to spread within a community (when the R0 of a disease is greater than 1, the infection will spread, as it indicates that one infected individual will spread the disease to more than one individual) and to determine

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the fraction of the community which should be vaccinated in order to prevent the growth of the epidemic (Hethcote, 2000).

The R0 should not be confused with the reproduction number (R), which is the average number of secondary cases of disease caused by a single infected individual over the infectious period. Unlike R0, R varies with time and is commonly used to describe the transmissibility of the pathogen during an epidemic. The variation of R over time reflects effectiveness of control measures and highlights when the control efforts need to be intensified. A value of R below one, close to zero reflects the success of the control measures in controlling the epidemic (Cori et al., 2013).

Sri Lanka reported its first local patient diagnosed with the novel coronavirus disease- 2019 (COVID-19) on March 11th, 2020 (Coronavirus disease 2019 (COVID-19) - Situation Report – 12.03.2020 – 10.00am, 2020). Since then, new patients were diagnosed daily, however, due to the aggressive preventive and control measures implemented, the spread of the virus was dampened. Thereafter, the infection of a naval officer, involved in the transport of patients, diagnosed on 22nd April, 2020 led to a rapid spread of the disease within the naval base Welisara, as well as among contacts of the naval officers. Prompt action was taken and the camp was isolated, soldiers on leave were asked to return and the contacts of the naval officers were quarantined ("EconomyNext", 2020). We aimed to calculate the R0 for the spread of COVID-19 in Sri Lanka using this cluster at the naval base.

2. METHODOLOGY

The total number of confirmed COVID-19 patients belonging to the navy cluster reported daily, was extracted from the situation reports of the Epidemiology Unit, Ministry of Health, Sri Lanka. The R0 was calculated using the exponential growth rate method and the maximum likelihood estimation method.

The exponential growth rate (r) of the observed epidemic curve can be used to estimate the initial reproduction number. R0 is calculated using the moment generating function of the assumed generation time distribution (M), by the equation $R0 = \frac{1}{M(-r)}$.2

The generation time is the time lag between infection in a primary case and a secondary case, and since it can not be directly observed, it is substituted with the serial interval that measures the time between symptoms onset (Wallinga & Lipsitch, 2006). A sensitivity analysis for an exponential regression model for the cumulative number of daily reported cases was carried out to find the best time period of the observed epidemic curve to obtain the growth rate.

The R0 estimated by the above method was corroborated by the maximum likelihood estimation method. Assuming that the number of secondary cases caused by an index case is Poisson distributed and the generation time interval is w, the expected value (R0) can be estimated by maximizing the log-likelihood for the observation of incident cases N0, N1..., NT (Forsberg White & Pagano, 2007).

$$LL(R0) = \sum_{t=1}^{T} \log\left(\frac{e^{-\mu_t}\mu_t^{N_t}}{N_t!}\right)$$

$$\text{where } \mu_t = R\sum_{i=1}^{t} N_{t-i} w_i$$

Since the likelihood must be calculated on a period of exponential growth, a sensitivity analysis was carried out to find the best time period.

The analysis was done using the R language for statistical computing.

3. RESULTS AND DISCUSSION

The exponential growth rate method calculated an R0 of 1.69 (Confidence Interval (CI): 1.47-1.93) with a root mean squared error (RMSE) of 15.77.

The R0 estimated using the maximum likelihood method was 1.89 (CI: 1.59- 2.23) with an RMSE of 30.13.

Both of the values calculated are comparable and have overlapping confidence intervals as illustrated in Figure 1.

The predictions of both models for the daily cumulative number of patients, along with the actual number reported is illustrated in Figure 2. It can be observed that both the models were able to predict the actual number of cases reported with a good fit.

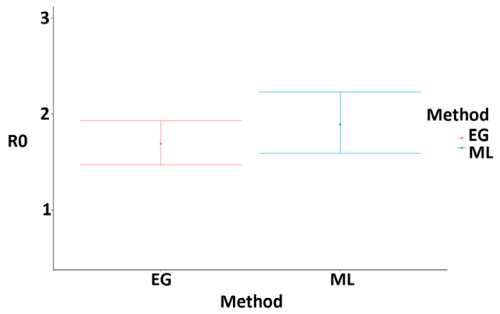

Figure 1. R0 calculated by each model with their respective confidence interval

The values (1.69 and 1.89) reflect a relatively lesser degree of spread in Sri Lanka in comparison to some other countries, where the spread has been detrimental. Interestingly, USA being among the highest hit countries, allocates 17.7% of its gross domestic product (GDP) towards healthcare, the highest worldwide. However, only 2.56% was allocated to public health according to figures published in 2018 ("Historical | CMS", 2018).

Sri Lanka allocated only 3.4% of its GDP to healthcare (2015) ("National Health Expenditure 1990–2016.", 2016), however it has a well-developed public health system, with many public health success stories to its name ("Public Health Success in Sri Lanka.", 2016).

Sri Lanka implemented a coordinated plan of action where the healthcare workers, police, military, and intelligence services worked in synergy, each perfoming a specific role. The contacts were traced by the intelligence services and the Epidemiology Unit, the military was tasked with ensuring disease containment and the police reduced the transmission of disease by imposing restrictions on the mobility of the public. Construction of designated centres, re-commissioning of existing hospitals and

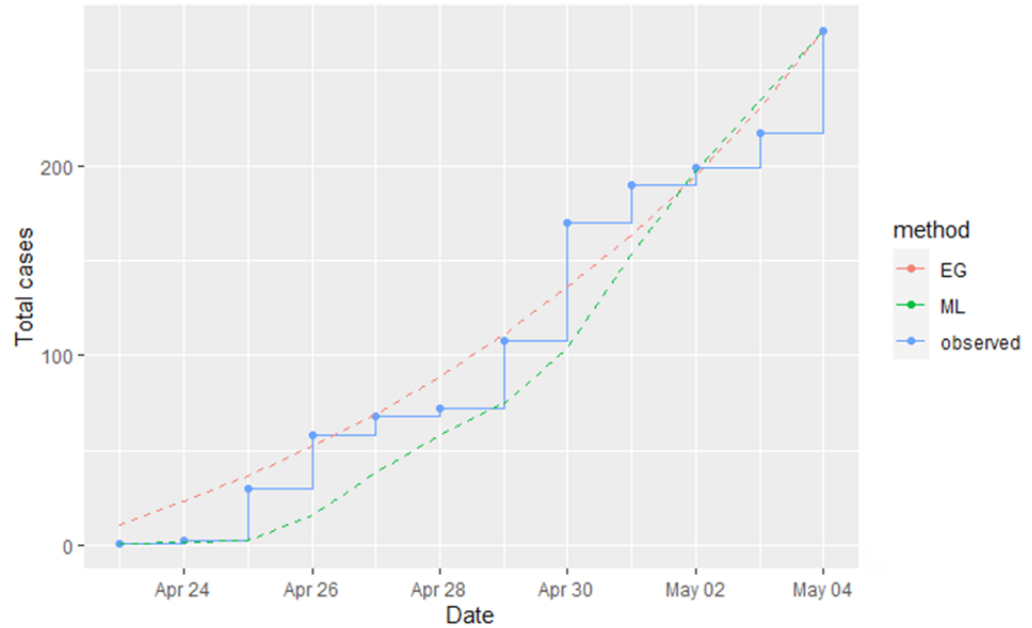

Figure 2. The daily reported total number of patients plotted against the predictions by the exponential growth rate method and the maximum likelihood estimation method.

improvising facilities for the treatment of COVID-19 infected patients ensured the readiness of the curative sector to combat this disease ("News – Presidential Secretariat of Sri Lanka", 2020).

This multi modal approach may be responsible for the relatively lower spread in Sri Lanka in contrast to countries such as China which reported a R0 of 2.2 (Li et al., 2020), and Italy as 2.4-3.1 (D'Arienzo & Coniglio, 2020).

The Figure 3 represents the daily total cases reported (in log scale) in countries worldwide, since the day of their first reported case. The United States of America (USA), Italy, Spain and Sri Lanka are highlighted and remaining countries are depicted as thin lines.

4. CONCLUSION

The estimated values for R0 for COVID-19 in Sri Lanka, calculated utilizing the navy cluster by two methods are 1.69 and 1.89 reflecting a lesser ability of the virus to spread within Sri Lanka in comparison to worldwide estimates.

REFERENCES

Cori, A., Ferguson, N., Fraser, C., & Cauchemez, S. (2013). A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. *American Journal Of Epidemiology*, *178*(9), 1505-1512. https://doi.org/10.1093/aje/kwt133

D'Arienzo, M., & Coniglio, A. (2020). Assessment of the SARS-CoV-2 basic reproduction number, R0, based on the early phase of COVID-19 outbreak in Italy. *Biosafety And Health*, *2*(2), 57-59. https://doi.org/10.1016/j.bsheal.2020.03.004

Delamater, P., Street, E., Leslie, T., Yang, Y., & Jacobsen, K. (2019). Complexity of the Basic Reproduction Number (R0). *Emerging Infectious Diseases*, *25*(1), 1-4. https://doi.org/10.3201/eid2501.171901

Epid.gov.lk. (2020). Coronavirus disease 2019 (COVID-19) - Situation Report – 12.03.2020 – 10.00am. Retrieved 9 May 2021, from https://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-12-03_10.pdf.

Forsberg White, L., & Pagano, M. (2007). A likelihood-based method for real-time estimation of the serial interval and reproductive number of an epidemic. *Statistics In Medicine*, *27*(16), 2999-3016. https://doi.org/10.1002/sim.3136

Hethcote, H. (2000). The Mathematics of Infectious Diseases. *SIAM Review*, *42*(4), 599-653. https://doi.org/10.1137/s0036144500371907

Historical | CMS. Cms.gov. (2018). Retrieved 14 February 2021, from https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nationalhealthaccountshistorical.

Li, Q., Guan, X., Wu, P., Wang, X., Zhou, L., & Tong, Y. et al. (2020). *Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia*. Retrieved 14 February 2021, from.

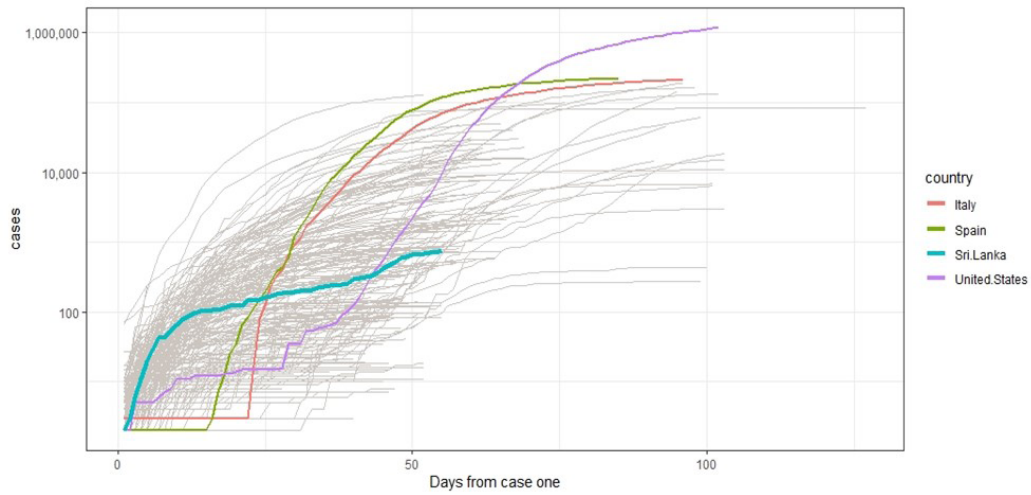

Figure 3. The number of confirmed cases of COVID- 19 reported from the first day of the first case for Italy, Spain, USA and Sri Lanka, using a log scale

National Health Expenditure 1990–2016.. Ihp.lk. (2016). Retrieved 14 February 2021, from http://www.ihp.lk/publications/docs/HES1805.pdf.

News – Presidential Secretariat of Sri Lanka. Presidentsoffice.gov.lk. (2020). Retrieved 14 February 2021, from https://www.presidentsoffice.gov.lk/index.php/news/.

Public Health Success in Sri Lanka.. Origin.searo.who.int. (2016). Retrieved 14 February 2021, from http://origin.searo.who.int/srilanka/documents/policybriefsfinal.pdf.

Wallinga, J., & Lipsitch, M. (2006). How generation intervals shape the relationship between growth rates and reproductive numbers. *Proceedings Of The Royal Society B: Biological Sciences*, *274*(1609), 599-604. https://doi.org/10.1098/rspb.2006.3754

Welisara Navy COVID 19 "cluster" has yielded 206 patients, as total reaches 596 | *EconomyNext*. EconomyNext. (2020). Retrieved 14 February 2021, from https://economynext.com/welisara-navy-covid-19-cluster-has-yielded-206-patients-as-total-reaches-596-68894/.

Data Driven Decision Making (DDDM) for COVID-19 in Sri Lanka

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ABSTRACT

COVID-19 is a new viral illness that can affect respiratory system of a person. The health experts are still learning about how this new coronavirus spreads and what factors are significantly influential on coronavirus spread. In such a situation it is useful to derive inferences based on 'data driven decision making' (DDDM). The objective of this study is to highlight results obtained by early May 2020 for the benefit of decision makers with respect to the first COVID-19 in Sri Lanka. The local daily data on COVID-19 infected cases (March to May) were used. The estimated values of expected number of cases an infected person will cause during their infectious period (R0 for four time periods during March to May) were less than one in all four periods confirmed that the probability of community transmission of COVID-19 is almost zero. These were estimated using the number of Freely Moving Infected (FMI) cases and Currently Infected (CI) cases. Based on statistical indicators: observed percentage increase in daily cumulative new cases, case fatality rate (CFR) and recovery rate (RR), it was confirmed that the COVID-19 in Sri Lanka does not spread as fast as in other countries and the COVID-19 curve would be flattening by later part of May 2020. Furthermore, it was shown that no need to fear for second wave on COVID-19, if people should be susceptible to follow the "intra vires" instructions given by the health authorities even after the situation comes back to normal. DDDM is more robust and efficient scientific method for effective planning.

Key words: Case fatality rate, COVID-19, DDDM, Freely moving infected, R0

1. INTRODUCTION

Sri Lanka reported the first patient with the novel Coronavirus disease-2019 (COVID-19) on the January 27th, 2020, in a Chinese female visiting the country (Reuters, 2020). The first local patient was reported on March 11th, 2020 thus bringing about unprecedented changes in the daily life in the country. Though, various preventive measures were implemented to reduce the spread of the disease, patients were reported almost every day.

COVID-19 is a new viral illness that can affect respiratory system of a person which has been spread to many countries in different intensities due to heteroscedasticity with respect to various variables among countries. Furthermore, as COVID-19 is a new disease, and health experts continue to learn about the factors that significantly influence its spread. Decision-making during such situations is best made by analyzing statistically the data collected, in collaboration with an expert applied statistician. This process is known as 'data driven decision making (DDDM)'.

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However, it is well known that during the first wave of the Covid-19 period most decisions related to COVID-19 were taken without statistically analyzing the data collected in the country. Thus, many newspaper articles were published (Peiris, 2020) during March to May 2020 to make aware of some predictions related to first wave of COVID-19 based on DDDM for the use of decision makers. The objective of this study is to demonstrate how DDDM is useful in decision making with respect to the first COVID-19 in Sri Lanka.

2. MATERIALS AND METHODS

2.1. Secondary Data

The daily data on COVID-19 patients who tested positive were obtained from the data base maintained by the Epidemiology Unit, Ministry of Health, Sri Lanka (Ministry of Health, 2020).

2.2. Data Analysis

2.2.1. Estimating R_O

R_0 is an important indicator in any epidemiology. It is a mathematical term that indicates how contagious an infectious disease is. It indicates the average number of people who will catch a disease from one contagious person. It specifically applies to a population of people who were previously free of infection and haven't been vaccinated (Delamater et al., 2019). Various methods have been suggested to estimate the R_0, but most of those methods have various conservative assumptions.

Some authors in Sri Lanka assumed various values for R_0 which vary from 1.5 to 3.5 and thus the results obtained were misleading the public as well as the decision makers. In this article the Ro is estimated using simple method based on the equation (1) below, where $\hat{R}_0$ is the estimator for R_0.

$$\hat{R}_0 = \frac{\text{Total number of currently infected (CI) cases}}{\text{Total number of freely moving infected (FMI) cases}} \quad (1)$$

If the $\hat{R}_0 < 1$, a disease outbreak should wane over time and if the $\hat{R}_0 > 1$, the outbreak would continue to increase.

2.2.2. Percentage of increase in daily cumulative covid-19 cases

Let the cumulative values of daily new cases on $(t-1)^{th}$ day and t^{th} day be y_{t-1} and y_t respectively. Then the percentage increase of the daily cumulative value at day t (PIC_t) with respect to the day t-1 is given by equation (2).

$$PIC_t = \frac{y_t - y_{t-1}}{y_{t-1}} \times 100 = \left(\frac{y_t}{y_{t-1}} - 1 \right) \times 100 \quad (2)$$

3. RESULTS AND DISCUSSION

It was assumed that each freely moving infected (FMI) case roams for 5 days. The total number of currently infected (CI) cases was assumed as three times of the infected cases during a given period to compensate due to lack of testing. Thus, the proxy estimator for R_0 was estimated as $\hat{R}_0 = \frac{3*CI}{FMI}$. The 95% confidence interval for R_0 was derived using Binomial distribution. The results obtained for four different periods are shown in Table 1.

As the estimators for R_0 in all four cases are less than one and the upper limit of the 95% confidence interval is also less than one, it can be concluded with 95% confidence, that the probability of community transmission of COVID-19 is almost zero.

3.1. Flattening the COVID-19 Curve

The plot of percentage of increase daily cumulative COVID-19 with time up to 18^{th} April is shown in Figure 1.

Figure 1 has a clear exponentially decreasing trend and in fact most of the percentages are low (< 10%), particularly as time increases. The PIC_t values varied from 200% to 50% at the very beginning, though the numbers were low. However, since the beginning of April 2020,

Table 1. Estimated R_0 values in different time periods

Period	$\hat{R}_0$	95% CI for R_0
13^{th} March - 6^{th} April	0.51	[0.47- 0.55]
13^{th} March – 12thApril	0.43	[0.40 – 0.46]
13^{th} March – 18thApril	0.38	[0.35 - 0.41]
13^{th} March – 30^{th} April	0.36	[0.33 - 0.39]

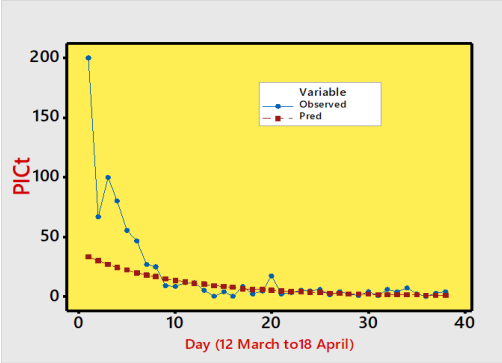

Figure 1. Trend in PIC_t New Cases up to 18th April

the percentage increase varied from 1.7% to 4.2%. The trend in Figure 1 was modeled by an exponential function. Although the model did not predict so well for the first few days, the fitted values were almost close to the observed values since the later part of March. Thus, it can be expected the same trend of percentage increase in the next few weeks too. This would be a better indication for the flattening of daily trend in new COVID-19 cases.

During the period from 11th March to 05th May, the probability of getting more than 25 cases of COVID-19 was increased to 0.16 due to unexpected incident in a Navy camp. This would delay the start of flattening the curve. This can be considered as an unusual phenomenon that happened against the natural course of the disease. To reduce such noise, the trend was plotted for 5-day median as the median is a better outlier resistant smoothing technique than day moving averages. This pattern i (Figure 2) is another confirmation to claim that the new cases are flattening.

The trend in PICt up to 01 May shown in Figure 3 further confirmed the flattening of the curve is almost sure. Based on the fitted model it was confirmed that covid19 curve in Sri Lanka would be flattening by latter part of May 2020.

3.2. Second wave of COVID-19

The trends of daily COVID-19 curve in Australia and Japan showed an increase after a clear decline in the first curve of the outbreak (Peiris, 2020). This can be considered as a 'second wave of COVID-19'. However, in Australia, the numbers are lower than that in Japan. It has taken 35 days to start the second wave in Australia and the corresponding period is 30 days in Japan. By combining various public health approaches and behavioral control of people, countries such as New Zealand (NZ), Sri Lanka (SL) and Iceland (IC) have almost halted the virus. In NZ, the daily COVID-19 has been less than 4 since 3rd May, and in

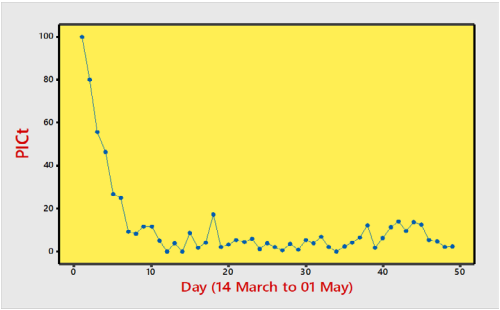

Figure 3. Trend in PCI_t up to 01 May

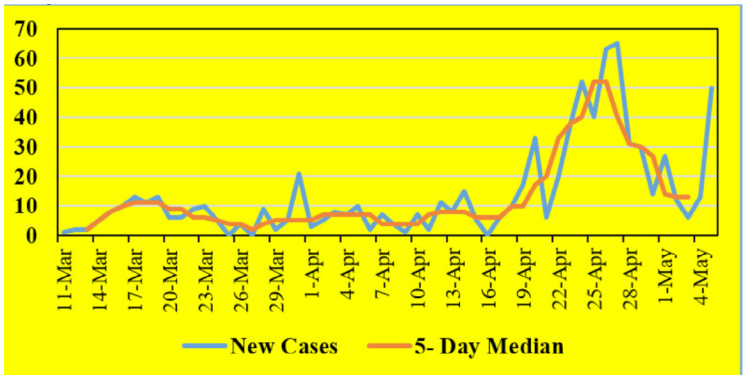

Figure 2. Temporal variability of covid-19 cases

Iceland (IC) it is less than 7 since 23rd April with an exception of 7 for 2 days (Peiris, 2020). In SL we did not find a single COVID-19 case from the community since 18th May with an exception on 8th July. The distributions of daily COVID-19 cases in those three countries after the dates are shown (Figure 4).

The probability of zero occurrence per day in SL is 98% since 18th May. The corresponding probabilities in NZ is 63% since 3rd May and 64% in IC since 23rd April. Of those three countries Sri Lanka has been performing better with respect to preventing a resurgence of a second wave of COVID-19 in the community. For the virus to spread, it requires a susceptible individual and an infected host in close contact. These factors are conveniently captured by the value of R_0, which is defined as the average number of new cases caused by one infected individual. In SL, under present circumstances, this value is less than 1, confirming that the chance of a second wave is low.

A second wave of COVID-19 is likely to depend on our capability and the effectiveness of getting these blips of infection, which we will invariably get, controlled within our system. Although we may have certain constraints in resources, we have been successful in case identification, isolation, contact tracing etc. Thus it can be concluded that we do not want to fear for the second outbreak.

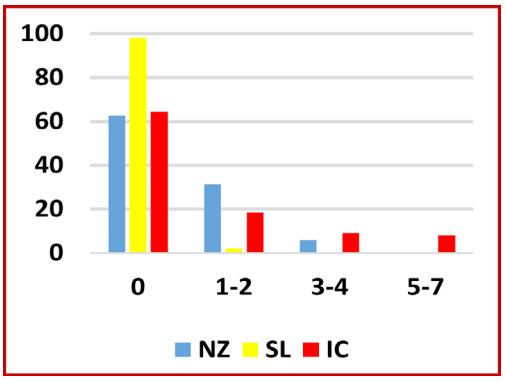

Figure 4. Percentage Distribution of the New COVID-19 Cases after Starting Flattening Curve

4. CONCLUSIONS AND RECOMMENDATIONS

It was shown that DDDM is an effective tool to predict useful information well in advance during the first COVID-19. However, we did not practice recommendations derived from DDDM. The COVID-19 in Sri Lanka does not spread as fast as in other countries and the probability of community transmission is almost zero. Based on data by 05th May, it was shown that covid19 curve in Sri Lanka would be flattening by later part of May 2020. However, people should be susceptible to follow the "intra vires" instructions given by the health authorities even after the situation is back to normal. Undue fear of a second wave can affect the normalizing process of the community.

We cannot expect to eliminate COVID19, even though an effective vaccine is found, because at any time there can be some probability that a COVID19 patient may be in the society. However, the government can relax various restrictions so that business can start and people can come back to normal life. Government should commence a mechanism to have expertise from a multidisciplinary group of professionals.

REFERENCES

Delamater, P. L., Street, E. J., Leslie, T. F., Yang, Y. T., & Jacobsen, K. H. (2019). Complexity of the Basic Reproduction Number (R_0). *Emerging Infectious Diseases*, *25*(1), 1–4. https://doi.org/10.3201/eid2501.171901

Ministry of Health. (2020). *Rolling updates on Coronavirus disease (COVID-19)*. Ministry of Health, Sri Lanka. https://hpb.health.gov.lk/en/covid-19

Peiris, T. S. G. (2020). *Data Driven Decision Making (Dddm) for Covid-19 in Sri Lanka* (1st ed., Vol. 1). Randhi Printers. https://uom.lk/sites/default/files/math/files/Covid%2019%20book_0.pdf

Reuters. (2020, January 28). *Chinese woman Sri Lanka's first confirmed case of coronavirus*. The Japan Times. https://www.japantimes.co.jp/news/2020/01/28/asia-pacific/science-health-asia-pacific/chinese-woman-sri-lankas-first-confirmed-case-coronavirus-health-official/

Mitigating covid-19 transmission in Sri Lanka: A mathematical outlook for decision support

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ABSTRACT

COVID-19 continues to obstruct not only healthcare systems, but also socio-economic context across the globe. No exceptions prevail for Sri Lanka too. It is evident that proper data processing is required for successful. Data processing should be established with proper data collection, storing and making reliable interpretations. It should necessarily lead to systematic decision support tools assessing the risk of COVID-19 transmission. Here, we propose a risk assessment mechanism via fuzzy membership functions covering three categories: Healthcare decision support (HDS), Age-specific decision support (ADS) and Space-specific decision support (SDS).

Each category is subdivided into several aspects captured via specific membership functions valued in [0,1]. Membership functions are designed using epidemiological and healthcare data relevant to Sri Lanka. Number of confirmed and recovered cases, records on hospitalization and PCR tests are the main data tracks of HDS. In ADS, age distribution of confirmed cases is the main track. District distribution of confirmed cases is used in SDS. Transmission potential due to adjacency of districts are assimilated via spatial autocorrelation measures Moran's I and Geary's C.

Membership functions are aggregated with the aid of parameterized Hamacher t-norm operator to investigate the combined effect. This aggregation procedure is carried out for each category HDS, ADS and SDS separately. Finally, decision support criteria can be customized as low-risk, moderate-risk and high-risk in [0,1] scale. For the trialled study period, many of the days are in moderate risk, age-classes between 20 and 49 are with high-risk and Colombo, Gampaha and Kalutara remain high-risk.

Key words: COVID-19, Fuzzy membership functions, Hamacher t-norm operator, Decision support system

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1. INTRODUCTION

COVID-19 pandemic has become the crisis of our time. Its burden expands all over the world not limiting into public health problems, but leading to economic and social problems too. Many countries are still at risk of overwhelming healthcare capacity in all aspects of testing, hygiene practices and clinical facilities (World Health Organization, 2020). In terms of confirmed cases, USA, India and Brazil top the list replacing China and European countries that dominated the early stage of transmission (Worldometer, 2020). This vulnerability has been prevailing with mixed outcome in mitigation efforts. Amidst this alarming situation, countries like Sri Lanka have shown a successful intervention complying with all sorts of control measures travel restrictions, social distancing, wearing face masks and washing hands, early testing and contact tracing, immediate hospitalization, extended quarantine procedures etc. As of the end of 2020, around 43,000 confirmed cases were reported in Sri Lanka, with around 200 deaths (Worldometer, 2020).

Many sophisticated ODE models are already applied to understand transmission dynamics catering the compartments susceptible, infected, exposed, recovered and dead. Further, PDE models, independently dealing with time and age can also be possible as carried out for Dengue in (Ganegoda et al.,2020). Considering compartmental models with different age groups is also an improved approach. According to a COVID-19 study done in South Korea (Yu et al.,2020), two peaks of daily new cases are reported in the age group 20-39 years, but not that significant in the other age groups. A similar type of analysis is due for Sri Lanka, which enables to determine the impact of full reopening with respect to age. We propose a decision support tool to reflect such time-specific and age-specific impact with the aid of census data and mobility data as well. Since the COVID-19 incidence of Sri Lanka is more concentrated around a few clusters, dynamics of Susceptible-Infected-Recovered compartments is vague and parameter estimation is also challenging. Therefore, we opt to quantify the risk via fuzzy approach, which is suitable for decision making amidst vague or imprecise information (Mardani et al., 2018).

Spatial autocorrelation can be utilized to compare the incidence levels of a certain region with those of neighbours (Wijaya et al., 2020). After the early spatial dynamics over several hotspots, Sri Lanka has experienced a considerable distribution over districts, emphasizing the need of assessing the risk with respect to spatial vulnerability.

Designing and implementing decision support systems for mitigating COVID-19 have gained much attention (Massachusetts Institute of Technology, 2020; Liu et al., 2020). A significant contribution from sophisticated technology also prevails to work with real-time data. This paper aims at a decision support mechanism via risk assessment. Fuzzy membership functions are used for such assessment covering three categories: healthcare capacity, age-specific risk and space-specific risk. It allows to scrutinize intervention measures already under taken and infer potential utility in the future. Existing data processing is also studied with the aim of establishing better utility of data.

2. METHODOLOGY

We start with screening official data provided by the Epidemiology Unit (EU-SL) and the Health Promotion Bureau (HPB-SL) of Sri Lanka. The EU-SL publishes daily situation reports giving the data regarding confirmed cases, recovered cases, deaths, hospital distribution of confirmed cases, district/quarantine center distribution of confirmed cases etc. (Epidemiology Unit, 2020) and HPB-SL has the records of daily PCR tests (Health Promotion Bureau, 2020). To quantify healthcare risk, epidemiological data on confirmed/recovered cases should be compared with the number of PCR tests.

The general routine to all the coming decision support tools lies with fuzzy membership functions representing different

factors. We investigate three categories: Healthcare decision support (HDS), Age-specific decision support (ADS) and Space-specific decision support (SDS). Each of these categories is subdivided into several aspects, where each aspect is captured via a specific membership function valued in [0,1]. Three aspects are incorporated in HDS as (i) testing capacity, (ii) recovered portion and (iii) hospitalization of confirmed and suspected cases. Another three aspects are in ADS as (i) distribution of confirmed cases by age, (ii) dense nature of each age class and (iii) age-specific mobility. SDS also contains three aspects as (i) spatial autocorrelation-global effect, (ii) spatial autocorrelation-local effect and (iii) spatial mobility attraction.

We apply the Hamacher *t*-norm operator (Jin et al., 2019) to combine or aggregate the risk shown by relevant membership functions. The aggregated effect of two membership functions $\mu_A(x)$ and $\mu_B(x)$ via the Hamacher *t*-norm operator is given in (1). The domain of x runs as time, age and district in HDS, ADS and SDS respectively.

$$\mu_A(x) * \mu_B(x) = \frac{\mu_A(x)\mu_B(x)}{p + (1-p)\left[\mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x)\right]} \quad (1)$$

Here, $0 \le p \le 1$ stands for softening the product effect of membership functions as $p = 1$ provides the product $\mu_A(x) * \mu_B(x) := \mu_A(x)\mu_B(x)$. This softening effect is illustrated in Figure 1 by fixing one membership value at a time. The Hamacher t-norm operator can be extended to more functions (in our case to three functions) to acquire required aggregations. To aggregate a third membership function $\mu_C(x)$, we should operate as $(\mu_A(x) * \mu_B(x)) * \mu_C(x)$. The Hamacher operator is obviously commutative and it adheres associative property too (Fodor & Keresztfalvi, 1994).

In age-specific aspects, we use distribution of confirmed cases by age as recorded by the EU-SL. In addition, census data that provide details on dense nature and potential of mobility of each age group are infused to quantify age-specific risk of COVID-19. Census data are obtained by the report of Census of Population and Housing 2012 issued by the Department of Census and Population - Sri Lanka (Department of Census and Population, 2012).

We aim at assessing space-specific risk in district level. Data on district distribution provided by the EU-SL are utilized here. In addition, autocorrelation measures Moran's *I* and Geary's *C* can be determined with proper

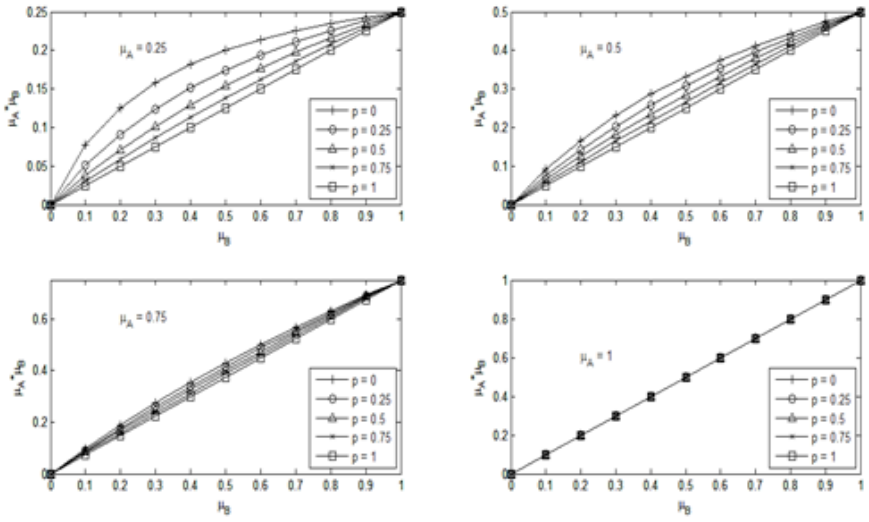

Figure 1. Behaviour of the Hamacher *t*-norm operator for different values of *p*.

weights, designed according to the human mobility induced by adjacency of districts. An approach via gravity model is also considered to assess mobility attracted by population density of districts (Stefanouli & Polyzos, 2017). A relaxation parameter is also proposed to incorporate prevailing travel and distancing restrictions.

The Hamacher *t*-norm operator gives a value in [0,1]. Therefore, one can decompose risk level into several categories in this [0,1] scale. A possible structure is given in Figure 2, where a (lower barrier) and b (upper barrier) are to be determined. We use Hamacher *t*-norm and quartiles whenever appropriate to guide the user for these barriers.

3. RESULTS AND DISCUSSION

Our approach on results is; choosing a form of membership functions, exact evaluation of membership functions using data, combined affect by Hamacher *t*-norm operator and declaring risk levels as a decision support. We present formulation of membership functions and corresponding quantifications for the three categories: (i) Healthcare capacity decision support, (ii) Age-structured decision support and (iii) Space-specific decision support.

3.1. Healthcare Decision Support (HDS)

Three aspects considered in HDS are depicted in Figure 3 and one quantification is to be designed for the risk level of healthcare capacity. Data are retrieved from daily situation reports of Epidemiology Unit.

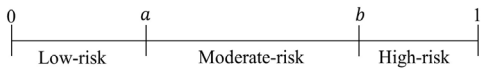

Figure 2. Decomposing risk levels

Risk associated with testing capacity is measured by the ratio of number of tests to the confirmed cases in a selected time frame. First, we quantify this ratio as $x(t_i)=\frac{c_i}{k_i}$ for a particular day t_i centered in a one-week window $[t_i-3, t_i+3]$. Here, c_i is the total of daily confirmed cases in the window $[t_i-3, t_i+3]$ and k_i is the total number of daily tests in the same window. This windowing provides a smooth outlook curtailing possible rapid changes in daily basis. Next, the membership function (μ_T) is designed as in (2).

$$\mu_T(t_i)=\frac{x(t_i)}{\max_{i\in I} x(t_i)} \qquad (2)$$

We deploy dividing by the maximum as a usual practice in normalization, while adhering to the scaling [0,1] required for a membership function. Here in the denominator, index i runs over the concerned period given by the index set I. In our illustration, we took $I=\{1,2,\ldots,14\}$ where t_1 = Dec 17, t_2 = Dec 18, …, t_{14} = Dec 30 covering two weeks.

Healthcare risk should be high when recovered cases are comparatively low than the confirmed cases in a particular period. We quantify this as $y(t_i)=\frac{c_i}{r_i}$ for a day t_i. Here, c_i is the total of daily confirmed cases in the window of one week $[t_i-3, t_i+3]$ as taken above. The total recovered cases in that window is indicated by r_i. Now, the membership

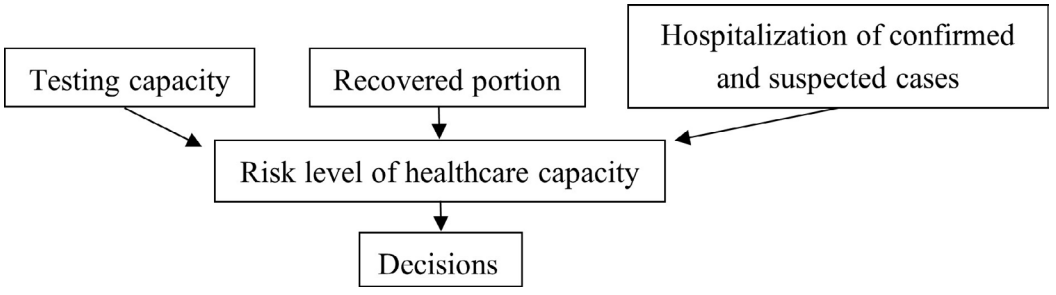

Figure 3. Aspects of healthcare decision support (HDS)

function (μ_R) is designed as in (3) with the similar meaning to index set I.

$$\mu_R(t_i) = \frac{y(t_i)}{\max_{i \in I} y(t_i)} \quad (3)$$

μ_R is not to measure recovery rate of confirmed cases, but to capture availability of healthcare facilities assisting confirmed cases to become recovered. As the third aspect, hospitalization of confirmed and suspected cases is considered. Here also an intermediate ratio is designed as $z(t_i) = \frac{h_i}{s_i}$ for a particular day t_i. Here, h_i and s_i represent the number of cases remaining at hospitals at t_i after being confirmed and suspected respectively. The membership function (μ_H) for this aspect is taken as in (4).

$$\mu_H(t_i) = \frac{z(t_i)}{\max_{i \in I} z(t_i)} \quad (4)$$

Higher μ_H indicates higher healthcare risk since the spread of disease can be minimized when more suspected cases are hospitalized. Data of h_i and s_i are available in daily basis considering the situation up to that day. Therefore, we do not consider a moving window as in other two aspects.

Now, the aggregated effect of the three aspects is obtained via Hamacher t-norm operator. First, we should aggregate two membership functions as in (5) and then repeat the same operation as in (6) to quantify the overall risk $R_{HDS}(t_i)$. Here, the subscript HDS stands for the category name Healthcare Decision Support.

$$\mu_T(t_i) * \mu_R(t_i) = \frac{\mu_T(t_i)\mu_R(t_i)}{p + (1-p)\left[\mu_T(t_i) + \mu_R(t_i) - \mu_T(t_i)\mu_R(t_i)\right]} \quad (5)$$

$$R_{HDS}(t_i) = \left(\mu_T(t_i) * \mu_R(t_i)\right) * \mu_H(t_i) \quad (6)$$

Here, parameter p stands for softening the product effect of two membership functions as illustrated in Figure 1. We assume $p = 0.5$ as a moderate measure, which is the same for subsequent categories too. $R_{HDS}(t_i)$ ranges in [0,1].

Figure 4 contains all the membership values and overall risk $R_{HDS}(t_i)$ for the time period Dec 17 – Dec 30, 2020. It can be observed that R_{HDS} shows a periodic pattern, which resembles the pattern of μ_H (hospitalization) for the concerned two-week period. Risk associated with recovered portion

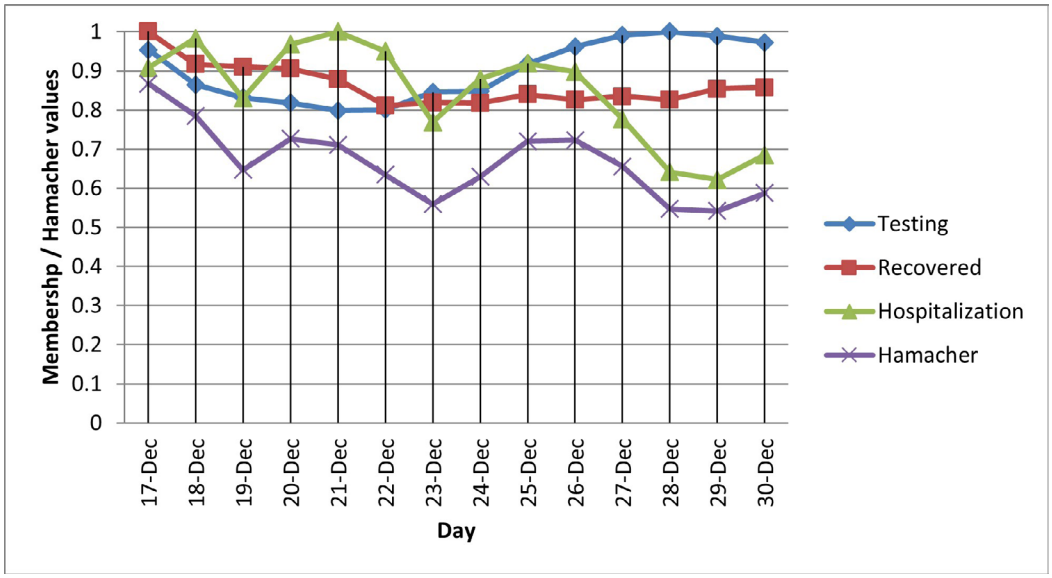

Figure 4. Membership and Hamacher values of HDS. (Labels - Testing: μ_T Recovered: μ_R Hospitalization: μ_H Hamacher: R_{HDS})

(μ_R) follows a consistent pattern and that of testing capacity (μ_T) shows a trough in the first week and a peak in the second week. Thus, one could recognize that though the testing capacity is in a vulnerable situation in the second week, hospitalization of suspected cases would curtail the risk. Risk level can be designated as low, moderate and high by using general appearance of membership values. We propose this as a customizing option as one can alter it according to the concerned time period. For instance in Figure 4, membership values wobble around 0.8 and 0.9 most of the time. Hence, we may decide a lower barrier for R_{HDS} by setting three membership values as 0.7, 0.8 and 0.9, while an upper bound is taken with membership values 0.8, 0.9 and 1. Order of assigning these values into μ_T, μ_R and μ_H is immaterial due to the commutative and associative properties of Hamacher *t*-norm operator. We took 0.7 and 1 respectively for lower and upper barriers keeping a symmetric deviation from earlier rough choice of 0.8 and 0.9. The resultant lower and upper barriers are 0.53 and 0.73 respectively.

Now, the decision support comes in [0,1] scale as: low-risk if $R_{HDS} < 0.53$, high-risk if $R_{HDS} > 0.73$, moderate-risk - otherwise. All the days except first two are with moderate-risk and no days are with low-risk. This analysis can be carried out selecting different time frames to understand risk involved in healthcare capacity.

3.2. Age-specific Decision Support (ADS)

Three aspects considered in ADS are depicted in Figure 5 and our aim is to design one quantification for the risk level of each age-class.

The membership function (μ_C) for distribution of confirmed cases by age is formulated in (7). This allows having higher membership value for age-class reported with higher portion of confirmed cases.

$$\mu_C(a_i) = \frac{P_C(a_i)}{\max_{i \in I} P_C(a_i)} \tag{7}$$

Here, a_i represents age-class and $P_C(a_i)$ stands for percentage of confirmed cases of age-class a_i out of all confirmed cases. Next, the membership function (μ_D) for dense nature of each age-class is formulated as in (8). Here, $P_D(a_i)$ is the percentage of population of age-class a_i out of whole population.

$$\mu_D(a_i) = \frac{P_D(a_i)}{\max_{i \in I} P_D(a_i)} \tag{8}$$

For age-specific mobility, the membership function (μ_M) comes as in (9). Here, $P_M(a_i)$ is the percentage of mobilized population of age-class a_i out of population of age-class. a_i. We use an indirect measure for mobility as population engaged in economic activities, which is available in census data.

$$\mu_M(a_i) = \frac{P_M(a_i)}{\max_{i \in I} P_M(a_i)} \tag{9}$$

Now, the aggregated effect of the three aspects is obtained via Hamacher *t*-norm operator. Aggregation of two membership

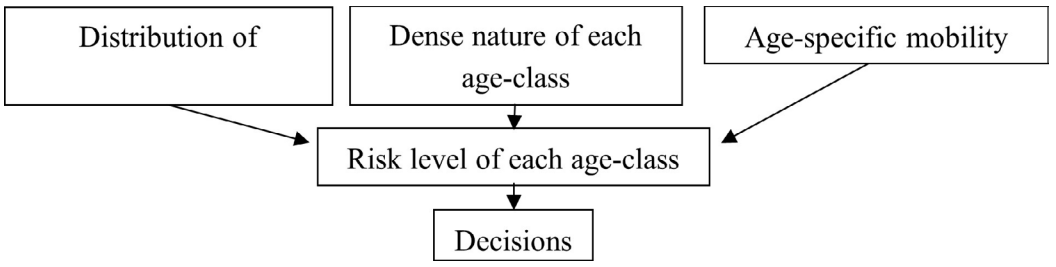

Figure 5. Aspects of age-specific decision support (ADS)

functions is in (10) and (11) quantifies the overall risk. Subscript ADS is for the category Age-specific Decision Support.

$$\mu_C(a_i)*\mu_D(a_i)=\frac{\mu_C(a_i)\mu_D(a_i)}{p+(1-p)\left[\mu_C(a_i)+\mu_D(a_i)-\mu_C(a_i)\mu_D(a_i)\right]} \quad (10)$$

$$R_{ADS}(a_i)=\left(\mu_C(a_i)*\mu_D(a_i)\right)*\mu_M(a_i) \quad (11)$$

$R_{ADS}(a_i)$ quantifies the risk associated with age-class a_i, which ranges in [0,1]. We illustrate this by taking data from relevant tracks. For $P_C(a_i)$, we use age distribution of COVID-19 confirmed cases reported as at January 07, 2021. For $P_D(a_i)$, census data are taken from the final report of Census of Population and Housing 2012 (Department of Census and Population, 2012). The same data source is used for $P_M(a_i)$ too. We use age-class separation in years as 1-4, 5-9, …, 75-79, 80-and-over. We adjusted available census data category 60-and-over into the classes 60-64, 65-69, …, 75-79, 80-and-over with appropriate distribution. Epidemiology data are available with class size of 10 year and it is also taken into classes as mentioned above. For instance, percentages relevant to 10-14 and 15-19 are taken similar to that of 11-20. Age distribution of engaging economic activities is available from age-class 15-19. For the lower age-classes, we assign percentages by assuming their mobility on attending schools. Even the percentage of engaging economic activities of age-class 15-19 can be replaced by a higher value assuming their movement for educational activities. If we consider a period where all the schools are closed, then mobility of lower age-classes are low. We set a rough estimate from 10% to 25% with 5% steps for the first four age-classes.

Figure 6 shows $R_{ADS}(a_i)$ subject to the above working out of data. The age-class 30-34 associates with the highest risk.

For decision support, we bias on the risk of confirmed cases (μ_C) as it is the ground-level indicator of infectivity. Values of μ_C roughly behaves around 0.2, 0.6 and 0.9. We take a lower barrier by setting three membership values as 0.2, 0.2 and 0.6, while an upper bound is taken with membership values 0.6, 0.9 and 0.9. The resultant lower and upper barriers are 0.043 and 0.51 respectively. Now, the decision support comes in [0,1] scale as: low-risk if $R_{ADS}<0.043$, high-risk if $R_{ADS}>0.51$, moderate-risk - otherwise. Age-classes between 20 and 49 are with high-risk and 0-4, 70-74, 75-79 and 80-and-over are with low-risk. Other age-classes remain in moderate-risk. In further

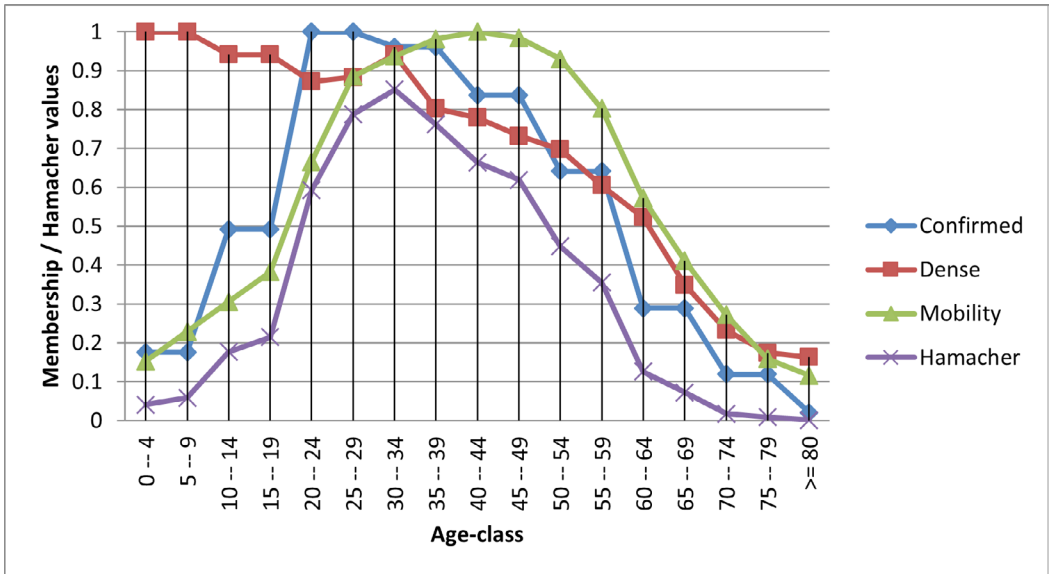

Figure 6. Membership and Hamacher values of ADS. (Labels - Confirmed: μ_C Dense: μ_D Mobility: μ_M Hamacher: R_{ADS})

simulations, one can incorporate possible changes in restrictions such as school closure to predict risk levels.

3.3. Space-specific Decision Support (SDS)

Three aspects for SDS are depicted in Figure 7 and one quantification for the risk level of each district must be obtained. Spatial autocorrelation-global effect is the first aspect and formulation of a membership function for risk is described below. We finally obtain the membership value of district d_i based on data of a particular day. District distribution of confirmed patients recorded in daily situation reports of EU-SL are utilized here.

Let c_i be the number of confirmed cases of district d_i. We take a preliminary risk as $u_i = \frac{c_i}{\max_i c_i}$, again normalizing via dividing by the maximum. Next, an intermediate entry is imposed as $v_i = u_i + rm_i u_i$. Here r stands as a relaxation parameter. A qualitative breakdown for r is given in Table 1.

The term m_i is the Moran's I value transformed into $[0,1]$ by adding 1 and dividing by 2 (Note that Moran's I usually lies in $[-1,1]$). Moran's I is obtained for each district d_i by adjusting the standard formula into the following form in (12).

$$I_i = \frac{N}{W}\frac{(c_i - \bar{c})\sum_j w_{ij}(c_j - \bar{c})}{\sum_j (c_j - \bar{c})^2} \quad (12)$$

N is the number of districts and $\bar{c} = \frac{1}{N}\sum_i c_i$, the mean of c_i's. w_{ij} is the spatial weight between district i and j. We basically set $w_{ij} = \frac{1}{n_{ij}}$ where n_{ij} represents a level of adjacency as follows. However, this can be adjusted according to user requirements. $w_{ij} = 0$ when $i = j$. Aggregation of weights is given by $W = \sum_j w_{ij}$.

Table 1. Description for relaxation parameter r

Parameter r	Description
0	No further spatial association
0.25	Travel/distancing restrictions are relaxed in local whereabouts
0.5	Travel/distancing restrictions are relaxed more than to local whereabouts
0.75	Travel/distancing restrictions are relaxed across the country, but not for unessential activities
1	Travel/distancing restrictions are fully relaxed

$n_{ij} = 1$ (if districts d_i and d_j are adjacent) - level 1 adjacency

$n_{ij} = 2$ (if district d_j is adjacent to an adjacent district of d_i) - level 2 adjacency

$n_{ij} = 3$ - level 3 adjacency, etc.

Now, the membership (μ_G) representing risk aspect of spatial autocorrelation-global effect is designed as in (13).

$$\mu_G(i) = \frac{v_i}{\max_i v_i} \quad (13)$$

Next, analogous work on spatial autocorrelation-local effect is described. Let c_i be the number of confirmed cases of district d_i

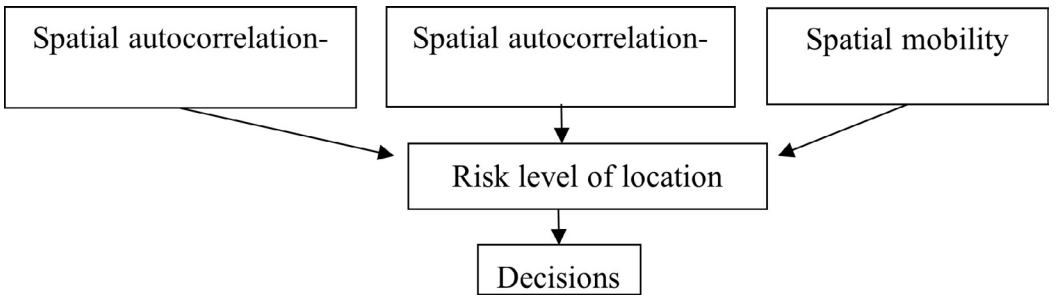

Figure 7. Aspects of space-specific decision support (SDS)

. Here also we take a preliminary risk as $u_i = \frac{c_i}{\max_i c_i}$. However, treatment on intermediate term is different as $v_i = u_i + \frac{1}{g_i} r u_i$. Here r stands for the relaxation parameter described earlier. The term g_i . is the Geary's C value obtained forh district . by adjusting the standard formula into the form in (14).

$$g_i = \frac{(N-1)}{2W} \frac{\sum_j w_{ij} \left(c_i - c_j\right)^2}{\sum_j \left(c_i - c_j\right)^2} \qquad (14)$$

Note that reciprocal $\frac{1}{g_i}$ acting for inverse proportion to the risk, where in Moran's I, it is directly proportional. This aligns with somewhat inversely related quality between Moran's I and Geary's C. Here N ., W and w_{ij} stand for the same description as for global case. Now, the membership function (μ_L) representing local spatial aspect of risk is designed as in (15).

$$\mu_L\left(d_i\right) = \frac{d_i}{\max_i d_i} \qquad (15)$$

As the third aspect, spatial mobility attraction is assumed to be associated with population density of that district and that of all the other districts in a weighted manner. Population density of a district is taken by dividing the population of that district by the total population of Sri Laa (Data source: Census of Population and Housing 2012). We are motivated to consider this since no normalization by population size is considered in earlier two aspects. We use the Gravity Model approach for attraction to district d_i as $A_i = \sum w_{ij} P_i P_j$. Here, P_i is the population density of district d_i and w_{ij} stands for spatial weights as defined above. Now, the membership function for mobility attraction is designed as in (16).

$$\mu_A\left(d_i\right) = \frac{A_i}{\max_i A_i} \qquad (16)$$

Next, membership functions representing each aspect are aggregated. The Hamacher t-norm operator for two membership functions $\mu_G\left(d_i\right)$. and $\mu_L\left(d_i\right)$ is given in (17) followed by aggregation of all three aspects in (18). Here, the subscript SDS stands for the category name Space-specific Decision Support.

$$\mu_G(d_i) * \mu_L(d_i) = \frac{\mu_G(d_i)\mu_L(d_i)}{p + (1-p)\left[\mu_G(d_i) + \mu_L(d_i) - \mu_G(d_i)\mu_L(d_i)\right]} \qquad (17)$$

$$R_{SDS}\left(d_i\right) = \left(\mu_G\left(d_i\right) * \mu_L\left(d_i\right)\right) * \mu_A\left(d_i\right) \qquad (18)$$

Table 2 shows R_{SDS} for each districtpproximately in two-week time steps from Nov 15. Districts are sorted from high-risk to low-risk. Districts with R_{SDS} less than 1st quartile are labelled as low-risk and districts with R_{SDS} higher than 3rd quartile are labelled as high-risk. Other districts are in moderate-risk. We prefer this criterion on top of lower/upper barriers in [0,1] since we guide towards risk mapping in a comparative way. We merge the two health districts Ampara and Kalmunai into Ampara as to follow administrative districts in Sri Lanka. As per experience, Kandy and Galle are assumed to be with level 1 adjacency with Colombo considering mobility attraction on top of existing adjacency. We set the relaxation parameter $r = 0.25$ aligning with prevailing conditions.

R_{SDS} should be interpreted relatively to the district having the highest risk (i.e. the district with $R_{SDS} = 1$). Therefore, R_{SDS} brings a qualitative indication compared to what is prevailing in Colombo district. Some of the highlights are; Colombo remains with the highest risk, Gampaha remains second but R_{SDS} decreases, Kalutara keeps the third but R_{SDS} increases at the latter stage, Kurunegala, Kandy, Ratnapura, Kegalle and Galle compete for the next three positions. Moreover, Ampara entered into high-risk showing a rapid increase in R_{SDS} and Mullativu keeps the last position, while Kilinochchi, Mannar, Vavunia and Trincomalee continue to be in low-risk category. Thus, a decision tool of this kind facilitates where to use travel ban and lockdown measures.

Table 2. Relative risk (R_s) of districts (Number format E refers to the power of 10. e.g. 9.55E-05 = 9.55×10^{-5})

		15-Nov, 2020		30-Nov, 2020		15-Dec, 2020		30-Dec, 2020	
		District	R_{SDS}	District	R_{SDS}	District	R_{SDS}	District	R_{SDS}
High-risk	1	Colombo	1.00E+00	Colombo	1.00E+00	Colombo	1.00E+00	Colombo	1.00E+00
	2	Gampaha	8.25E-01	Gampaha	4.41E-01	Gampaha	3.19E-01	Gampaha	3.02E-01
	3	Kalutara	1.66E-02	Kalutara	1.59E-02	Kalutara	2.28E-02	Kalutara	3.18E-02
	4	Kurunegala	4.21E-03	Kandy	3.01E-03	Kandy	7.36E-03	Kandy	8.68E-03
	5	Kandy	3.27E-03	Kurunegala	2.65E-03	Kurunegala	2.37E-03	Kurunegala	2.57E-03
	6	Kegalle	1.51E-03	Galle	7.60E-04	Ratnapura	1.23E-03	Ampara	2.14E-03
Moderate-risk	7	Ratnapura	9.76E-04	Kegalle	7.19E-04	Ampara	1.15E-03	Ratnapura	1.90E-03
	8	Galle	8.22E-04	Ratnapura	4.81E-04	Galle	8.11E-04	Galle	1.40E-03
	9	Puttalam	3.59E-04	Puttalam	2.42E-04	Puttalam	7.80E-04	Kegalle	1.15E-03
	10	Batticaloa	1.49E-04	Nuwara Elliya	2.35E-04	Kegalle	4.29E-04	Nuwara Elliya	8.26E-04
	11	Nuwara Elliya	9.90E-05	Anuradhapura	1.34E-04	Nuwara Elliya	3.90E-04	Puttalam	7.67E-04
	12	Badulla	6.55E-05	Ampara	8.72E-05	Badulla	1.64E-04	Matara	3.37E-04
	13	Anuradhapura	5.26E-05	Batticaloa	7.02E-05	Matara	9.55E-05	Badulla	1.46E-04
	14	Matale	3.30E-05	Badulla	6.28E-05	Anuradhapura	9.29E-05	Anuradhapura	9.91E-05
	15	Matara	2.97E-05	Matara	3.21E-05	Batticaloa	4.33E-05	Hambantota	4.22E-05
	16	Ampara	2.66E-05	Matale	1.98E-05	Hambantota	3.07E-05	Batticaloa	4.08E-05
	17	Hambantota	1.66E-05	Hambantota	7.20E-06	Matale	2.54E-05	Monaragala	3.56E-05
	18	Jaffna	1.09E-05	Polonnaruwa	5.61E-06	Jaffna	1.31E-05	Matale	3.09E-05
	19	Polonnaruwa	8.84E-06	Jaffna	4.41E-06	Monaragala	5.50E-06	Jaffna	2.62E-05
Low-risk	20	Monaragala	6.05E-06	Monaragala	2.95E-06	Polonnaruwa	4.32E-06	Trincomalee	1.38E-05
	21	Trincomalee	2.99E-06	Trincomalee	1.93E-06	Trincomalee	2.85E-06	Polonnaruwa	6.62E-06
	22	Vavunia	2.12E-06	Vavunia	8.44E-07	Vavunia	5.75E-07	Vavunia	1.04E-06
	23	Mannar	6.45E-07	Mannar	2.25E-07	Mannar	1.87E-07	Kilinochchi	1.56E-07
	24	Kilinochchi	5.17E-08	Kilinochchi	1.98E-07	Kilinochchi	1.65E-07	Mannar	1.20E-07
	25	Mullaitivu	5.12E-09	Mullaitivu	1.77E-09	Mullaitivu	6.76E-09	Mullaitivu	1.20E-08

As a further analysis, district distribution for next few weeks can be predicted via regression and the resultant values can be trialled in the above procedure. It will lead to identify most risky districts and plan interventions such as district border closures. Medical Officer of Health (MOH) areas can also be tested instead of districts since such smaller units would reflect precise local dynamics.

4. CONCLUSION

We bring a mathematical insight into COVID-19 related decision making via assessing risks in three categories: time-specific healthcare risk, age-specific risk and space-specific risk. Fuzzy membership functions and Hamacher *t*-norm operator are the tools used. Design of membership functions are carried out for nine aspects as three for each category. Membership values are aggregated via Hamacher *t*-norm operator to quantify overall risk of each category. In addition to the data on infectivity of COVID-19, we incorporate census data to assess potential risk. Three risk levels are designated as low-risk, moderate-risk and high-risk choosing suitable barriers on [0,1] scale of aggregated Hamacher values. These barriers can be customized according to the requirements of the user. Decisions on mitigating efforts can be drawn via these risk levels. In particular, how risky a concerned time period, which age-classes are in high-risk and most risky districts, can be overseen to decide intervention measures.

ACKNOWLEDGEMENTS

Authors acknowledge the assistance given by the Epidemiology Unit – Sri Lanka in processing data.

REFERENCES

Department of Census and Population - Sri Lanka. (2012). Census of Population and Housing 2012 – Final Report, Retrieved from http://www.statistics.gov.lk/Population/ StaticalInformation/CPH2011/CensusPopulationHousing2012-FinalReport.

Fodor, J.C. & Keresztfalvi, T., (1994). A characterization of the Hamacher family of t-norms, *Fuzzy Sets and Systems*, 65, 51–58.

Epidemiology Unit - Ministry of Health - Sri Lanka. (2020). COVID-19 Daily Situation Report, Retrieved from https://www.epid.gov.lk/web/index.php?option=com_ content&view=article&id=225&lang=en.

Health Promotion Bureau - Sri Lanka. (2020). Details of Daily PCR tests, Retrieved from https://www.hpb.health.gov.lk/en.

Ganegoda, N., Götz, T., & Wijaya, K.P. (2020). An age-dependent model for dengue transmission: Analysis and comparison to field data. *Applied Mathematics and Computation*. 388, 125538. doi: 10.1016/j.amc.2020.125538.

Jin, Y., Wu, H., Merigó, J.M. & Peng, B. (2019). Generalized Hamacher Aggregation Operators for Intuitionistic Uncertain Linguistic Sets: Multiple Attribute Group Decision Making Methods, *Information*, 10(6), 206. 10.3390/info10060206.

Liu, Y., Wang, Z., Ren, J.,Tian, Y., Zhou, M., Zhou, T., Ye, K., Zhao, Y., Qiu, Y. & Li, J. (2020). A COVID-19 Risk Assessment Decision Support System for General Practitioners: Design and Development Study, *Journal of Medical Internet Research*, 22(6). e19786. doi: 10.2196/19786.

Mardani, A., Nilashi, M., Zavadskas, E.K., Awang, S.R., Zare, H., & Jamal, N.M. (2018). Decision Making Methods Based on Fuzzy Aggregation Operators: Three Decades Review From 1986 to 2017, *International Journal of Information Technology & Decision Making*.

Massachusetts Institute of Technology. (2020). Vida Decision Support System for COVID-19. Retrieved from https://www.media.mit.edu/projects/vida-decision-support-system/overview/.

Stefanouli, M. & Polyzos, S. (2017). Gravity vs radiation model: two approaches on commuting in Greece, *Transportation Research Procedia*, 24, 65-72. doi: 10.1016/j.trpro.2017.05.069.

Wijaya, K.P., Aldila. D., Erandi, K.K.W.H., Fakhruddin, M., Amadi, M., and Ganegoda N. (2021). Learning from panel data of dengue incidence and meteorological factors in Jakarta, Indonesia, *Stochastic Environmental Research and Risk Assessment*, 35, 437–456. doi: 10.1007/s00477-020-01887-w.

World Health Organization (2020). Coronavirus disease (COVID-19) pandemic. Retrieved from https://www.who.int/emergencies/diseases/novel-coronavirus-2019.

Worldometer (2020). Reported Cases and Deaths by Country, Territory, or Conveyance. Retrieved from https://www.worldometers.info/coronavirus/.

Yu, X., Duan, J., Jiang, Y., & Zhang, H. (2020). Distinctive trajectories of the COVID-19 epidemic by age and gender: A retrospective modeling of the epidemic in South Korea, *International Journal of Infectious Diseases*. 98, 200-205. doi: 10.1016/j.ijid.2020.06.101.

Guiding the frontliners to face the pandemic: The story of preparing guidelines for Sri Lankan primary care for COVID-19

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ABSTRACT

The guidelines on COVID-19 issued by the Ministry of Health(MOH) largely focused on hospital-based care. No guideline was available for the Primary Care Physicians (PCPs). There was uncertainty among PCPs, especially the General practitioners (GPs), which led them to refrain from practicing. A group of PCPs teamed with the objective to prepare a guideline for the PCPs to face the COVID-19 pandemic.

The team extensively searched for relevant literature. Primary care friendly, locally adaptable practices were extracted with the consensus of the team. Practices acceptable to both state PCPs and private GPs were included. Document was reviewed by experts in primary care and relevant fields. The version 2 was submitted to the MOH COVID-19 guideline committee for approval hence could be included in the National Guideline portal. The guideline was revised thrice with emerging evidence and made available 'live' online in the website 'Primary Care Physicians of Sri Lanka' allowing rapid minor changes. Four versions of the guideline were prepared within the period of 6 weeks. The guideline consisted of guidance on primary care management of suspected cases, managing other patients with upper respiratory tract symptoms, follow up of COVID-19 patient after discharge, COVID-19 and mental health, home visits, handling deaths at primary care, clinic preparations and precautionary methods. An important inclusion was 'Remote Consultation'.

In addition to the positive response locally, this effort was recognized internationally as well. This guideline was able to fill the hiatus and provide guidance for the PCPs in the curative sector at the hour of need.

Key words: Family physician, General practitioner, Primary care guideline, Primary care physician, COVID-19

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1. INTRODUCTION

Sri Lanka despite being a lower middle-income country, has achieved favorable health indicators compared to its neighbors in the South Asian region. When the novel Coronavirus pandemic affected several affluent countries around the world, Sri Lanka responded with unique strategies to face the threat.

First confirmed case of Coronavirus infected person was reported from Sri Lanka on 27th January 2020 (*Coronavirus Disease 2019 (COVID-19) - Situation Report – 17.03.2020*, 2020) By 16th March 2020 there were 19 confirmed cases and the government imposed curfew in selected areas and the schools were closed. By 20th March 2020 there were 66 confirmed cases (*Coronavirus Disease 2019 (COVID-19) - Situation Report – 20.03.2020*, 2020) and island wide lockdown was imposed which continued till 11th June 2020. The first wave was successfully curtailed with strenuous contact tracing and quarantine. Yet observing the epidemic trends in the rest of the world, it was foreseen the need to arm the frontlines with necessary information, skills and logistics to fight against Coronavirus disease 2019 (COVID-19). With the second wave immerging in mid-October 2020 (*Epi-Curve of COVID 19 Patients, Sri Lanka - 06.01.2021*, 2021) the transmission followed a more steady spread despite lockdown of limited areas. By the end of first week of 2021 there were 45726 confirmed cases (*Coronavirus Disease 2019 (COVID-19) - Situation Report – 06.01.2021*, 2021) and 215 deaths due to COVID-19. As a result of timely guidance through Guidelines, academic sessions and support planned and implemented during the first wave, today with the rising incidence with COVID-19 the Primary Care Physicians (PCPs) are able to provide care for both suspected COVID and non-COVID conditions with confidence.

While in most other countries of the world, the secondary and tertiary care received the first guidance and resources, Sri Lanka gave much of the responsibility to the primary preventive healthcare teams as well. The preventive arm of primary healthcare was activated with explicit guidelines, but the curative arm of the primary health care sector lagged behind. The guidelines on COVID-19 issued by the Ministry of Health (MoH) were largely focused on hospital-based care. The initial guideline on clinical management was published as early as 6th February 2020 primarily focusing on hospital care (*Revision to Interim Summary Guidelines for Clinical Management of Patients with Novel Corona Virus*, 2020) As the number of cases increased, a wider contribution for all levels of health care was needed. Some of the recommendations in guidelines for hospitals were inappropriate for primary care settings. (*Hospital Preparedness for COVID-19 A Practical Manual*, 2020) Recommendations such as having two triage sites and a "COVID operational cell" consisting of specialists were not applicable for divisional hospitals headed by specialist Family Physicians and for other primary care settings which had even lesser facilities. The recommendations on disposing suspected patients were confusing for PCPs at grass root level as the structure and facilities differed. During the initial phase of the first wave where a country wide lockdown was implemented primary care providers at community level was advised by government to withhold services temporarily due to lack of provisions for personal protective equipment (PPE) and directives. The guidelines published overseas focused on first contact care level could not be directly adopted as the health system structure and logistics varied widely while some recommendations contradicted with MoH circulars and guidance. With the advances in knowledge and experience on COVID-19, both local and overseas guidance changed rapidly making it challenging for practicing clinicians to be updated regularly. Adding to the complexity, the local guidance applicable to primary care were confusing and lacked cohesion due to multiple guidelines and circulars issued by MoH targeting hospital-based care. Therefore a more reader friendly guideline collating the MoH recommendations relevant to PCPs, supplemented with appropriate guidance from international agencies such as World Health Organization (WHO), Center for Disease Control (CDC)

and Royal College of General Practitioners (RCGP) was a timely need.

Cornerstone of the success of Sri Lankan health systems lies with community-based health services supported by the Primary Health Care (PHC) system. At district level preventive care services are delivered through the Medical Officer of Health (MOH) and their staff catering a defined population. (Senanayake et al., 2017) These health care workers (HCW) contributed largely for mass education, implementation of COVID – 19 transmission prevention methods, screening and home quarantine. The curative services at primary care level is provided by the Outpatient departments (OPDs) of hospitals at all levels, Primary Medical Care Units (PMCU) and GPs in the private sector. With the evolution of the pandemic the secondary and tertiary level healthcare institutions focused on COVID 19 positive patients. Medical officers (MOs) at OPDs PMCUs and the GPs had to continue with first contact care to non –COVID patients and patients with COVID like symptoms. The role of PCPs were mainly to provide care for chronic diseases and non-COVID conditions and adhering to safety precautions while detecting and appropriately disposing COVID suspected patients.

There was no specific guideline available for the Primary Care Physicians (PCPs) both in the state sector primary care institutions as well as private Family Doctors/ General Practitioners. There was an uncertainty among PCPs about offering their services to their clients, especially the full-time and part-time Family Doctors/General Practitioners, which led them to refrain from practicing.

A group of PCPs from the Ministry of Health and Universities teamed together to fulfill the task of guiding the curative arm of primary care. The objective of this team was to prepare a guideline for the Primary Care Physicians, in both state and private settings, to face the COVID-19 pandemic enabling to provide care to COVID suspected and non-COVID patients while adhering to MoH recommendations.

2. METHODS AND MATERIALS/ METHODOLOGY

2.1. Team formation

First step was to form a balanced team to formulate the guideline. Out team leader took the initiative and gave the lead and invited academics and clinicians in Primary care who were keen and knowledgeable on COVID-19 and was involved in the management of these patients. The team comprised of academics from medical faculties of Kelaniya, Colombo and Eastern University and included professors to junior lecturers in Family Medicine. Members from the Government sector included Consultant Family Physicians managing Divisional Hospitals to Medical Officers managing COVID 19 patients in wards and OPDs. Part time and full time Family Physicians comprised the rest of the group. Further, to get technical help, medical officers competent in IT and software development and interested in primary care were chosen. The reviewers were a Consultant Virologist, a Professor in Public Health, a senior General Practitioner and a Consultant Physician specialized in geriatric care

2.2. The process

At the initial brain storming session, we identified different themes and subheadings to structure the guideline to suit the Sri Lankan Primary Health Care system and to support and compliment the already issued COVID 19 management guidelines, circulars and other directives from the Ministry of Health for the Health department staff.

2.3. Literature search

Literature search was done through various platforms and sources in an ongoing manner. The guideline was based only on Evidence Based Medicine. The sources of information are the WHO, the CDC, National Health Service- United Kingdom (NHS-UK), journals such as British Medical Journal (BMJ), New England Journal of Medicine (NEJM), Ministry of Health website, websites of AAFP, RACGP, CEBM and other guidelines

and directives issued by different Colleges such as Ceylon College of Physicians etc. The most challenging task was to keep up with the rapidly developing field with the availability of many publications from different sources and a situation where international guidelines were changing almost on a daily basis.

2.4. Formulation of the guideline

The team was divided into several groups and different topics were given to each group to do the literature search and formulate their part of the guideline and a deadline was given. When all sections were complete, they were compiled together and organised as one guideline. Thereafter, a consensus was reached on controversial areas, scrutinizing the recommendations and formatting with an aim of releasing an information rich, well structured, reader friendly guideline tailor-made for the PCPs.

2.5. Publishing of the Guideline

Version 1 of the guideline was formulated and contained more information for the private sector family physicians. It was presented to the College of General Practitioners of Sri Lanka and was published in the College website on 17th March 2020 under the heading "COVID-19 Outbreak in Sri Lanka; Guidance for Sri Lankan General Practitioners".

As more information became available on the modalities of spread of the virus, diagnosis and treatment, a Version 2 developed and named "COVID-19 Outbreak in Sri Lanka; Guidance for Sri Lankan Primary Care Physicians" This was approved by the Ministry of Health, Sri Lanka and released on the 25th of March 2020. In both versions, we addressed the challenges encountered by the primary care physicians in 'face to face' consultations and recommended 'remote consultations' which would be the ideal solution in a pandemic situation.

We moved to formulate the next version of our guideline using new and emerging information available in internationally and nationally published guidelines. Version 3.1 included more information than the previous version, especially on prevention, organization of a primary care setting and the management of COVID-19 patients and suspected patients in Government sector Primary Health Care institutions, in private sector settings and General Practice clinics. This was a concise guideline relevant to any primary care setting in the country.

Version 3.1 was launched and uploaded to our website the "Primary Care Physicians Sri Lanka" (https://www.primarycarephysiciansl.org/) on 23rd April 2020. Version 3.1 guideline is a "live guideline" in the PCPSL website as it is periodically updated when new information is available. A PDF format of the Version 3.1 was presented on 23rd April 2020 to the officials of the Ministry of health including the DGHS and was accepted as the guideline for Primary Care Settings of the Ministry of Health for management of COVID-19 pandemic in Sri Lanka. It was subsequently uploaded to the Ministry website with the other guidelines and directives of the Ministry on management of the COVID 19 Pandemic.

3. RESULTS

The guideline developed by the team, "COVID-19 (new Coronavirus) Outbreak in Sri Lanka; Interim Guidelines for Sri Lankan Primary Care Physicians, version 3.1" consisted of 16 chapters. These were: Introduction, Case definitions, Primary care consultation and remote consultations, History, Examination, Investigations, Treatment, Management and disposition of the suspected patients and notifications, Procedure following a close contact, Managing symptomatic patients with possible exposure, Managing other patients with upper respiratory tract (URTI) symptoms, Follow up of COVID patients after discharge, COVID-19 and mental health, Home visits, Handling deaths at primary care settings, Guidance for primary care doctors/ GPs and other staff for clinic preparation and precautionary measures.

As the condition was novel to Sri Lanka and the whole world, the chapter on introduction

discussed the characteristics of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), evolving epidemiology and its knowledge relevant to primary care doctors. Case definitions were based on MoH circular "Updated interim case definitions on covid-19 and advice on Initial management of patients" version dated 4th April 2020. Primary care doctors provide consultations for a wide range of conditions of which, respiratory tract infections are among the top in the primary care morbidity profile (de Silva & Mendis, 1998). Our guideline discouraged face to face consultations for URTI due to lack of transmission prevention measures at the initial stage of the pandemic, as well as most of the respiratory tract infections could be managed remotely as these presented at an early stage with mild symptoms. Our guideline gave a comprehensive guide on remote consultation of any condition before the patient arrived at the primary care setting with a quick reference infographic. (Figure 1, Figure 2)

History taking is very important to detect at risk patients, to diagnose and to identify the severity of the illness. A graphic representation was used to summarize the symptoms of COVID infection (*COVID-19 Symptoms Tracker*, 2019). Epidemiological characteristics of increasing vulnerability of a person to COVID-19 infection and risk factors associated with complications were described, which need to be elicited in the history. The chapter on examination emphasized, when needed to perform a primary care oriented focused examination, adhering to transmission-based precautions. The chapter on investigations described the contemporary recommendations on tests used for confirming the diagnosis of COVID-19. It also described the anticipated COVID-19 related changes in investigations commonly undertake in patients with fever and URTI symptoms. The guideline emphasized that these findings are not alternatives or even complementary for diagnostic testing using RT-PCR. All PCPs were recommended to refer all suspected cases of COVID-19 to closest or the designated hospital (as per MoH guideline), and under the chapter on treatment any medication use was discouraged as treatment or prophylaxis for COVID-19 in primary care.

Recommendations on management and disposition of COVID-19 suspected patients was based on MoH circulars (*Revision to Interim Summary Guidelines for Clinical Management of Patients with Novel Corona Virus*, 2020). The recommendations were classified according to risk category and summarized in a table for easy reference. When recommendations were adapted to suit the primary care setting, the existing infrastructure, facilities and expertise of the staff was carefully considered. Even for the private sector GPs it was strongly recommended to liaise with the regional epidemiologist, MOH of the area and the PHI.

The recommendations given for health care workers (HCW) following close contacts was based on local as well as concurrent CDC recommendations, as the local guidelines did not explicitly describe exposure risk stratification at the initial stage, neither the management in primacy care settings.

The guideline elaborated on managing URTI which cannot be compromised during the pandemic. At the time of writing version 3.1 community spread was highly unlikely. The PCPs were encouraged to do a face-to-face consultation only after triage over phone or at the entry point of the health care setting. Most importantly the document emphasized the importance of managing chronic diseases adhering to safety measure and using remote consultations when permits. Follow-up of covid-19 patients after discharge is an important role of PCPs. The guideline described how PCPs could engage, following discharge of COVID-19 patients. The chapter on COVID-19 and mental health described how to enhance mental wellbeing in persons affected by COVID-19, how to screen persons for depression and mentioned a hotline for psychiatric help. Although having a high risk of contracting the infection, the guideline did not totally discourage home visits but advised to judiciously select the most needed patients and to adhere strictly to transmission-based precautions. It was recommended to gather

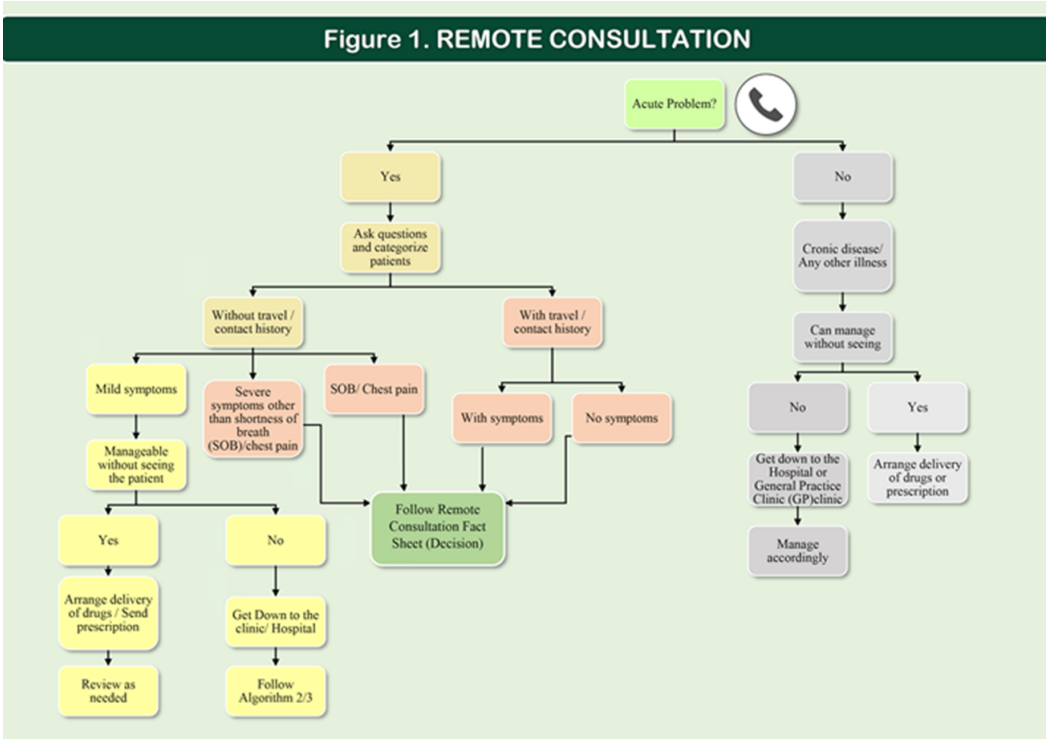

Figure 1. Remote consultation

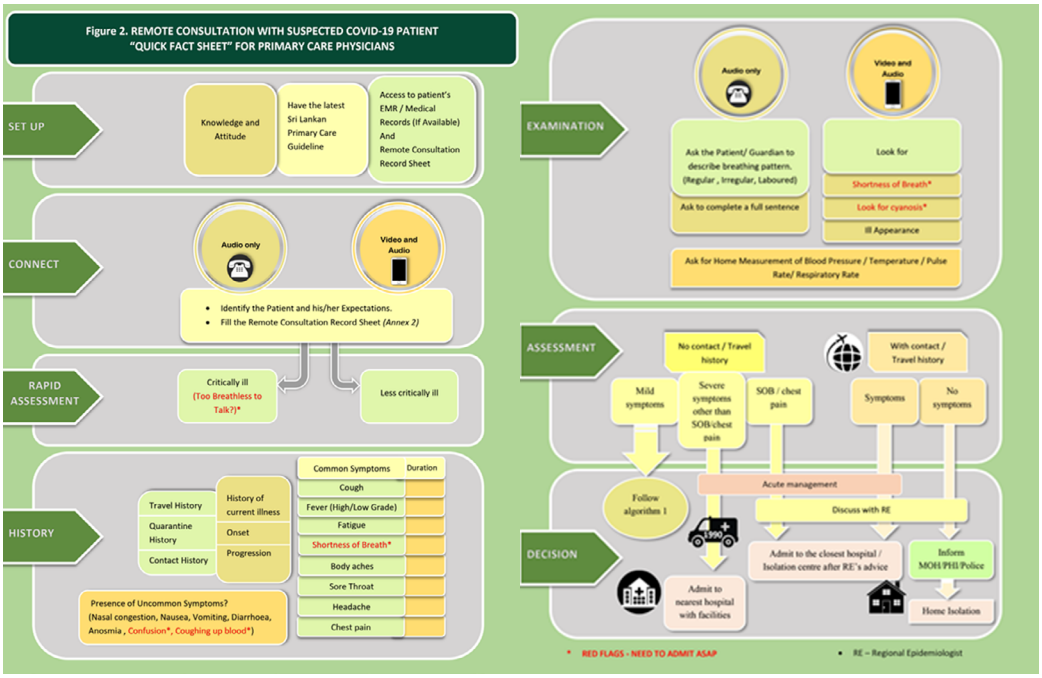

Figure 2. Remote consultation with suspected Covid-19 patient "Quick Fact Sheet" for primary care physicians

much of the information and deliver health advice remotely and use face to face time for essential examination and interventions. As home deaths could be anticipated guidance on handling deaths at primary care settings was detailed in the document.

Due to the island wide lockdown and withhold of primary care health services PCPs had to restart their clinics adapting their settings to face the new normal. This was included as an infographic with clear, easily understandable directives. It elaborated on restructuring the workplace, transmission-based precautions including personal protective equipment (PPE), waste management and self-care after work. (Figure 3).

To keep in pace with evolving information, the guideline was made available 'live' online in the website 'Primary Care Physicians of Sri Lanka' allowing rapid minor changes.

4. DISCUSSION

The primary care is an essential component in a health system of any country. In Sri Lanka, Curative Primary care is being delivered successfully for many long years in different settings in an organized manner with minimum to maximum standards. Thus, primary care delivery cannot be underestimated or ignored by any means. Rather it should be utilized to manage such health threats to the society. As such a guideline for front liners is mandatory for managing Covid-19 patients and other upper respiratory tract infections effectively. As local information relevant to PCPs were scatted over may publications, judiciously collating these to a single guideline gave the PCPs a comprehensive and all-inclusive document for reference, on managing COVID-19.

Clinical practice guidelines are statements that include evidence based recommendations intended to optimize patient care which should be feasible and achievable. (*Clinical Practice Guideline Manual*, n.d.) Guideline help to improve quality of care my promoting interventions with proven benefit (Woolf et al., 1999) Many countries with well-established primary care responded to the pandemic by providing timely guide to the frontline HCW

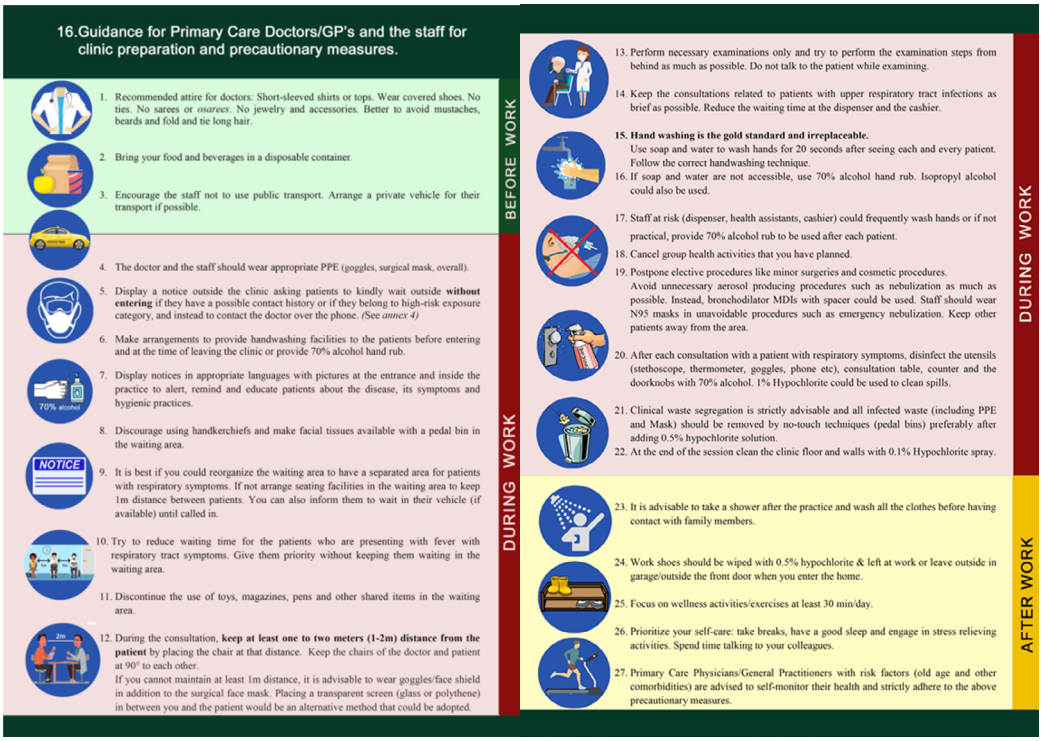

Figure 3. Guidance for primary care doctors/GOs and the staff for clinic preparation and precautionary measures

which was updated frequently(*COVID-19 Latest Guidance*, n.d.) (*RACGP - Coronavirus (COVID-19) Information for GPs*, n.d.). Hence this guideline fills a gap in the Sri Lankan context. Most of international resources were web based. With the limited technical infrastructure, the guideline was made available on https://www.primarycarephysiciansl.org with web links to relevant resources. This gave the opportunity to the PCPs to access primary care related resources on COVID-19 beyond our guideline as per individual information needs.

In response to the pandemic and in order to keep their businesses safe, GPs in some countries have rapidly moved to new models of care, incorporating telehealth and responded to uncertain availability of PPE with innovation. These changes have shown the adaptability of general practice, helped keep patients and staff safe, and reduced transmission and mortality(Wright et al., 2020). Similarly, our guideline included a comprehensive guide on conducting remote consultations considering the technical limitations in the local primary care setting.

In addition to the positive response from the Sri Lankan PCPs, this effort was recognized by international fora. Our guideline was published in Asian Preparedness Partnership web site (ADPC, n.d.). It was also included in a review, conducted in April 2020 to examine available national primary care guidelines for COVID-19(Haldane et al., 2020) which identifies only 17 such documents globally. This signifies the prompt response of our team to the situation as PCPs. After publishing the guideline, the team received an invitation from the Ariadne Labs at Harvard School of Public Health and Brigham women's hospital for an interview regarding how Sri Lanka was able to ensure access to routine and essential services using telehealth. This was published under COVID-19 promising practices.(*COVID-19 Promising Practice Sri Lanka.Pdf*, n.d.)

Abiding by the MoH guidelines/circulars is an important strength of the guideline and this prevented confusion among PCPs when implementing these recommendations at both public and private health care institutions. It created a framework to bridge primary care curative arm manned by PCPs with primary care preventive arm and secondary/tertiary care services. Guideline development group composition is an important determinant in the process of developing trustworthy guidelines(*Clinical Practice Guideline Manual*, n.d.). When preparing COVID-19 guideline for primary care, a fair representation by PCPs ensured recommendations more feasible and acceptable to grass root level clinicians.

Not adhering to some of the widely accepted principles of guideline development (*Clinical Practice Guideline Manual*, n.d.) such as inclusion of a systematic review and rating strength of recommendations is a limitation but acceptable in the current COVID 19 pandemic.

5. CONCLUSIONS

The early preparation of a comprehensive guideline for PCPs enabled smooth functioning of primary care services during the second wave, preventing a negative impact on non-COVID-19 and chronic disease management. "COVID-19 (new Coronavirus) Outbreak in Sri Lanka; Interim Guidelines for Sri Lankan Primary Care Physicians" met the national need of providing PCPs evidence based up-to-date recommendations to function effectively in the front line and manage both COVID and non-COVID conditions within the unique primary care health system.

REFERENCES

ADPC. (n.d.). *Asian Preparedness Partnership (APP)*. ADPC. Retrieved 15 January 2021, from http://app.adpc.net/publications/interim-guidelines-sri-lankan-primary-care-physicians

Clinical Practice Guideline Manual. (n.d.). AAFP. Retrieved 15 January 2021, from https://www.aafp.org/family-physician/patient-care/clinical-recommendations/cpg-manual.html

Coronavirus disease 2019 (COVID-19)—Situation Report – 06.01.2021. (2021). Epidemiology Unit, Sri Lanka.

Coronavirus disease 2019 (COVID-19)—Situation Report – 17.03.2020. (2020). Ministry of health Epidemiology Unit Sri Lanka. https://www.

epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-17-03_10.pdf

Coronavirus disease 2019 (COVID-19)—Situation Report – 20.03.2020. (2020). Epidemiology Unit Sri Lanka. https://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-20-03_10.pdf

COVID-19 latest guidance. (n.d.). Retrieved 15 January 2021, from https://www.rcgp.org.uk/covid-19/latest-covid-19-guidance-in-your-area.aspx

COVID-19 Promising Practice Sri Lanka.pdf. (n.d.). Retrieved 15 January 2021, from https://improvingphc.org/sites/default/files/COVID-19%20Promising%20Practice%20Sri%20Lanka.pdf

COVID-19 Symptoms Tracker. (2019). The Centre for Evidence-Based Medicine. https://www.cebm.net/covid-19/covid-19-signs-and-symptoms-tracker/

de Silva, N., & Mendis, K. (1998). One-day general practice morbidity survey in Sri Lanka. *Family Practice*, *15*(4), 323–331. https://doi.org/10.1093/fampra/15.4.323

epi-curve of COVID 19 patients, Sri Lanka—06.01.2021. (2021, June 1). https://www.epid.gov.lk/web/images/pdf/Circulars/Corona_virus/epi-curve_06_01_2021_2.jpg

Haldane, V., Zhang, Z., Abbas, R. F., Dodd, W., Lau, L. L., Kidd, M. R., Rouleau, K., Zou, G., Chao, Z., Upshur, R. E. G., Walley, J., & Wei, X. (2020). National primary care responses to COVID-19: A rapid review of the literature. *BMJ Open*, *10*(12), e041622. https://doi.org/10.1136/bmjopen-2020-041622

Hospital Preparedness for COVID-19 A Practical Manual. (2020, April). Google Docs. https://drive.google.com/file/d/1FD2EZpEZesnMP4qvcG7DSt2e6W8-USkN/view?usp=sharing&usp=embed_facebook

RACGP - Coronavirus (COVID-19) information for GPs. (n.d.). RACGP. Retrieved 15 January 2021, from https://www.racgp.org.au/coronavirus

Revision to interim Summary guidelines for clinical management of patients with novel Corona virus. (2020). Ministry of health. https://www.epid.gov.lk/web/images/pdf/Circulars/Corona_virus/revisionsummary.pdf

Senanayake, S., Senanayake, B., Ranasinghe, T., & Hewageegana, N. S. R. (2017). How to strengthen primary health care services in Sri Lanka to meet the future challenges. *Journal of the College of Community Physicians of Sri Lanka*, *23*(1), 43–49. https://doi.org/10.4038/jccpsl.v23i1.8092

Woolf, S. H., Grol, R., Hutchinson, A., Eccles, M., & Grimshaw, J. (1999). Potential benefits, limitations, and harms of clinical guidelines. *BMJ : British Medical Journal*, *318*(7182), 527–530.

Wright, M., Versteeg, R., & Hall, J. (2020). General practice's early response to the COVID-19 pandemic. *Australian Health Review: A Publication of the Australian Hospital Association*, *44*(5), 733–736. https://doi.org/10.1071/AH20157

Boosting immunity with vitamin D for preventing complications and deaths from COVID-19

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ABSTRACT

The severity and deaths from COVID-19 differed between countries. Northern and southern countries were most affected by the first and the second wave of COVID-19. In contrast, the third wave affects geographically restricted regions: certain south-east Asian countries, Brazil, etc. China, Singapore, South Korea, Vietnam, and Hong Kong, countries that previously experienced SARS, met the challenges effectively with better public cooperation and coordinated public health actions. There was a lack of firm policies in the west, ambiguous and politically motivated guidance from health organisations such as WHO and CDC and some governments that eroded trust. Due to the year-long sunlight, countries proximate to the equator reported low prevalence and death rates from COVID-19. Low reported deaths were unrelated to curfew but due to a combination of reasonable vitamin D levels secondary to passive exposure to sunlight, greater use of ivermectin and hydroxychloroquine, and conducting very low (5% of the needed) number of PCT testing. These led to detecting a few PCR positive cases and related deaths. We examined the published data on the impact of vitamin D on immune functions, differences in reported deaths, and cost-effective ways to prevent complications and deaths from COVID-19. Data suggests that sufficient vitamin D is the most crucial factor protecting against infection, reducing complications and deaths from COVID-19. Despite the rhetoric, considering current inequitable immunisations, relatively short-lived immunity, and high mutation rates, global herd immunity is unlikely to be achieved. Based on recent clinical studies, including RCTs, the combination of population-wide supplementation of vitamin D and safe sun exposure, wearing facemasks, and vaccination is the most effective way to keep COVID under control. Boosting and maintaining innate immunity with nutrients (e.g., vitamin D sufficiency) and acquire immunity through vaccination will facilitate having overall, strong immunity. This combined approach would be the most effective and economical way to control the pandemic. Data are pointing that just antibody-based adaptive immune responses primed by prior infection or vaccination are insufficient to prevent SARS.CoV-2 outbreaks. In the absence of such priming, the robust innate and adaptive immune systems ensure rapid recovery and a low risk of complications. This is most effective when the serum 25-hydroxyvitamin D [25(OH) D] concentration maintained over 50 ng/mL optimal immune systems function.

Key words: Coronavirus, Viral infection, Inflammation, Innate immune system, 25-hydroxyvitamin D [25(OH)D], Pandemic; SARS-CoV-2

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1. INTRODUCTION

There is a robust negative relationship between serum 25(OH)D (25-hydroxyvitamin D) concentration and clinical outcome from COVID-19 infections. In addition, clinical studies confirmed that the majority who died from COVID-19 had serum 25(OH)D concentration less than 12 ng/mL.

1.1. How much is vitamin D necessary for robust immune responses?

Scientists previously believed that the optimal immune stimulation occurs when the serum 25-hydroxyvitamin D [25(OH) D] concentration above 30 ng/mL. On the contrary, recent data confirmed that 25(OH)D concentrations higher than 50 ng/mL needed for full immune functions and protection from pathogenic microbes (Quraishi et al., 2014). This 50 ng/mL or more (at least above 40 ng/mL) serum concentration can reliably attain daily or weekly vitamin D_3 supplementation (but not more infrequently than once a month).

Most people are not getting adequate UVB rays from sunlight, either due to sun avoidance behaviour or lack of sufficient sunlight. Therefore, supplementation with the proper doses or food fortification with natural vitamin D is the way forward. These include exclusively breastfed infants, pregnant mothers, and those who are breastfeeding. However, because of too conservative doses used food fortification on its own, unable to provide adequate vitamin D supplements to achieve required levels.

Vitamin D supplementation is essential for those who live in higher and lower latitudes (42nd parallel). A few UV-B rays are reaching from sunlight for approximately six months-winter periods. Therefore, it is safer for them to consuming about 5,000 IU per day or 10,000 IU every other day without any adverse effect. However, these doses take several months to provide the required 25(OH)D blood levels. Alternatively, one can take or 50,000 IU once or twice a week, which will raise the blood levels within six weeks.

Safe sun exposure: For people with light coloured skin, one-hour daily exposure to summerlike sunlight between 10.30 AM and 1.30 PM with one-third of the skin exposed. Wearing a brimmed hat and sunglasses are strongly recommend for protecting the face and eyes. Those with melanin-rich skin require prolonged UV-B exposure daily, generally not compatible with modern lifestyles for many.

Especially during the pandemic era, the recommended daily dose is between 4,000 and 7,000 IU (average of 5,000 IU =0.125 mg) per day or 50,000 once a week for 70 kg, non-obese adult. Those who are overweight or obese require a higher intake: increase the ratio of D_3 to bodyweight. It is important to note that D_3 supplemented using these doses takes few months to build serum 25(OH) D levels. In clinical emergencies, due to immune dysfunctions, such as COVID-19, sepsis, Kawasaki disease, and Multisystem Inflammatory Syndrome, the use of such doses is not practical and ineffective.

In part, this can be overcome by upfront bolus doses of D_3, but still, it takes one to three days to convert vitamin D to 25(OH)D in the liver (a rate-limiting step). Therefore, the administration of D_3 alone is insufficient in emergencies. However, recent data confirmed that for 70 kg adults, a single oral dose of partially activated vitamin D, calcifediol (25-hydroxyvitamin D), is adequate to raise serum 25(OH)D to therapeutic level within four hours. This should be followed up with 200,000 IU vitamin D_3 (single or in divided doses over four days), provides the desired blood levels within four hours and maintain it for several weeks (Castillo, 2020).

Mentioned single-dose quantity is minimal: between 0.5 to 1.0 mg calcifediol, administered at the earliest opportunity. It rapidly boosts all immune functions and allows people to maintain serum 25(OH) D concentration. This allows to overcome microbial invasions and prevent severe complications from COVID-19. Recent clinical studies using calcifediol confirmed that this protocol reduces the complications

and deaths from COVID by ~75% (see clinical study section) (Castillo, 2020; Nogués, 2021).

1.2. Significant causes of vitamin D deficiency

The three most common causes of vitamin D deficiency are unavailability of UVB rays (e.g., winter months, air pollution), sun avoiding behaviour, and ageing-associated reduction of vitamin D synthesis in the skin. Typically, hypovitaminosis D occurs following insufficient exposure to sunlight. Examples include living in higher or lower latitudes or regions with significant air pollution, sun avoidance behaviour (Conticini et al., 2020; Ebadi & Montano-Loza, 2020; Grant et al., 2020; Martelletti & Martelletti, 2020; Zhu et al., 2020), persons with darker skin living in cooler environments, and gastrointestinal absorption difficulties. In addition, taking medications that up-regulate hepatic cytochrome P450 increases the catabolism of vitamin D: examples are anti-epileptic and anti-retroviral therapies.

Diets contain only small amounts of vitamin D. Humans are dependent on exposure to sunlight (UV-B rays) or vitamin D supplements to obtain sufficient vitamin D. Vitamin D undergoes its first 25-hydroxylation in the liver, forming calcifediol (calcidiol): [25-hydroxyvitamin D; 25(OH)D]. Hepatic 25-hydroxylation catalysed by enzyme CYP2R1 enzymes (2–4). The steps of activating vitamin D illustrated in Figure 1.

25(OH)D is the main form of vitamin D in circulation and storage. It has a half-life of approximately three weeks at healthy levels, such as 50 ng/mL. Vitamin D blood tests measure the concentration of 25(OH)D circulating in the bloodstream.

25(OH)D is the proper measure of vitamin D sufficiency. Blood $1,25(OH)_2D$ concentration should not be measured to assess the vitamin D status. . There is no known function of 25(OH)D, apart from being the precursor for forming the hormonal and intracellular form of calcitriol. Circulating 25(OH)D concentration determines the amount and how this precursor enters into targets cells to produce intracellular calcitriol, which is crucial for immune functions.

1.3. Formation of active 1,25(OH)2D (calcitriol)

The best-known system is the kidneys, converting 25(OH)D into feedback-controlled, low concentrations of circulating calcitriol that diffuses back into the circulation: after

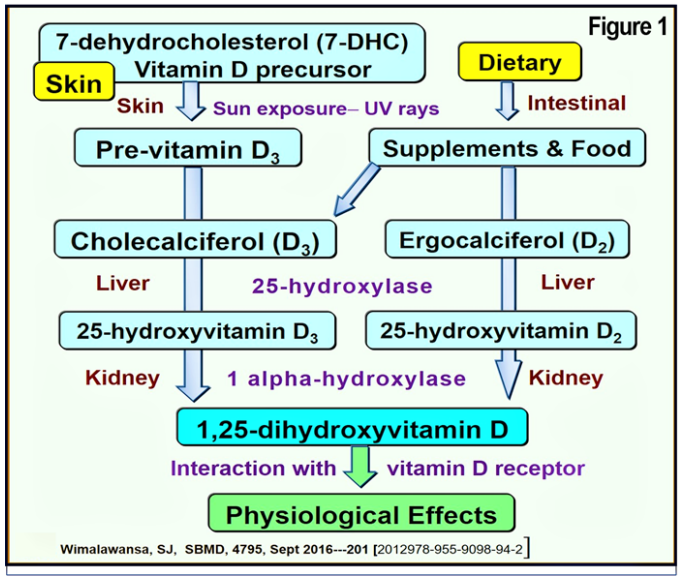

Figure 1.

here called 1,25$(OH)_2$D. This circulating 1,25$(OH)_2$D acts as a hormone (an endocrine signalling agent). The circulatory calcitriol (the hormonal form) concentration is control by the kidneys. Its primary functions are intestinal and renal tubular calcium absorption: together with parathyroid hormone, it modulates bone metabolism and skeletal/cartilage calcification.

The second system, which is not widely known, is the distant actions generated via target cell generated intracellular calcitriol. Here, we only concentrate on the step by immune cells. Circulatory 25(OH)D enters into the cytosol of immune cells through diffusion from the circulation. In extra-renal tissues, as in immune cells, a cytochrome P450 enzyme CYP27B1 (1α-hydroxylase) converts 25(OH)D into 1,25$(OH)_2$D (5).

Active vitamin D, 1,25$(OH)_2$D binds to vitamin D receptor (VDR), a nuclear receptor family of ligand-regulated transcription factor (Bishop, Ismailova, Dimeloe, Hewison, & White, 2020). This interaction leads to most physiological effects of calcitriol through selectively regulating gene transcription (Christakos et al., 2016). In addition, target tissues such as immune cells also contain CYP24A1 enzyme that catabolise 25(OH)D and 1,25$(OH)_2$D into inactive compounds; a built-in negative feedback loop to prevent the excess generation of calcitriol (Bishop et al., 2020). Important to note a significant biological difference between the hormonal calcitriol and that generated within the target tissue cells.

1.4. Autocrine and paracrine functions of calcitriol

Intracrine/autocrine synthesis of 1,25$(OH)_2$D by macrophages and dendritic cells increase the expression of anti-microbial proteins, such as cathelicidin (LL37), and suppression of hepcidin enhances autophagy. Besides, calcitriol mediates several T-cell responses, including suppressing inflammatory T helper (Th)1 and Th17 cells and stimulating T-regulatory responses that enhance immunotolerance while preventing autoimmunity (Bishop et al., 2020).

As an autocrine signalling agent, it interacts with the intracellular VDR molecules: 1,25$(OH)_2$D-VDR complexes enter the nucleus, binds to DNA strands, and up-or down-regulate dozens of genes, thus altering the cell's behaviour. The type of genes modulated by calcitriol varies between the type of cells. For optimum autocrine actions, cells need a higher concentration of 25(OH)D concentration (50 ng/mL). Insufficient production of calcitriol within immune cells rapidly weakens immune functions that increase the risks for infections. As a result, some with severe vitamin D deficiency develop the disseminated infections, hyper-immune syndromes like cytochrome storm, autoimmunity and autoimmune diseases (Cao et al., 2020; Grant et al., 2020).

Epidemiological and observational studies strongly support a protective role of vitamin D in persons with COVID-19. Until the end of 2020, most published studies were retrospective or based on small samples (Castillo, 2020; Kaufman et al., 2020; Maghbooli et al., 2020; Meltzer et al., 2020; Panagiotou et al., 2020; Zemb et al., 2020). However, many valuable clinical studies have published in recent months. These include several randomised controlled clinical studies (RCTs) using vitamin D as the intervention in persons with COVID-19. Currently, there are more than 60 adequately powered, and large RCTs are underway in multiple countries.

1.5. Prolonged and weekend curfews are ineffective in controlling COVID-19

There is no scientific rationale for intermittent curfews, including weekends, to controlling COVID-19. Such is not only ineffective in preventing community spread of SARS.CoV-2 but also increase outbreaks. Moreover, lockdowns in 2020 significantly harmed people and livelihoods and the economy. Besides, such actions increased social disharmony, unemployment, loss of livelihood, alcoholism, addiction, domestic violence, child abuse, alcoholism, robberies,

and the community spread of COVID-19 and deaths.

Another unintended consequence of curfew was restricting people to their homes that further prevented sun exposure. Therefore, lockdowns worsened the vitamin D deficiency and further increased the vulnerability to COVID-19 and developing complications. A similar thing happened when patients hospitalised for an extended period without providing nutrient supplements.

1.6. Types of lockdown that are acceptable to control COVID-19

During a pandemic or an epidemic, it is necessary to carry out extensive community surveillance and screening or diagnostic testing to identify and understand the extent and pattern of the spread of the disease. These real-time data are beneficial to make firm decisions to control the spread. Despite harm, there are occasions lockdowns are justifiable in pandemics. First, with a few cases or clusters in a limited area (smaller outbreaks), implementing geographically limited village or city limit-based lockdowns not exceeding 14 days.

Second, when there is a nationwide community spread (as happened in October 2020 and early April 2021), confining to houses and the country-wide strict travel restriction is necessary without exceptions, for not exceeding 21 days. In either case, the government must pre-arrange and ensure the availability of essential supplies, especially food, while giving a few day notices before imposing lockdowns.

When surveillance data indicate rapid community outbreaks spreading across districts suggests the need for a country-wide lockdown, but it must be done promptly. For example, in April 2021, a critical five-week delay before implementing the lockdown in Sri Lanka. That error led to a significant community spread across the entire country. Similar community spread occurred a few days after specific events. Examples include the USA, following the Memorial and Independence Day celebrations); April 2021 new-year celebration in Sri Lanka, and allowing large-scale religious festivals in India amid community outbreaks.

Following mentioned significant outbreaks, it may be necessary a country-wide lockdown for between 14 to 21 days. When data, however, indicate a lockdown, it must be implemented fully and promptly: doing so at the right time is essential. In these situations, shorter duration lockdowns are inappropriate and only increase the community spread of COVID-19.

Lockdowns drastically affect small businesses and self-employed and daily wage-earners, accounting for two-thirds of adults. It also markedly disrupted supply chains, tourism-related industries, and the national economy. The curfew also interrupted air travel, the hotel industry, and import and export trade, increasing food insecurity and imposed a significant financial burden on over 80% of the population. Therefore, the decision to lockdowns should not be taken lightly.

2. VITAMIN D DEFICIENCY, COMPLICATIONS AND PROGNOSIS OF COVID-19

2.1. Association between vitamin D intake and COVID-19 severity and deaths

Residents of nursing homes and disability centres have the worst combination of having the highest prevalence of vitamin D deficiency and multiple chronic disorders (i.e., comorbidities). Besides, they have weaker immune systems, hence, vulnerable to infections. Moreover, residents in these institutions (so as prisoners), rarely get exposed to sunlight. Consequently, this group of people are highly vulnerable to contract COVID-19 and dying from it (Bäcker A, 2020): in 2020, the mortality rate exceeded 25% in some of these centres.

Additional evidence includes that the COVID-19 fatality rates were more than double in countries (A) with a high prevalence of vitamin D deficiency, (B) located in northern

and southern latitudes, (C) have a higher percentage of elderly, and (D) among the black and ethnic minorities living in temperate regions (Bäcker A, 2020). These data strongly support hypovitaminosis D as a critical risk factor for COVID-19 infection, developing complications and death.

2.2. Ethnic minorities are at a higher risk

The intensive care (ICU) admissions and the death rates of Black, Asian, and Minority Ethnic (BAME) population living in temperate countries, such as the northern part of the USA, the UK, is over four-fold than for whites (Aldridge et al., 2020; Raisi-Estabragh et al., 2020; Trivedy et al., 2020). In addition, advanced age, chronic comorbid conditions (e.g., asthma, COPD, ischemic heart diseases, renal failure, obesity, diabetes, hypertension), and the male gender also have higher risks for developing complications and dying from COVID-19 (Ebadi & Montano-Loza, 2020; Hastie et al., 2020; Meschia et al., 2020; Temgoua et al., 2020).

Therefore, the groups mentioned above must be prioritised for treatment, including vaccination (Aldridge et al., 2020; Holmes et al., 2020). Violations of these, whether by politicians, law-enforcement officers, or administrators, must not be tolerated. In addition, the current policy and the approach by physicians not to intervene to boost patient's immunity by D_3 supplementation to achieve at least 50 ng/mL 25(OH)D is a grave mistake.

2.3. Ethnic, regional, and psychosocial differences related to hypovitaminosis D and increased mortality rates-racial disparities

Because of the routine intake of vitamin D supplementation and diets containing fatty fish, people in Scandinavian countries have a higher population average of 25(OH)D levels. Consequently, irrespective of other measures taken, the death rate is lower from COVID-19 in these countries, even though they located in northern latitudes (Bäcker, 2020). On the other hand, European countries with more significant ethnic minorities-those with melanin-rich skin (BAME groups) in the UK, Germany, and Italy, had disproportionately higher fatalities rate from COVID-19 in 2020.

There are examples of significant differences in death rates in ethnic minorities within a country. For instance, in Sweden, Somalian nationals comprise less than 1% of the total population but had 40% of deaths from COVID-19 (Brown, 2020; Osmancevic et al., 2016; Saaf et al., 2011). So, as in Muslim countries, as in Iran, Indonesia, and Middle Eastern countries (due to customs and harsh climatic conditions), women, in particular, minimise skin exposure to sunlight. This also happens in China, India, and Sri Lanka; people avoid the sun to prevent skin darkening, thus having relatively low serum 25(OH)D concentrations (Braiman, 2020).

For example, approximately 75% of suburban Indians and Chinese have low vitamin D. Hypovitaminosis D is common and is due to multiple reasons. As in India, despite plenty of sunlight, it can happen due to severe air pollution that filters out ultraviolet B (UV-B) rays. Another example is the African American population in the USA. Darker skin colour, impoverishment, and healthcare disparities have led to disproportionately high morbidity and mortality from COVID-19 (Bäcker, 2020). The underlying commonality, however, is the high prevalence of hypovitaminosis D.

Figure 2 illustrates (A) age-specific, racial disparity of infections and deaths from COVID-19 and (B) comparative hospitalisation due to COVID-19 among White, Asian and Black people in the UK and Blacks and Latinos in the USA (from, https://vitamindwiki.com).

2.4. Plausible reasons why the reported incidences and death rates were low in tropical countries

The reported deaths from SARS.CoV-2 in 2020 was unexpectedly low in tropical countries due to relatively higher population vitamin D due to inevitable sunlight exposure. Higher temperature and higher humidity

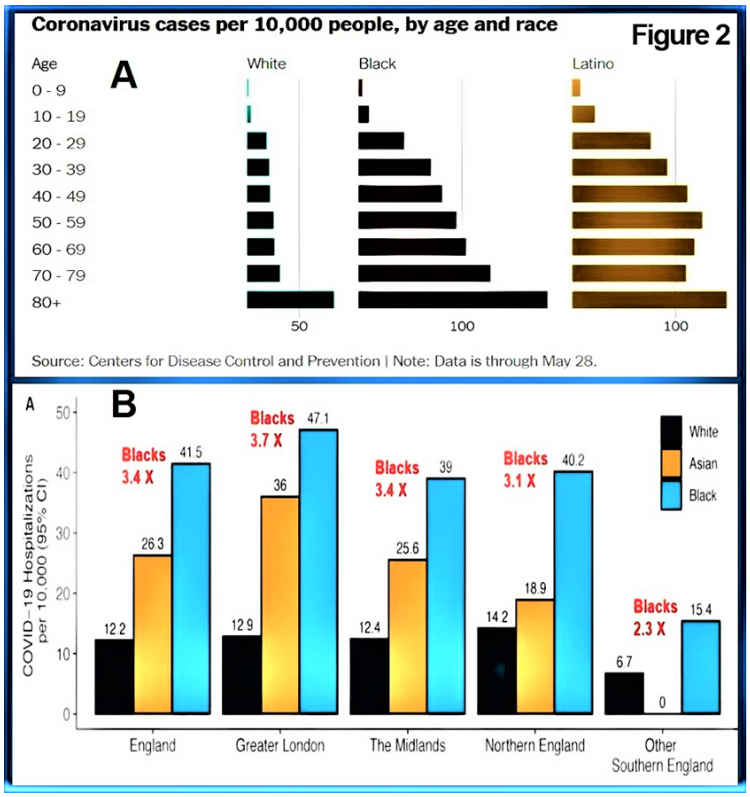

Figure 2.

are likely to reduce the community spread (Mecenas et al., 2020; Wang J, 2020), but some reports contradicted this (Auler et al., 2020). Low humidity enables exhaled droplets to dry into free-floating SARS-CoV-2 viruses, rather than the droplet and its viruses dropping to the ground quickly.

In 2020, a fewer number of PCR patients and deaths reported in south-east Ascian counties. Except for Singapore, other south-east Asian countries carried out less than 5% of PCR tests per million population than indicated. Because of the low number of testing, only a few patients detected. This erroneous policy continued till late October 2020, when they increased PCR testing to the current level. Because of the mentioned errors, Sri Lankan authorities continued falsely denying having the community spread of COVID-19. Even though data demonstrated that it had broad community spread since May 2020.

In addition to significantly low PCR testing, politically motivated coverups and statistical manipulations allowed country-wide dissemination of COVID-19 by the end of October 2020. Due to sunlight exposure, persons with severe vitamin D deficiency are few in most tropical countries. However, this is not the case in Gulf counties due to harsh climatic conditions. In these countries, severe hypovitaminosis D increased the number of people with symptomatic COVID syndrome needing ICU care, complications and deaths from SARS.CoV-2 virus (Neher et al., 2020; Wang, 2020).

Apart from Africa, most low and middle-income countries (LMICs-emerging economies and developing countries) located in the tropics. In contrast to the western-industrialised countries, LMICs have less international travel and large gatherings in confined spaces (e.g., arenas, stadiums, etc.). Moreover, percentage of younger people are higher than older people (Chung et al., 2020).

For the mentioned reasons, generally, there is a lower prevalence of COVID-19 and deaths in tropical LMICs.

2.5. Specific issues related to India and China-vulnerability to COVID-19:

Neither India nor China is considered wholly tropical countries, although both have some states and provinces deemed tropical. In these two countries, the states with higher average sunlight had lower complications and mortality rates from COVID-19 but higher mortality reported in the northern states.

In India and Sri Lanka, the third wave of COVID-19 could have mitigated if they had the right policies and taken affirmative actions timely. In contrast to Sri Lanka, air pollution is very high in cities and suburbs in India and China, which filter the UVB rays reaching the earth surface. Besides, in both countries, the prevalence of vitamin D deficiency exceeds 70% when measured by conventional standards, either with 20 ng/mL or 30 ng/mL thresholds.

No country has more than a fraction of its population with serum 25(OH)D concentrations 50 ng/mL or more, all year round: regarding the immune system, the true measure of vitamin D repletion. Unlike India, despite China has widespread vitamin D deficiency, the government has managed to control COVID-19 through strict quarantine and compulsory public health measures, and most recently with vaccination. However, the local vaccines likely to fail to control the emerging new variants of SARS.CoV-2, China is expected to see a delayed third wave spreading across the country due to mutated viruses.

India and China both have a high incidence of air pollution in suburban regions and poverty in rural areas, and a high prevalence of vitamin D deficiency. Consequently, both countries have an increased risk of getting an uncontrollable third wave of COVID-19 extending to the winter period driven by new variants [such as Beta (South African variant), Gamma (Brazilian variant), Delta (Indian variant), and future virulent strains).

In addition to being more infectious, some new mutants are less vulnerable to the antibody-mediated immunity induced by prior infection and/or by AstraZeneca and Sinopharm (or other two Chinese) vaccines. Thus, vulnerability to develop complications and deaths will be significantly high in those with vitamin D deficiency. Neither country, however, are proactively addressing this issue.

2.6. Reasons for fewer deaths in homeless people

Despite rampant malnutrition and major socioeconomic disadvantages, in many countries, such as northern parts of the USA and the UK, homeless people and farmers had significantly less symptomatic COVID-19 and deaths than those who live in the suburbs. This unexpected significant trend explained by their daily routine exposure to sunlight. A similar phenomenon observed among slum-dwellers in India and Brazil: some groups had over 50% antibodies against SARS.CoV-2, but the death rate was less than 0.2% (Yadaver, 2020).

The above-unexpected phenomena most likely due to the robust vitamin D status of mentioned groups through their outdoor lifestyles. As a result, they have a higher average serum 25(OH)D concentrations than suburban populations and better innate immunity to fight against coronaviruses. Besides high fertility rates (larger family size) and lower life expectancy, these groups have fewer elderly. Moreover, most homeless people in the USA and UK consist of African and Hispanic origin and Asians (i.e., darker skin, non-white ethnic groups). The melanin-rich skinned people who live in suburban areas in northernly located countries had a high death rate due to COVID-19. In contrast, despite having darker skin, fewer homeless people died from COVID.

2.7. Link between hypovitaminosis D and severe complications from COVID-19

In the USA, UK, and a few other countries, melanin-rich skin population racial/ ethnic groups had a significantly higher mortality rate from COVID-19 than whites (Raisi-Estabragh et al., 2020; Trivedy et al., 2020). These data should have prompted immediate public health actions to alleviate hypovitaminosis D. Instead, uninformed authorities and conflicted scientists continue to refute these data than accept them readily and take steps to rectify the root cause leading to prevent unnecessary deaths. Strengthening the population immunity through natural means significantly reduce the incidence, severity, and deaths and the need for ICU admissions(Wimalawansa, 2020c, 2020f, 2020c).

The example in Figure 3 illustrates the unique beneficial effects of exposure to UV-B rays during the summertime in the UK. So as in the USA, the rate of infection and deaths were significantly lower during the summer months of 2020: a similar effect will occur in 2021, with potential outbreaks of COVID-19 from November 2021. The reported decline of COVID-19 incidence and deaths in 2021 in the USA and UK is due to the summer effect and vaccination. Nevertheless, both administrations entirely rely on vaccines to eliminate COVID-19, which is highly unlikely to happen.

2.8. Importance of strengthening the immune system to overcome viral infections

Human immune systems depend on a balanced diet rich in vitamins (D in particular), minerals (zinc and selenium) and other essential components, such as omega-3 fatty acids (ratio), quercetin, magnesium, etc. Vitamin D deficiency weakens the innate immune system, as its driver most immune functions. It increases the vulnerability to contracting microbial infections, including viruses and developing complications.

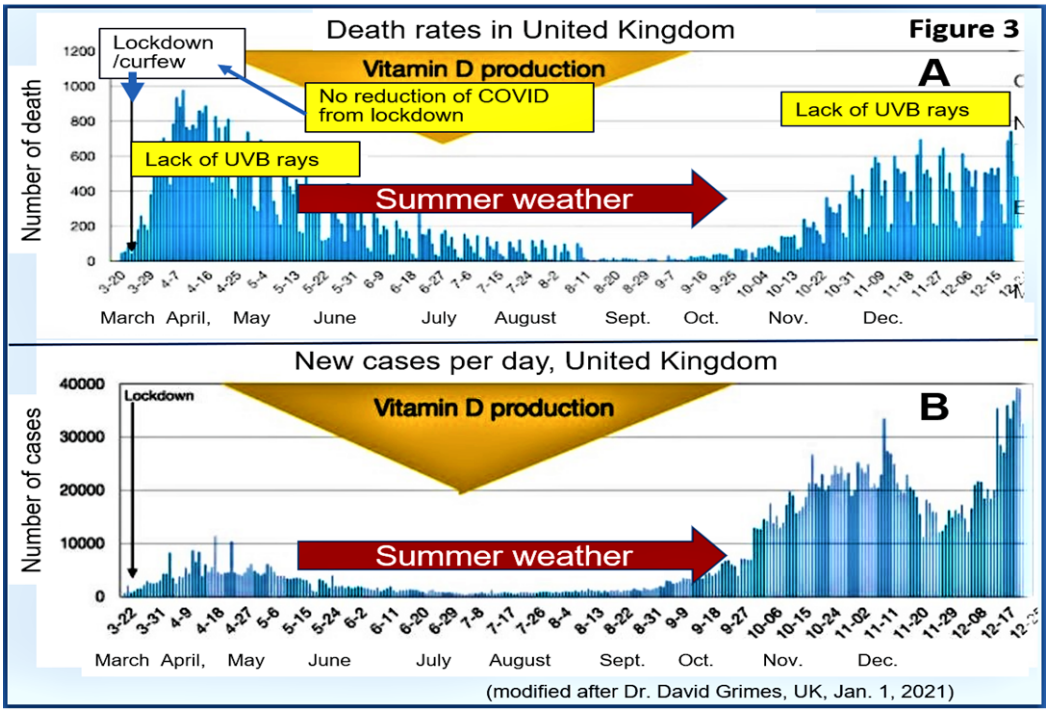

Figure 3.

Vitamin D_3 is arguably not a vitamin since people can synthesise it themselves. However, as noted above, foods, including fortified foods, do not provide adequate quantities of vitamin D. The situation aggravated due to sun avoiding behaviour and inadequate UVB exposure year-round. Thus, even a "balanced diet" does not provide vitamin D to support the immune system for most people unless supplemented with vitamin D.

The 5,000 IU per day D_3 is generally sufficient for 70 kg non-obese adult to attain these levels, yet some viewed it as a large dose due to misunderstanding. However, one IU is $1/40^{th}$ of a microgram-the amount a six-gram baby rat requires per day to avoid rickets. 5,000 IU/day or a single 50,000 IU capsule every ten days equals 0.125 mg of vitamin D a day (this equal to one gram administered, once every 22 years). Pharma grade D_3 costs $2.50 per gram, ex-factory, in 1 kg lots: so, it is not an expensive compound.

2.9. The role of vitamin D in the immune system

Innate and adaptive immunity from Immune cells, anti-inflammatory and anti-oxidative regulatory functions rely on having over 50 ng/mL circulating 25(OH)D concentration (physiological levels needed for cells). This applies to the modulatory effects of all immune cells and autocrine (within) and paracrine (adjacent) signalling systems. Therefore, serum 25(OH)D concentration is an easily monitored, excellent indicator of overall immune status.

Vitamin D dependent release of products and actions from immune cells include antibodies and anti-microbial peptides, macrophage-, dendritic cells, WBC-mediated removals of pathogens, overcoming excessive inflammation and oxidative stress. Conversely, hypovitaminosis-induced weakened immune systems (the frontline defence system) make people vulnerable to viruses, such as SARS-CoV-2 and increases the risks for developing complications and deaths.

The successful autocrine and paracrine immune signalling occurs when the serum 25(OH)D concentrations are above 50 ng/mL. Such levels not only provide the most robust and fastest possible innate and adaptive defences against pathogens. In addition, it enables Th1 lymphocytes and other types of regulatory immune cell to function correctly. In contrast, when autocrine/paracrine signalling systems fail, Th1 lymphocytes remain stuck in their initial pro-inflammatory program long after they should have switched to their anti-inflammatory shutdown program.

This failure in Th1 lymphocytes from the lungs of hospitalised COVID-19 patients - and other similar failures is arguably the cause of severe COVID-19, as the dysregulated inflammatory attack damages the pulmonary endothelium. This gives rise to hyper-coagulative blood and micro-embolism, which causes hypoxia and lead to the formation of larger clots that damage the lungs, heart, central nervous system, and kidneys. The exact molecular processes by which these Th1 lymphocytes fail, elucidated by McGregor et al. in July 2020 (McGregor, 2020).

Properly functioning immune cells also control oxidative stress by improving mitochondrial functions, suppressing the expression of inflammatory cytokines, and subduing the renin-angiotensin hormonal system (RAS) (Adams et al., 1989; Grant, Lahore, et al., 2020). Furthermore, they increase the secretion of anti-inflammatory cytokines and anti-microbial peptides, cathelicidin and defensin, while stimulating all immune cells (Antal, Dombrowski, Koglin, Ruzicka, & Schauber, 2011), including macrophages.

2.10. A lost opportunity (lessons to learn)

In mid-March 2020, we suggested to the government of Sri Lanka a comprehensive national program to accomplish the above through sun expose and vitamin D supplementation for the entire adult population. This would have cost only a half of one day's opportunity costs of curfew. Such

a program would have prevented the need for curfew entirely and associated economic calamities. Taking such proactive measures needs an understanding of the big picture. It would have mitigated most economic losses and avoided lengthy lockdown and curfews (Wimalawansa, 2020b, 2020c). Supporting primary and emerging clinical data including RCTs, and recent reviews and meta-analyses, provided strong evidence of the benefit from vitamin D supplements. However, in March 2020, we needed the knowledge to make the right decision (Wimalawansa, 2020a, 2020d, 2020e).

These include (A) a significantly higher percentage of people who died from COVID-19 had severe vitamin D deficiency, (B) countries with lower population vitamin D status (winter effect) had the highest COVID-19-related mortality, and (C) a strong, inverse linear relationship exists between lower serum 25(OH)D concentrations of individuals and the severity of complications and deaths from COVID-19 (see the section below under clinical and RCT studies) (Castillo, 2020; Kaufman et al., 2020; Maghbooli et al., 2020; Meltzer et al., 2020; Panagiotou et al., 2020; Zemb et al., 2020).

Overall data strongly suggests a significant overall benefit of population-wide vitamin D supplementation to boost and strengthen innate immunity, especially in viral epidemics and pandemic. Together with safe sun exposure guidance, and mandatory wearing of facemasks and keeping social distance, it would have the most tangible benefit on minimising the spread of COVID-19 and deaths at least cost and economic disruption (Wimalawansa, 2020c, 2020d). Mentioned interventions are, however, not mutually exclusive.

2.11. Reasons for the inability to achieve herd immunity against SARS.CoV-2

Based on data, one could envisage that strengthening the immune system of everyone would prevent (or eliminate) the infection, reduce risks of severe complications and deaths. However, it is not glamorous for politicians and administrators and is not as profitable for companies as expensive antiviral agents, monoclonal drugs, and vaccines. In contrast, vaccines strengthen a narrow area of the acquired immune system, while vitamin D predominantly strengthens the immune system as a whole at a fraction of the cost.

For several scientific reasons, we predicted that, as per the current approach by the WHO and other authorities and the greed of pharmaceutical companies refusing to relax patent rights, it would be impossible to achieve herd immunity against SARS.CoV-2. Instead of eliminating the virus, the industry wants COVID vaccines to become a profitable annual event. Thus, relying on vaccines and eliminating public health and nutritional aspects is a grave miscalculation. Instead, the most sensible approach is to achieve population vitamin D sufficiency to strengthen innate immunity and use a broader vaccination program to induce acquired immunity.

3. CLINICAL STUDIES AND RANDOMISED CONTROL STUDY DATA

Over 60 randomised clinical studies are currently registered in clinical trial registries and are in progress: results will be available in mid to late 2021. Emerging data suggest that sufficient vitamin D levels in individuals and populations would protect against infections like SARS.CoV-2 (Wimalawansa, 2020a, 2020c). Several recent prospective clinical studies reported that vitamin D supplements prevented complications (Ilie e al., 2020; Merzon et al., 2020), such as cytokine storm (Crane-Godreau et al., 2020) and deaths from COVID-19.

For persons infected with COVID-19, the need for admitting to intensive care units (ICU) was significantly (between 60 and 80%) reduced in those who are vitamin D sufficient or supplemented with high-dose vitamin D or calcifediol administered earliest possible (Castillo, 2020; Grasselli et al., 2020) (Annweiler et al., 2020; Bäcker, 2020; Cangiano et al., 2020; Castillo, 2020; Chaccour et al.,

2020; Kaufman et al., 2020; Maghbooli et al., 2020; Meltzer et al., 2020; Merzon et al., 2020; Radujkovic et al., 2020; Rastogi et al., 2020; Tan et al., 2020; Vassiliou et al., 2020). Detailed critical published studies related to vitamin D and COVID-19 are available on the following websites:

- https://vdmeta.com/
- https://vitamindwiki.com/
- https://c19study.com/d
- https://vitamind4all.org/letter.html
- https://c19ivermectin.com/
- VitaminD.Wiki-Prof.Wimalawansa-COVID overview-Dec. 2020
- https://c19study.com/
- https://aminotheory.com/cv19/#vc
- https://vitamindstopscovid.info/

3.1. The benefit of vitamin D in other viral diseases:

Vitamin D deficiency is associated with increased risks not only from COVID-19 but also from other viral illnesses. Adequate circulating 25(OH)D reduces the severity and subdued hyper-inflammatory syndrome and related complications (Guo et al., 2020; Wimalawansa, 2020b). Several studies reported that vitamin D sufficiency reduced the severity and deaths from dengue fever (Loke et al., 2002; Villamor et al., 2017), especially relevant for Sri Lanka. Others have noted that supplements of 4,000 IU for 10-days were significantly more effective than 1,000 IU in reducing dengue virus replication and controlling pro-inflammatory cytokine-induced hyper-reaction (Arya & Dwivedi, 2020). However, bolus D_3 or, better still, a single 1 mg dose of calcifediol would have been more effective in a rapid recovery from dengue and reducing complications.

Examples of highly expressed pro-inflammatory cytokines are TNF-α, INF-γ, IL-1β, IL-6, -12, -17, -19 and -33 and NFκB. The expression of inflammatory cytokines and chemokines suppressed by higher circulating 25(OH)D, zinc, and PUFAs (Story, 2021). Mentioned cytokines are released mainly from mast cells, neutrophils, dendritic cells, white cells, Th-1, -2, -18, and Treg cells, causing generalised inflammation. These inflammatory cytokines are present in high concentrations in the circulation, especially in those who are developing complications and dying from COVID-19.

Mentioned inflammatory markers could use for early identification of the worsening condition. For example, to identify those who would benefit from the administration of potent glucocorticoids. These inflammatory markers are also present in moderate levels in the circulation in ageing, uncontrolled diabetes, chronic pulmonary and cardiovascular diseases, and cancer. However, in persons with COVID-19 complications, these are at much higher concentrations than in the aforementioned conditions (Story, 2021).

4. SCIENTIFIC EXPLANATIONS FOR THE LINK BETWEEN VITAMIN D DEFICIENCY AND COVID-19 OUTCOMES

A study by Grassrootshealth reported that better clinical outcomes, including low levels of biochemical markers of inflammations, are associated with higher serum 25(OH) D concentrations. Figure 4 illustrates the vitamin D status based clinical outcomes and associations using a cut-off point of 30 ng/mL as the normal: (A) Less severe COVID-19 and lower lymphocyte counts (a marker of mild-moderate cases); (B) Less inflammation (lower CRP) and possibly reduced risk of cytokine storm; (C) 50% fewer cases of hypoxia, 84% fewer cases of unconsciousness, and 55% fewer deaths (Figure 4: after, Grassrootsthealth, 2020)

4.1. Innate immunity, vitamin D, and COVID-19

The ability to control invading microbes is dependent on robust innate immunity. In these circumstances, a rapid immune cells-mediated production of anti-microbial peptides and neutralising antibodies occur, together with chaperoning microbes to macrophage and dendritic cells to destroy them (Wang & Wang, 2004). Furthermore, the peptides defensins and cathelicidin (LL37;

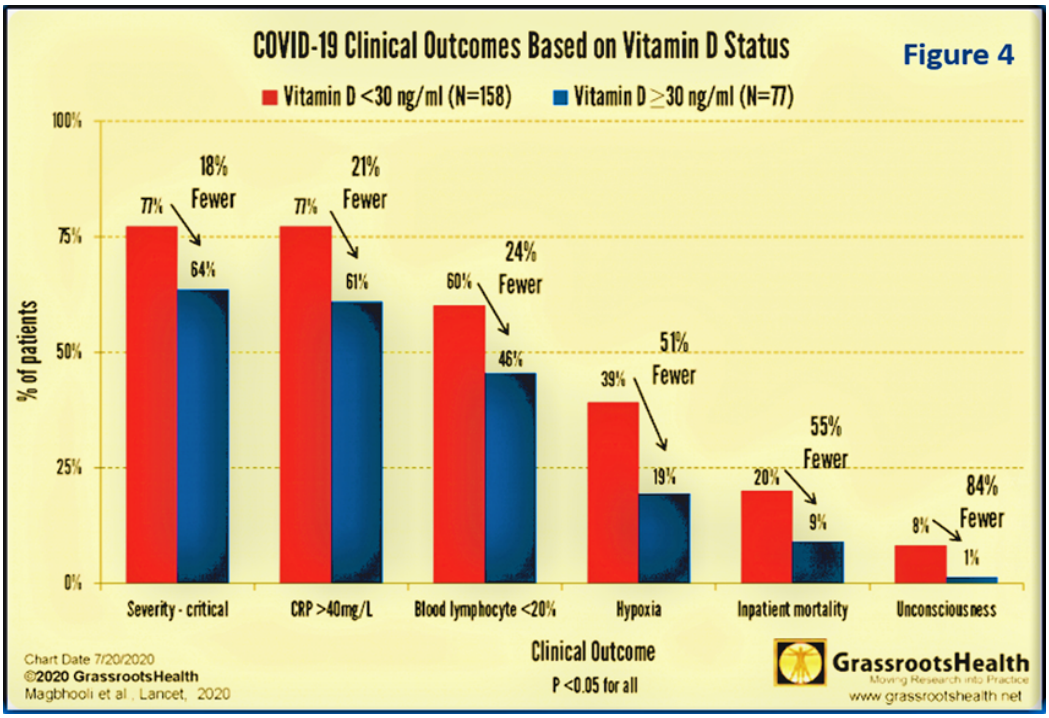

Figure 4.

a 37 amino acid cationic peptide generated by extracellular cleavage of hCAP18 protein by serine proteases) (Kahlenberg & Kaplan, 2013) neutralise the cellular invasion of COVID-19. Therefore, irrespective of age, gender, or skin colour, severe complications following COVID-19 (e.g., cytokine storm, ARDS, and death) occur at the highest among those with severe vitamin D deficiency (Crane-Godreau et al., 2020).

A previous meta-analysis (2017; a multi-country, 25 RCTs) reported favourable outcomes from viral respiratory tract infections in those with vitamin D_3 supplements (Martineau et al., 2017). In parallel, serum 25(OH)D concentrations inversely correlated with clinical outcomes from COVID-19 syndrome (El Zowalaty & Jarhult, 2020; Wimalawansa, 2020c). Persons with severe vitamin D deficiency have weak innate immunity, the highest risk of contracting COVID-19 infection (Ghasemian, 2020; Molloy & Murphy, 2020; Wimalawansa, 2020d) and dying from it (AlSafar et al., 2021).

4.2. Vitamin D enhances resistance to viral illnesses

Several clinical studies in acute respiratory tract infections have demonstrated significant clinical improvements following vitamin D supplementation (AlSafar et al., 2021; Grant, Lahore, et al., 2020; Hribar et al., 2020; Martineau et al., 2017). In addition, studies reported that higher serum 25(OH)D concentrations strengthen immune responses to seasonal and winter-associated respiratory tract infections: a significant, 50% reduction of incidence and duration of the illness (Boucher, 2012; Kumar, 2021; Sabetta et al., 2010).

Another meta-analysis revealed that 89% of persons infected with COVID-19 had low serum 25(OH)D concentrations [46% were deficient, and 43% were insufficient (Ghasemian, 2020) (https://vdmeta.com/). Furthermore, an inverse relationship reported between vitamin D status and the recovery/mortality rates from COVID-19 in different countries. Figure 5 illustrates the relationship between serum 25(OH)D concentration and

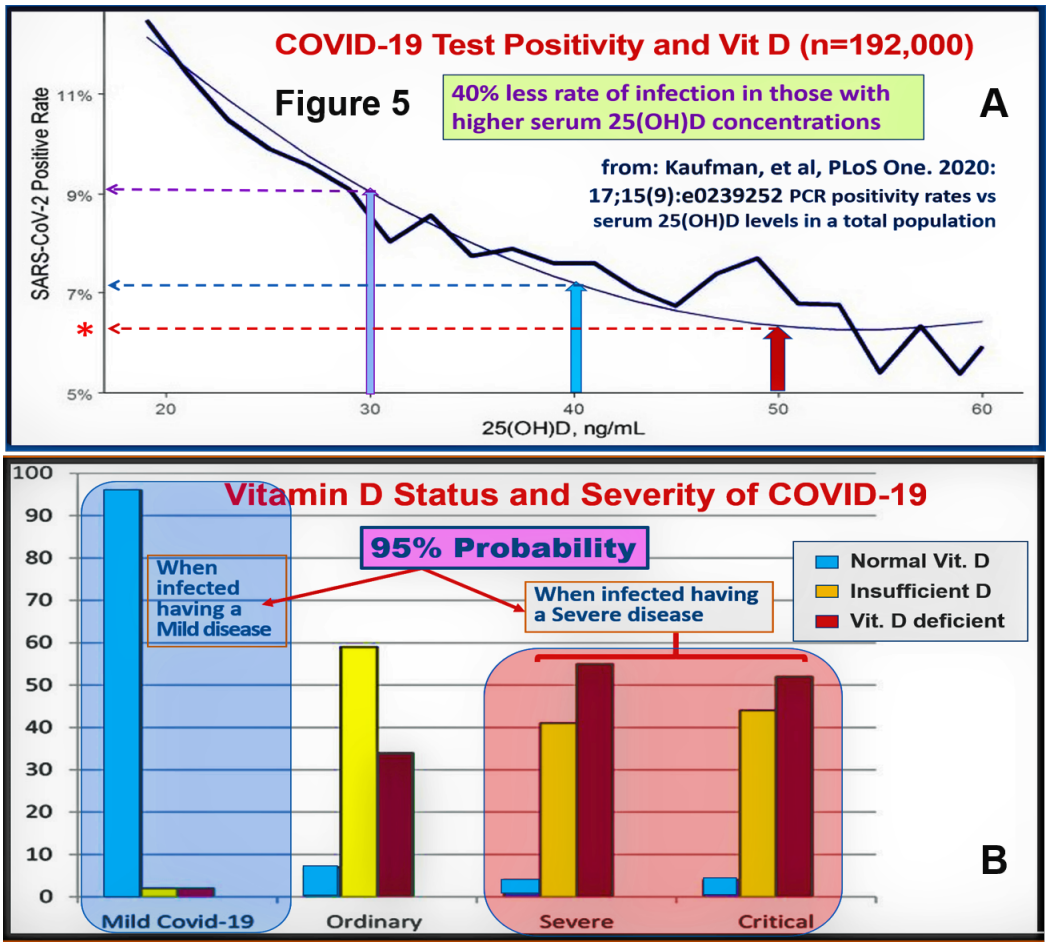

Figure 5.

(A) PCR positivity persons (i.e., increased probability of getting infected), and (B) the relationship probability of getting infected versus serum 25(OH)D status.

Acute respiratory distress syndrome (ARDS) is one of the most common lethal condition in persons with COVID-19; generally, patients develop it in ICUs: a single dose of calcifediol can prevent that (Castillo, 2020; Nogués, 2021). Moreover, 1,25$(OH)_2$D establishes a balance between lipopolysaccharide (LPS) induced damage and subdue the RAS in persons with ARDS that helps recovery (Xu, 2017).

However, to achieve such protection, the minimum serum 25(OH)D concentration needed is 40 ng/mL 100 nmol/L)(Grant et al., 2020; Holick, 2009). However, Quraishi et al. study confirmed (Quraishi et al., 2015) that in the presence of any infections, the immune functions are most effective when serum 25(OH)D concentration maintained above 50 ng/mL. As mentioned above, the dose range needed to achieve such varies between 5,000 to 10,000 IU/day (a longer-term intake need) or 50,000 IU once a week.

4.3. Most effective serum 25(OH) D concentration to overcome COVID-19

Quraishi et al. also demonstrated that the minimum serum 25(OH)D concentration necessary to generate optimum immune responses against infections is 50 ng/mL. Such sustained serum 25(OH)D concentration will maintain robust innate and adaptive responses against invading pathogens. It also prevents

pro-inflammatory responses and immune dysregulation. These data directly apply to severe COVID-19 syndrome, Kawasaki-like syndromes, multi-system inflammatory syndrome, sepsis, and ARDS. The minimum serum 25(OH)D concentration needed to control mentioned disorders is above 50 ng/mL (125 nmol/L.) (Quraishi et al., 2014) (Figure 6).

4.4. The root causes of COVID-19 complications and death

Vitamin D deficiency weakens innate and adaptive immune responses. The risk reduced to less than 2.5% (optimised immune responses) when the serum 25(OH)D concentrations are kept above 50 ng/mL. Figure 7 illustrates COVID-19 risks reported by several data sets based on circulating 25(OH)D levels.

The accepted minimal concentration of vitamin D sufficiency, as considered by the (American) Endocrine Society guidelines of 30 ng/mL developed to ensure the kidneys produce sufficient hormonal 25(OH)D. However, this concentration is not high enough to adequately diffuse into immune cells. Most patients admitted with COVID-19 have 25(OH)D concentrations between 5 and 20 ng/mL, which is insufficient for immune protection (Figure 6). Those who develop severe complications or die typically have less than 12 ng/mL (AlSafar et al., 2021; Radujkovic et al., 2020).

4.5. Vitamin D protects people from COVID-19:

Observational and retrospective clinical studies have reported strong associations between serum 25(OH)D concentration and the incidence, severity, and deaths from COVID-19 (Garg et al., 2020; Molloy & Murphy, 2020; Shiravi et al., 2020; Stohs & Aruoma, 2020). Nevertheless, there are other reasons for low serum 25(OH)D concentrations in hospitalised patients.

Above include prolonged hospitalisation or institutionalisation for any reason and lack

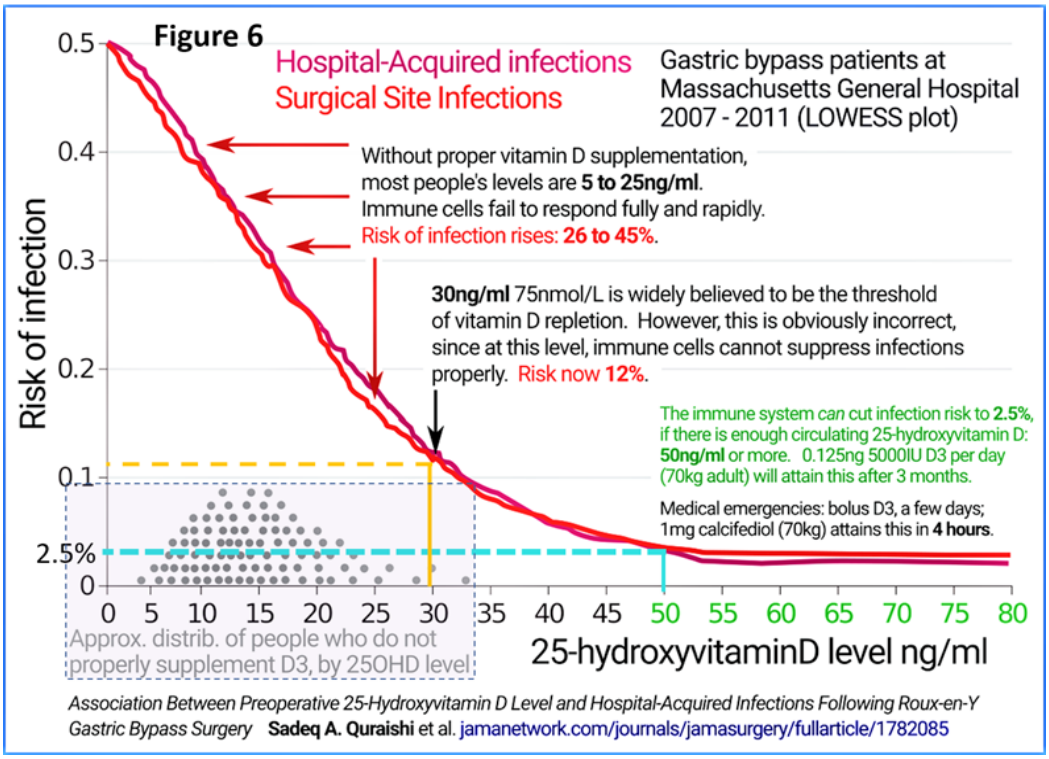

Figure 6.

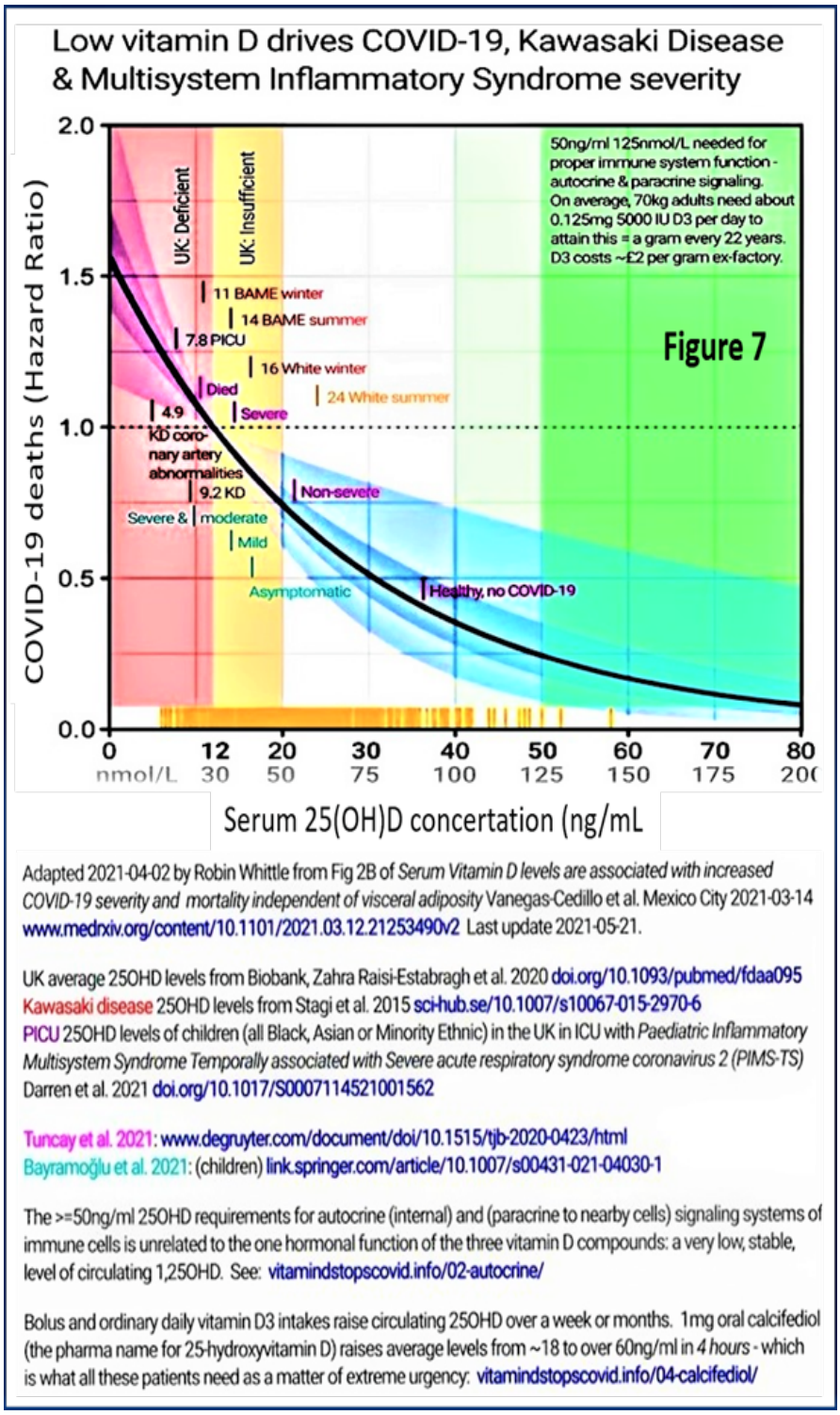
Low vitamin D drives COVID-19, Kawasaki Disease & Multisystem Inflammatory Syndrome severity
COVID-19 deaths (Hazard Ratio)
2.0
1.5
1.0
0.5
0.0
UK: Deficient
UK: Insufficient
50ng/ml 125nmol/L needed for proper immune system function - autocrine & paracrine signaling. On average, 70kg adults need about 0.125mg 5000 IU D3 per day to attain this = a gram every 22 years. D3 costs ~£2 per gram ex-factory.
11 BAME winter
14 BAME summer
7.8 PICU
16 White winter
Died
24 White summer
4.9
Severe
KD coronary artery abnormalities
9.2 KD
Non-severe
Severe & moderate
Mild
Asymptomatic
Healthy, no COVID-19
Figure 7
0 12 20 30 40 50 60 70 80
nmol/L 30 50 75 100 125 150 175 200
Serum 25(OH)D concertation (ng/mL
Adapted 2021-04-02 by Robin Whittle from Fig 2B of Serum Vitamin D levels are associated with increased COVID-19 severity and mortality independent of visceral adiposity Vanegas-Cedillo et al. Mexico City 2021-03-14 www.medrxiv.org/content/10.1101/2021.03.12.21253490v2 Last update 2021-05-21.
UK average 25OHD levels from Biobank, Zahra Raisi-Estabragh et al. 2020 doi.org/10.1093/pubmed/fdaa095
Kawasaki disease 25OHD levels from Stagi et al. 2015 sci-hub.se/10.1007/s10067-015-2970-6
PICU 25OHD levels of children (all Black, Asian or Minority Ethnic) in the UK in ICU with Paediatric Inflammatory Multisystem Syndrome Temporally associated with Severe acute respiratory syndrome coronavirus 2 (PIMS-TS) Darren et al. 2021 doi.org/10.1017/S0007114521001562
Tuncay et al. 2021: www.degruyter.com/document/doi/10.1515/tjb-2020-0423/html
Bayramoğlu et al. 2021: (children) link.springer.com/article/10.1007/s00431-021-04030-1
The >=50ng/ml 25OHD requirements for autocrine (internal) and (paracrine to nearby cells) signaling systems of immune cells is unrelated to the one hormonal function of the three vitamin D compounds: a very low, stable, level of circulating 1,25OHD. See: vitamindstopscovid.info/02-autocrine/
Bolus and ordinary daily vitamin D3 intakes raise circulating 25OHD over a week or months. 1mg oral calcifediol (the pharma name for 25-hydroxyvitamin D) raises average levels from ~18 to over 60ng/ml in 4 hours - which is what all these patients need as a matter of extreme urgency: vitamindstopscovid.info/04-calcifediol/

Figure 7.

exposure to sunlight or pre-existing vitamin D deficiency: these cascade vulnerabilities to infections. A slight reduction in circulating 25(OH)D can also arise from its consumption by immune cells during illness, especially grossly dysregulated, self-destructive/ autophagy, inflammatory responses. Figure 8 illustrates data from a recent meta-analysis from 84 clinical studies, demonstrating the efficacy of vitamin D in the early and later stages of COVID-19 (from: vdmeta.com).

In addition to the diurnal variation of serum 25(OH)D concentrations, reduced levels can also occur following severe acute illnesses, including COVID-19: this known as reverse

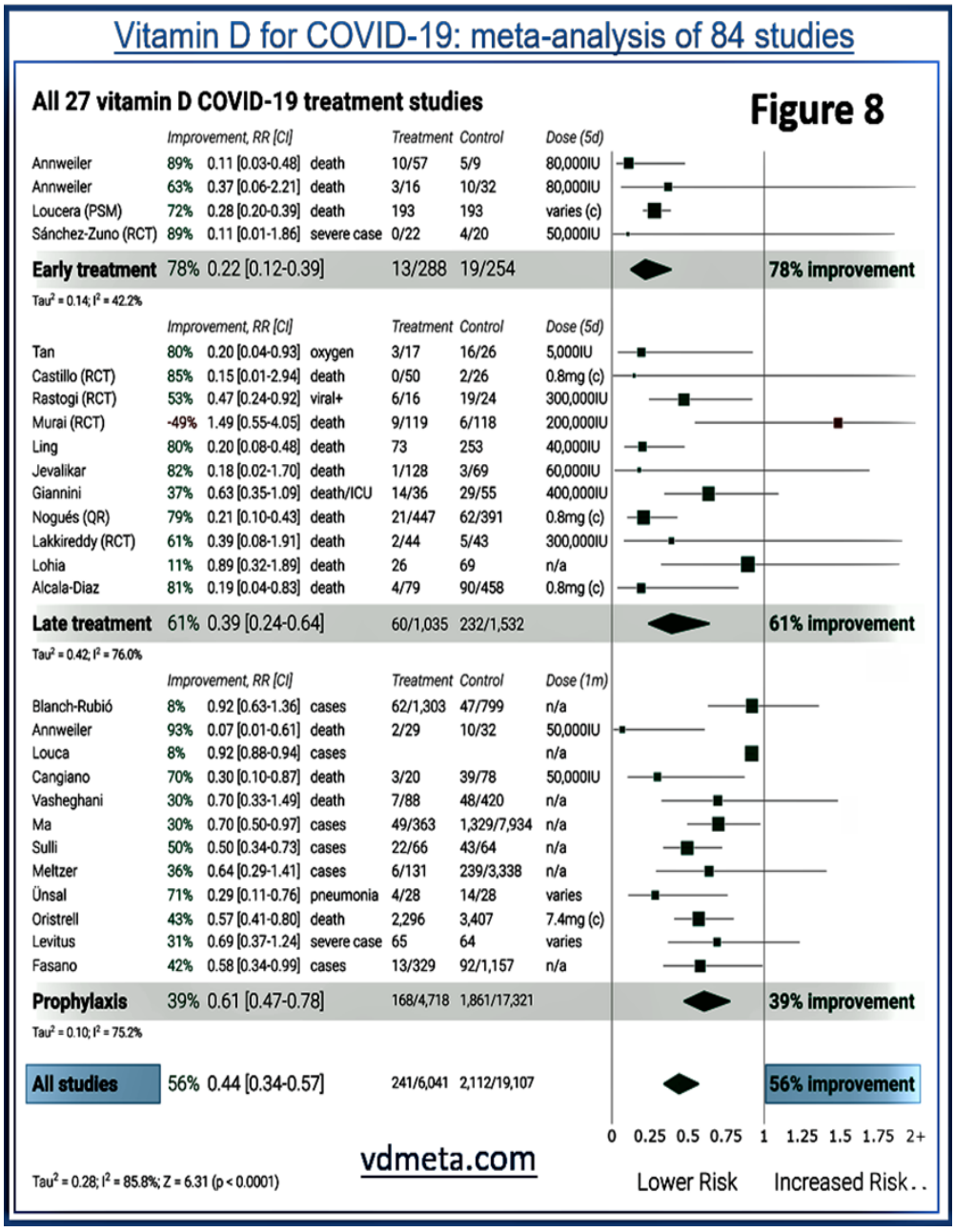

Figure 8.

causality (French et al., 2019). In addition, other acute and chronic diseases could also modulate serum 25(OH)D concentration (Hastie et al., 2020; Martineau et al., 2015). To overcome these, some suggested using the 25(OH)D concentrations measured at least two weeks before developing symptoms of COVID-19 to avoid confounders (French et al., 2019). Nevertheless, the effects of COVID-19 on lowering serum 25(OH)D concentration insignificant.

4.6. Hypovitaminosis D increases RAS activity and thus, worsen COVID-19 outcomes

In addition to lesser sun exposure, the skin's ability to produce vitamin D from UVB gradually decreases after 50 years (Gasmi et al., 2020; Grant et al., 2020). Therefore, it is common to have low serum 25(OH)D concentrations in the elderly. For example, in northern Italy and Spain, older persons have a high prevalence of severe vitamin D deficiency correlated with death rates (Saaf et al., 2011; Yousef et al., 2019). Furthermore, several studies reported that the geographic distribution of patients with severe complications from COVID-19, related to less sun exposure, has been attributed to vitamin D deficiency (Bäcker, 2020).

Consequently, above 70% of the USA nursing homes (Okan et al., 2020), developmental disability facilities (Grant et al., 2015), and institutionalised people (Wimalawansa, 2012), and those with chronic renal failure on dialysis shown to have severe vitamin D deficiency and at high risk for viral diseases (Ilie et al., 2020; Kennel et al., 2010). Because of the high incidence of severe vitamin D deficiency, 40% of deaths from COVID in the USA occurred in the above groups.

Reduced 25(OH)D concentrations are typical in those with metabolic disorders such as obesity, diabetes, hypertension, COPD, cardiovascular diseases, and those who get less exposure to sunlight. Therefore, they have a higher risk for COVID-19 and developing related complications and deaths. Besides having darker skin, synthesising vitamin D is reduced in those who live in higher and lower latitudes (Grant et al., 2020; Hastie et al., 2020). Hypovitaminosis D not only causes weaken innate immunity and aggravates common systemic diseases, such as diabetes, obesity and metabolic syndrome.

4.7. Poor COVID-19 outcomes are mostly due to hypovitaminosis D

Evidence of point toward a strong association between vitamin D status and COVID-19 complications and mortality. Despite mounting evidence, many governments, medical associations, and some sponsored scientists downplay the beneficial role effects of vitamin D in COVID syndrome due to conflicts of interest. Either they dismiss by stating that there is no evidence of vitamin D benefits or unwilling to recommend vitamin D supplements.

These ill-informed sources and biased recommendations assumed that evidence to link vitamin D and COVID-19 is insufficient, theoretical, and emphasise the possible harm from the extremely low incidence of toxicity (https://vitamind4all.org/letter.html) (Hunter et al., 2020; Rhodes et al., 2020). Figure 9 illustrates the effectiveness of vitamin D in different states of COVID-19 syndrome.

5. UTILISING VITAMIN D AS A PROPHYLACTIC AND THERAPEUTIC TOOL

5.1. Minimum serum levels of vitamin D needed to overcome disorders

Research suggests that 40-60 ng/mL is needed to prevent non-musculoskeletal, including viral respiratory infections. Others recommend maintaining concentrations between 50-80 ng/mL to reverse hypertension and cardiovascular diseases [47] and minimise infections (Quraishi et al., 2014). In a randomised controlled trial, subjects with vitamin D insufficiency who took 10,000 IU/day for three years did not develop any adverse effects (Burt et al., 2019).

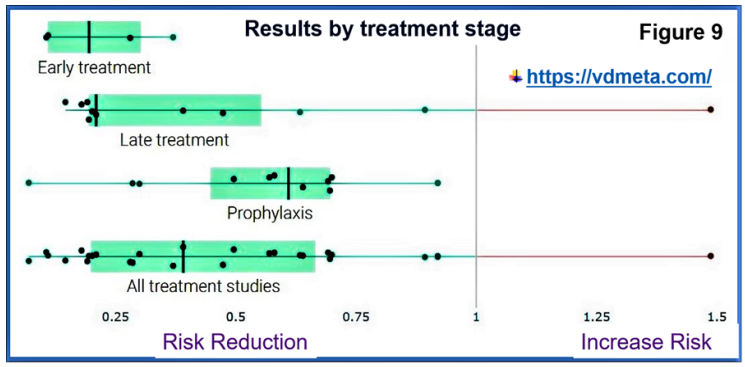

Figure 9.

While 400 IU/day treated group did not increase the mean 25(OH)D concentrations, those who took 4,000 and 10,000 IU/day increased their serum levels by 53 ng/mL and 58 ng/mL, respectively (Burt et al., 2019). Another meta-analysis of vitamin D supplementation indicated that long-term daily supplementation of vitamin D, 5,000 IU/day was safe and effective in preventing acute respiratory infections (Kakodkar et al., 2020; Martineau et al., 2017). Table 1 summarised outcomes from 131 clinical studies, intervene with vitamin D in persons with COVID-19, up to the end of April 2021.

5.2. Potential Adverse Effects of Vitamin D

Vitamin D toxicity occurs only in serum concentrations above 150 ng/mL and associated with hypercalcemia-related signs and symptoms (Hribar et al., 2020; Marcinowska-Suchowierska et al., 2018) (Kimball et al., 2017). Historically, toxic levels of vitamin D have almost exclusively resulted from industrial errors (inaccurate doses of supplements) and a few cases of deliberate overuse. Stopping the supplement and maintaining hydration is generally adequate to reverse the situation (Lim & Thadhani, 2020; Spiller et al., 2016).

Because of the built-in safety mechanism, exposure to sunlight will not cause vitamin D toxicity. A 24-hydroxylase enzyme, CYP24A1, inactivates high levels of vitamin D, 25(OH)D, or 1,25(OH)2D produced. A self-limiting, protective mechanism. The naturally acquired average blood 25(OH)D concentrations among traditionally living Masaai pastoralists and Hadzabe hunter-gatherers in equatorial Africa is 46 ng/mL (Kimball et al., 2017).

Table 1.

Type of Clinical Study (131 vitamin D studies)	# of Studies	# of Patients	% Improvement	Range (%)
Treatment RCTs	5	482	45	17 - 74
Treatment studies	27	25,148	56	43 -66
Cholecalciferol (D_3) Rx	22	17,608	49	35 - 60
Calcifediol + D_3 Rx	5	7,540	70	52 - 82
Reducing deaths (mortality	15	9,363	67	50 - 78
Sufficiency studies	57	32,205	56	47 - 64

Modified from ,: Vitamin D for COVID-19: real-time meta analysis of 84 studies (vdmeta.com)

To develop toxicity, one needs to consume extraordinarily high amounts, such as over 40,000 IU/day for many months or a couple of years, reaching serum 25(OH)D concentration over 150 ng/mL. Following accidental or suicidal attempts that cause toxic levels (Lowe et al., 2011). However, the diagnosis of vitamin D toxicity is made only in the presence of hypercalcaemic signs and symptoms (Hribar et al., 2020; Lim & Thadhani, 2020).

Most people can maintain serum concentration above 30 ng/mL by ingesting vitamin D doses between 2,000 and 6,000 IU/day. However, those who are obese, taking anti-epileptic or anti-retroviral agents, or genetic or gastrointestinal absorption abnormality, requiring much higher doses, such as over 10,000 IU per day, maintain serum concentrations above 30 ng/mL (Kimball et al., 2017).

5.3. Ways to boost innate immunity in emergencies like the COVID-19

Since diet provides little vitamin D, it must either be generated following sunlight exposure or ingested as supplements. Standard daily oral doses, such as between 2,000 and 5,000 IU, take several months to raise circulating 25(OH)D to the required level. Therefore, in emergencies, it is necessary to consume upfront higher doses to attain this level as soon as possible. Suggested amounts are between 100,000 and 400,000 IU as single or divided doses over a few days. Even then, it takes two to five days to raise serum 25(OH)D concentration. Therefore, such loading doses will maintain the serum 25(OH)D concentrations for between two to four months.

Another approach to rapidly raising 25(OH)D is to take 50,000 IU (or 60,000 capsules in India) daily for 5 to 7 days, followed by the same maintenance dose, weekly or biweekly. Irrespective of the amount administered, a daily maintenance dose of 5,000 IU/day or 50,000 IU weekly every other week is necessary to maintain serum 25(OH)D levels. Those who are obese, have gastrointestinal problems, including gastric bypass surgery, or taking medications that enhance catabolism of vitamin D, need two to four-fold higher daily doses to maintain the required serum 25(OH)D concentration (Swami et al., 2011; Wimalawansa et al., 2017).

Because of the inability to maintain serum 25(OH)D concentration, administering doses less frequently than once a month should be avoided. However, daily or weekly administration of vitamin D supplementation have significant benefits ($p<0.001$) for persons with severe deficiency [i.e., baseline 25(OH)D concentrations less than 10 ng/mL] even when compared to those with vitamin D insufficiency ($p<0.02$) and infrequent administration (Martineau et al., 2017).

Clinical studies reported that vitamin D supplementation is exceptionally safe, even when using short-term high doses and longer-term moderate doses (Martineau et al., 2017). However, clinical investigations must be conducted based on the serum 25(OH)D concentrations achieved, not the amount of vitamin D administered or consumed (Fabbri et al., 2020; Haq et al., 2018; Pludowski et al., 2018; Wimalawansa et al., 2017).

5.4. Randomised control clinical trial on prevention of COVID-19 in Sri Lanka

Previous studies reported that vitamin D supplements prevent acute respiratory tract infections, reduce the severity [66], and have a dose-related effect on subduing respiratory infections (Martineau et al., 2017). Also, vitamin D deficiency increases the severity of acute respiratory infections and mortality in children and adults (Esposito & Lelii, 2015; Martineau et al., 2017). Vitamin D also exerts a broader immunomodulation function (Chirumbolo et al., 2017) and improves defences by suppressing anti-microbial peptides in response to vitamin D (Han et al., 2017).

The innate immune system is activated within two to three days of administration of high doses of vitamin D and protects from

viral respiratory tract infection. Therefore, we hypothesised that high-dose vitamin D reduces the incidence, morbidity, and mortality from COVID-19 infection. Furthermore, with its known efficacy in reducing the risks of respiratory viral diseases, data support that this approach to control COVID-19 is highly cost-effective (Wimalawansa, 2020a). However, to achieve the intended benefits, serum 25(OH) D concentration be raised quickly to boost the innate immune system (Wimalawansa, 2020c), necessitating the administration of upfront higher doses.

Therefore, based on the need, we designed two randomised control trials (RCTs) to evaluate cost-effective ways of preventing and treating persons with COVID 19. The prevention study was to be at selected quarantine centres in Sri Lanka, enrolling 2,000 subjects. This RCT was designed to assess whether using a single dose of vitamin D, 400,000 IU, would significantly reduce people getting infected with COVID-19 at the quarantine centres. This RCT would have been the first COVID prevention study in the world.

The second study was designed to evaluate the comparative efficacy of approved agents, vitamin D, hydroxychloroquine, and ivermectin in the early stages of COVID-19. In addition, clinical outcomes of the mentioned three active groups to compare with a group that received a placebo. Based on the Power Analysis, the goal was to recruit 900 PCR positive subjects per group (total n=3,600): at the "early" stage of the disease, admitted to the IDH hospital. It was the first and the largest COVID hospital in Sri Lanka.

Both studies had adequate statical power to achieve the primary endpoints with confidence. We sought ethical approval (ERC/IRB) from the Sri Lanka Medical Association and the national medical regulatory authority (NMRA). Moreover, administrative permissions sought from the heath minister/secretary, director of health, director at the IDH, and the director of the COVID task force to conduct the mentioned two RCTs. RCTs were self-funded, and there was no cost to the government or health department. To date, neither of these two RCTs formally approved by the administration. Sri Lanka missed an excellent opportunity to lead the global COVID clinical research to place it on the top of the research map.

By the end of 2020, these two complementary RCTs would have generated precious data for the world on cost-effective ways of preventing and treating COVID-19. Instead of interfering with progress and erecting barriers, governments and bureaucrats should have practical and sensible to facilitate essential clinical research in emergencies. The administrators' theme, however, was how to block the progress and not how to facilitate it. Instead of raising barriers, administrators, including review boards (ERCs) and NMRA, should seek ways to facilitate clinical research in the future.

5.5. Latest break though in the prevention of complications from COVID-19

Most recent RCTs demonstrated that chemical formulation of 25(OH)D, calcifediol (a partially activated vitamin D), can be used orally at a dose between 0.5 and 1.0 mg, that raises the serum 25(OH)D concentration by four hours, instead of an average, three days (Castillo, 2020; Nogués X., 2021). This preparation can immediately overcome the few day delays in raising the blood 25(OH) D concentration with oral vitamin D. This is a significant advance that has already been a lifesaver in persons with COVID-19. Calcifediol is available as an over-the-counter medication at a reasonable cost in many counties, including the USA, the UK, Canada, and Australia.

Calcifediol to be used when a person with PCR positive or suspected of infected with SARS.CoV-2 virus (or any other virus) admitted (i.e., at the earliest opportunity). Figure 10 illustrates the high efficacy of 0.523 mg of calcifediol in persons with moderate COVID-19 syndrome, preventing deaths (75% reduction of deaths than in the control

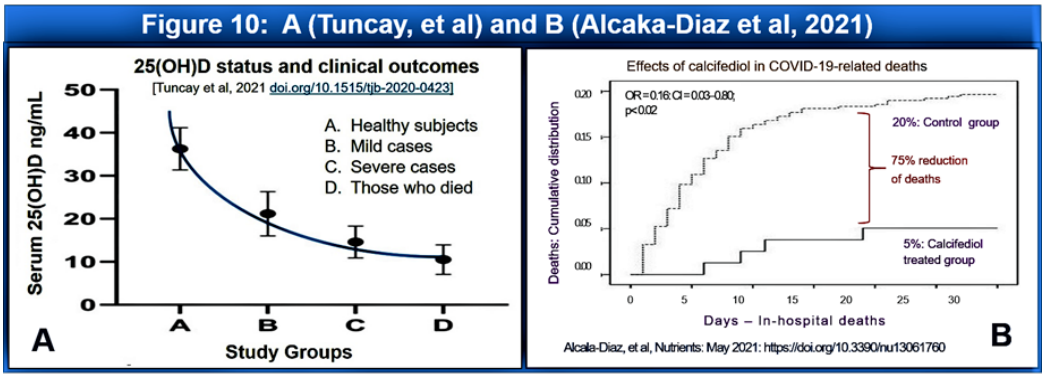

Figure 10.

group) (i.e., early and late interventions and prophylactic preventative use.

Calcifediol can be used in hospitalised patients at the time of admission or immediately after the diagnosis of SARS.Cov-2 virus, and in those with COVID-19 syndrome associate complications, as effectively demonstrated in two RCTs recently in Cordoba, Italy (Castillo, 2020) (Figure 10). Therefore, the single-dose calcifediol should be a standard (life-saving) therapy immediately after becoming PCR positive or with COVID-19 to minimise the risks of complications and deaths. This should be followed up with 200,000 IU of vitamin D (or 50,000 IU daily for four days) as a single dose or divided doses over four days to maintain the benefits of calcifediol.

6. CONCLUSIONS

Apart from avoiding exposure and reducing the viral load by using effective facemasks, the most critical strategies against COVID-19 syndrome is strengthening the immune system at the earliest possible. The first is achieved through adhering to public health measures (especially wearing protective face masks and avoid crowd gatherings), a balanced diet, physical activities, etc. A robust immune system can be achieved and maintained by taking high dose vitamin D and appropriate COVID vaccines.

Neither of these strategies requires expensive or expansion of expensive hospital equipment, protocols, quarantine centres, creating more ICU beds, task forces, or lockdowns and curfew. These expansions are needed when administrations failed to manage COVID properly. Lockdowns and curfews may temporarily reduce community exposure, as evident in Australia, New Zealand, and China, but at the expense of multiple adverse outcomes such as increased poverty, hunger, suicides, community deaths, spousal and child abuse, depression, other psychosocial factors.

This paper examined broader aspects of preventing COVID-19 using public health measures and approved cost-effective medications. Presented data overwhelmingly support and strengthen initial observations made in early 2020, that (A) those with vitamin D sufficiency rarely develop symptomatic disease or death, (B) vitamin D deficiency increases the risk of COVID-19, complications and deaths, (C) high dose vitamin D, significantly reduces the complications and deaths, and (D) 1.0 mg calcifediol is highly beneficial in preventing complications and deaths from COVID-19.

Inefficient immunity, secondary to vitamin D deficiency, causes a cascade of negative consequences following COVID-19. Meanwhile, there is no credible evidence to date that antiviral treatments, monoclonal antibodies, plasma therapy etc., have a significant effect in reducing complications and deaths. Therefore, we recommend an appropriate single dose of combined

vitamin D and calcifediol in PCR positive persons or suspected of having COVID and prevent community spread of the pandemic. Furthermore, the significant impact of using vitamin D supplementation and calcifediol together with wearing facemasks is highly cost-effective in preventing the spread of COVID-19 and reduce the severity of SARS-CoV-2.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Adams, J. S., Modlin, R. L., Diz, M. M., & Barnes, P. F. (1989). Potentiation of the macrophage 25-hydroxyvitamin D-1-hydroxylation reaction by human tuberculous pleural effusion fluid. *J Clin Endocrinol Metab, 69*(2), 457-460. doi:10.1210/jcem-69-2-457

Aldridge, R. W., Lewer, D., Katikireddi, S. V., Mathur, R., Pathak, N., Burns, R., . . . Hayward, A. (2020). Black, Asian and Minority Ethnic groups in England are at increased risk of death from COVID-19: indirect standardisation of NHS mortality data. *Wellcome Open Res, 5*, 88. doi:10.12688/wellcomeopenres.15922.2

AlSafar, H., Grant, W. B., Hijazi, R., Uddin, M., Alkaabi, N., Tay, G., . . . Al Anouti, F. (2021). COVID-19 Disease Severity and Death in Relation to Vitamin D Status among SARS-CoV-2-Positive UAE Residents. *Nutrients, 13*(5). doi:10.3390/nu13051714

Annweiler, G., Corvaisier, M., Gautier, J., Dubee, V., Legrand, E., Sacco, G., & Annweiler, C. (2020). Vitamin D Supplementation Associated to Better Survival in Hospitalised Frail Elderly COVID-19 Patients: The GERIA-COVID Quasi-Experimental Study. *Nutrients, 12*(11). doi:10.3390/nu12113377

Antal, A. S., Dombrowski, Y., Koglin, S., Ruzicka, T., & Schauber, J. (2011). Impact of vitamin D3 on cutaneous immunity and anti-microbial peptide expression. *Dermatoendocrinol, 3*(1), 18-22. doi:10.4161/derm.3.1.14616

Arya, A., & Dwivedi, V. D. (2020). Synergistic effect of vitamin D and remdesivir can fight COVID-19. *J Biomol Struct Dyn*, 1-2. doi:10.1080/07391102.2020.1773929

Auler, A. C., Cassaro, F. A. M., da Silva, V. O., & Pires, L. F. (2020). evidence that high temperatures and intermediate relative humidity might favor the spread of COVID-19 in tropical climate: A case study for the most affected Brazilian cities. *Sci Total Environ, 729*, 139090. doi:10.1016/j.scitotenv.2020.139090

Bäcker, A. (2020). Slower COVID-19 morbidity and mortality growth at higher solar Iirradiance and elevation. *Social Science Research Network, Rochester, NY*. doi:10.2139/ssrn.3604729

Bäcker A, M. M. (2020). Double COVID-19 confirmed case fatality rate in countries with high elderly female vitamin D deficiency prevalence. *Social Science Research Network, Rochester, NY*. doi:10.2139/ssrn.3623662

Bishop, E., Ismailova, A., Dimeloe, S. K., Hewison, M., & White, J. H. (2020). Vitamin D and immune regulation: antibacterial, antiviral, anti-inflammatory. *JBMR Plus*. doi:10.1002/jbm4.10405

Boucher, B. J. (2012). The problems of vitamin d insufficiency in older people. *Aging Dis, 3*(4), 313-329.

Braiman, M. (2020). Latitude Dependence of the COVID-19 Mortality Rate—A Possible Relationship to Vitamin D Deficiency? . *Social Science Research Network*. doi:10.2139/ssrn.3561958

Brown, R. A. (2020). Preventing a covid-19 pandemic-COVID-19: Vitamin D deficiency; and, death rates; are both disproportionately higher in elderly Italians, Spanish, Swedish Somali, and African Americans? A connection. *BMJ, Letter to the Editor*.

Burt, L. A., Billington, E. O., Rose, M. S., Raymond, D. A., Hanley, D. A., & Boyd, S. K. (2019). Effect of High-Dose Vitamin D Supplementation on Volumetric Bone Density and Bone Strength: A Randomised Clinical Trial. *JAMA, 322*(8), 736-745. doi:10.1001/jama.2019.11889

Cangiano, B., Fatti, L. M., Danesi, L., Gazzano, G., Croci, M., Vitale, G., . . . Bonomi, M. (2020). Mortality in an Italian nursing home during COVID-19 pandemic: correlation with gender, age, ADL, vitamin D supplementation, and limitations of the diagnostic tests. *Aging (Albany NY), 12*(24), 24522-24534. doi:10.18632/aging.202307

Cao, Z., Wu, Y., Faucon, E., & Sabatier, J. M. (2020). SARS-CoV-2 & Covid-19: Key-Roles of the 'Renin-Angiotensin' System / Vitamin D Impacting Drug and Vaccine Developments. *Infect Disord Drug Targets, 20*(3), 348-349. doi:10.2174/1871526520999200505174704

Castillo, M. E., Costa, L.M.E, Barrios, J.M.V, Diaz, J.F.A, Miranda, J.L, Bouillon, R, Gomez, J.M.,Q. (2020). Effect of calcifediol treatment and best available therapy versus best available therapy on intensive care unit admission and mortality among patients hospitalised for

COVID-19: A pilot randomised clinical study. *J Steroid Biochem Mol Biol, 203*(203), 105751, https://www.sciencedirect.com/science/article/abs/pii/S0960076020302764/. doi:10.1016/j.jsbmb.2020.105751

Chaccour, C., Ruiz-Castillo, P., Richardson, M. A., Moncunill, G., Casellas, A., Carmona-Torre, F.,Rabinovich, R. (2020). The SARS-CoV-2 Ivermectin Navarra-ISGlobal Trial (SAINT) to Evaluate the Potential of Ivermectin to Reduce COVID-19 Transmission in low risk, non-severe COVID-19 patients in the first 48 hours after symptoms onset: A structured summary of a study protocol for a randomised control pilot trial. *Trials, 21*(1), 498. doi:10.1186/s13063-020-04421-z

Chirumbolo, S., Bjorklund, G., Sboarina, A., & Vella, A. (2017). The Role of Vitamin D in the Immune System as a Pro-survival Molecule. *Clin Ther, 39*(5), 894-916. doi:10.1016/j.clinthera.2017.03.021

Christakos, S., Dhawan, P., Verstuyf, A., Verlinden, L., & Carmeliet, G. (2016). Vitamin D: Metabolism, Molecular Mechanism of Action, and Pleiotropic Effects. *Physiol Rev, 96*(1), 365-408. doi:10.1152/physrev.00014.2015

Chung, C., Silwal, P., Kim, I., Modlin, R. L., & Jo, E. K. (2020). Vitamin D-Cathelicidin Axis: at the Crossroads between Protective Immunity and Pathological Inflammation during Infection. *Immune Netw, 20*(2), e12. doi:10.4110/in.2020.20.e12

Conticini, E., Frediani, B., & Caro, D. (2020). Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy? *Environ Pollut, 261*, 114465. doi:10.1016/j.envpol.2020.114465

Crane-Godreau, M. A., Clem, K. J., Payne, P., & Fiering, S. (2020). Vitamin D Deficiency and Air Pollution Exacerbate COVID-19 Through Suppression of Antiviral Peptide LL37. *Front Public Health, 8*, 232. doi:10.3389/fpubh.2020.00232

Ebadi, M., & Montano-Loza, A. J. (2020). Perspective: improving vitamin D status in the management of COVID-19. *Eur J Clin Nutr, 74*(6), 856-859. doi:10.1038/s41430-020-0661-0

El Zowalaty, M. E., & Jarhult, J. D. (2020). From SARS to COVID-19: A previously unknown SARS- related coronavirus (SARS-CoV-2) of pandemic potential infecting humans - Call for a One Health approach. *One Health, 9*, 100124. doi:10.1016/j.onehlt.2020.100124

Esposito, S., & Lelii, M. (2015). Vitamin D and respiratory tract infections in childhood. *BMC Infect Dis, 15*, 487. doi:10.1186/s12879-015-1196-1

Fabbri, A., Infante, M., & Ricordi, C. (2020). Editorial - Vitamin D status: a key modulator of innate immunity and natural defense from acute viral respiratory infections. *Eur Rev Med Pharmacol Sci, 24*(7), 4048-4052. doi:10.26355/eurrev_202004_20876

French, C. B., McDonnell, S. L., & Vieth, R. (2019). 25-Hydroxyvitamin D variability within-person due to diurnal rhythm and illness: a case report. *J Med Case Rep, 13*(1), 29. doi:10.1186/s13256-018-1948-9

Garg, M., Al-Ani, A., Mitchell, H., Hendy, P., & Christensen, B. (2020). Low population mortality from COVID-19 in countries south of latitude 35 degrees North-supports vitamin D as a factor determining severity. Authors' reply. *Aliment Pharmacol Ther, 51*(12), 1438-1439. doi:10.1111/apt.15796

Gasmi, A., Noor, S., Tippairote, T., Dadar, M., Menzel, A., & Bjorklund, G. (2020). Individual risk management strategy and potential therapeutic options for the COVID-19 pandemic. *Clin Immunol, 215*, 108409. doi:10.1016/j.clim.2020.108409

Ghasemian, R., Amir Shamshirian, Heydari, K, Malekan, M, Alizadeh-Navaei, R, Ali Ebrahimzadeh, M, Jafarpour, H, Rezaei Shahmirzadi, A, Khodabandeh, M, Seyfari, B, Sedaghat, M, Motamedzadeh, A, Dadgostar, E, Aalinezhad, M, Behnamfar, M, Asadi, A, Zarandi, B, Razzaghi, N, Yaghoubi Naei, V, Hessami, A, Azizi, S, Mohseni, AR, Shamshirian, D. (2020). The role of vitamin D in the age of COVID-19: A systematic review and meta-analysis along with an eological approach. *medRxiv, (Preprint)*.

Grant, W. B., Al Anouti, F., & Moukayed, M. (2020). Targeted 25-hydroxyvitamin D concentration measurements and vitamin D3 supplementation can have important patient and public health benefits. *Eur J Clin Nutr, 74*(3), 366-376. doi:10.1038/s41430-020-0564-0

Grant, W. B., Lahore, H., McDonnell, S. L., Baggerly, C. A., French, C. B., Aliano, J. L., & Bhattoa, H. P. (2020). Evidence that Vitamin D Supplementation Could Reduce Risk of Influenza and COVID-19 Infections and Deaths. *Nutrients, 12*(6), 1626. doi:10.3390/nu12040988

Grant, W. B., Wimalawansa, S. J., Holick, M. F., Cannell, J. J., Pludowski, P., Lappe, J. M., . . . May, P. (2015). Emphasising the health benefits of vitamin D for those with neurodevelopmental

disorders and intellectual disabilities. *Nutrients, 7*(3), 1538-1564. doi:10.3390/nu7031538

Grasselli, G., Zangrillo, A., Zanella, A., Antonelli, M., Cabrini, L., Castelli, A., . . . Viola, U. (2020). Baseline Characteristics and Outcomes of 1591 Patients Infected With SARS-CoV-2 Admitted to ICUs of the Lombardy Region, Italy. *JAMA*. doi:10.1001/jama.2020.5394

Guo, L., Ren, L., Yang, S., Xiao, M., Chang, Yang, F., . . . Wang, J. (2020). Profiling Early Humoral Response to Diagnose Novel Coronavirus Disease (COVID-19). *Clin Infect Dis, 71*(15), 778-785. doi:10.1093/cid/ciaa310

Han, J. E., Alvarez, J. A., Jones, J. L., Tangpricha, V., Brown, M. A., Hao, L., . . . Ziegler, T. R. (2017). Impact of high-dose vitamin D3 on plasma free 25-hydroxyvitamin D concentrations and antimicrobial peptides in critically ill mechanically ventilated adults. *Nutrition, 38*, 102-108. doi:10.1016/j.nut.2017.02.002

Haq, A., Wimalawansa, S. J., Pludowski, P., & Anouti, F. A. (2018). Clinical practice guidelines for vitamin D in the United Arab Emirates. *J Steroid Biochem Mol Biol, 175*, 4-11. doi:10.1016/j.jsbmb.2016.09.021

Hastie, C. E., Mackay, D. F., Ho, F., Celis-Morales, C. A., Katikireddi, S. V., Niedzwiedz, C. L., . . . Pell, J. P. (2020). Vitamin D concentrations and COVID-19 infection in UK Biobank. *Diabetes Metab Syndr, 14*(4), 561-565. doi:10.1016/j.dsx.2020.04.050

Hastie, C. E., Pell, J. P., & Sattar, N. (2020). Vitamin D and COVID-19 infection and mortality in UK Biobank. *Eur J Nutr*. doi:10.1007/s00394-020-02372-4

Holick, M. F. (2009). Vitamin D status: measurement, interpretation, and clinical application. *Ann Epidemiol, 19*(2), 73-78. doi:10.1016/j.annepidem.2007.12.001

Holmes, L., Jr., Enwere, M., Williams, J., Ogundele, B., Chavan, P., Piccoli, T., . . . Dabney, K. W. (2020). Black-White Risk Differentials in COVID-19 (SARS-COV2) Transmission, Mortality and Case Fatality in the United States: Translational Epidemiologic Perspective and Challenges. *Int J Environ Res Public Health, 17*(12). doi:10.3390/ijerph17124322

Hribar, C. A., Cobbold, P. H., & Church, F. C. (2020). Potential Role of Vitamin D in the Elderly to Resist COVID-19 and to Slow Progression of Parkinson's Disease. *Brain Sci, 10*(5). doi:10.3390/brainsci10050284

Hunter, J., Arentz, S., Goldenberg, J., Yang, G., Beardsley, J., Mertz, D., & Leeder, S. (2020). Rapid review protocol: Zinc for the prevention or treatment of COVID-19 and other coronavirus-related respiratory tract infections. *Integr Med Res, 9*(3), 100457. doi:10.1016/j.imr.2020.100457

Ilie, P. C., Stefanescu, S., & Smith, L. (2020). The role of vitamin D in the prevention of coronavirus disease 2019 infection and mortality. *Aging Clin Exp Res, 32*(7), 1195-1198. doi:10.1007/s40520-020-01570-8

Kahlenberg, J. M., & Kaplan, M. J. (2013). Little peptide, big effects: the role of LL-37 in inflammation and autoimmune disease. *J Immunol, 191*(10), 4895-4901. doi:10.4049/jimmunol.1302005

Kakodkar, P., Kaka, N., & Baig, M. N. (2020). A Comprehensive Literature Review on the Clinical Presentation, and Management of the Pandemic Coronavirus Disease 2019 (COVID-19). *Cureus, 12*(4), e7560. doi:10.7759/cureus.7560

Kaufman, H. W., Niles, J. K., Kroll, M. H., Bi, C., & Holick, M. F. (2020). SARS-CoV-2 positivity rates associated with circulating 25-hydroxyvitamin D levels. *PLoS One, 15*(9), e0239252. doi:10.1371/journal.pone.0239252

Kennel, K. A., Drake, M. T., & Hurley, D. L. (2010). Vitamin D deficiency in adults: when to test and how to treat. *Mayo Clin Proc, 85*(8), 752-757; quiz 757-758. doi:85/8/752 [pii]
10.4065/mcp.2010.0138

Kimball, S. M., Mirhosseini, N., & Holick, M. F. (2017). Evaluation of vitamin D3 intakes up to 15,000 international units/day and serum 25-hydroxyvitamin D concentrations up to 300 nmol/L on calcium metabolism in a community setting. *Dermato-Endocrinology, 9*(1), e1300213-e1300213. doi:10.1080/19381980.2017.1300213

Kumar, R., Rathi, H., Haq, A, Wimalawansa, S.J, Sharma, A. (2021). Putative roles of vitamin D in modulating immune response and immunopathology associated with COVID-19. *Virus Res, 292*, 198235. doi:10.1016/j.virusres.2020.198235

Lim, K., & Thadhani, R. (2020). Vitamin D Toxicity. *J Bras Nefrol, 42*(2), 238-244. doi:10.1590/2175-8239-JBN-2019-0192

Loke, H., Bethell, D., Phuong, C. X., Day, N., White, N., Farrar, J., & Hill, A. (2002). Susceptibility to dengue hemorrhagic fever in vietnam: evidence of an association with variation in the vitamin d receptor and Fc gamma receptor IIa genes. *Am J Trop Med Hyg, 67*(1), 102-106. doi:10.4269/ajtmh.2002.67.102

Lowe, H., Cusano, N. E., Binkley, N., Blaner, W. S., & Bilezikian, J. P. (2011). Vitamin D toxicity due to a commonly available "over the counter"

remedy from the Dominican Republic. *J Clin Endocrinol Metab, 96*(2), 291-295. doi:10.1210/jc.2010-1999

Maghbooli, Z., Sahraian, M. A., Ebrahimi, M., Pazoki, M., Kafan, S., Tabriz, H. M., . . . Holick, M. F. (2020). Vitamin D sufficiency, a serum 25-hydroxyvitamin D at least 30 ng/mL reduced risk for adverse clinical outcomes in patients with COVID-19 infection. *PLoS One, 15*(9), e0239799. doi:10.1371/journal.pone.0239799

Marcinowska-Suchowierska, E., Kupisz-Urbanska, M., Lukaszkiewicz, J., Pludowski, P., & Jones, G. (2018). Vitamin D Toxicity-A Clinical Perspective. *Front Endocrinol (Lausanne), 9*, 550. doi:10.3389/fendo.2018.00550

Martelletti, L., & Martelletti, P. (2020). Air Pollution and the Novel Covid-19 Disease: a Putative Disease Risk Factor. *SN Compr Clin Med*, 1-5. doi:10.1007/s42399-020-00274-4

Martineau, A. R., Hanifa, Y., Witt, K. D., Barnes, N. C., Hooper, R. L., Patel, M., . . . Griffiths, C. J. (2015). Double-blind randomised controlled trial of vitamin D3 supplementation for the prevention of acute respiratory infection in older adults and their carers (ViDiFlu). *Thorax, 70*(10), 953-960. doi:10.1136/thoraxjnl-2015-206996

Martineau, A. R., Jolliffe, D. A., Hooper, R. L., Greenberg, L., Aloia, J. F., Bergman, P., . . . Camargo, C. A., Jr. (2017). Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. *BMJ, 356*, i6583. doi:10.1136/bmj.i6583

McGregor, E., Kazemian M, Afzali, B, et al. (2020). An autocrine Vitamin D-driven Th1 shutdown program can be exploited for COVID-19 *https://www.biorxiv.org/content/10.1101/2020.07.18.210161v1*.

Mecenas, P., Bastos, R., Vallinoto, A. C. R., & Normando, D. (2020). Effects of temperature and humidity on the spread of COVID-19: A systematic review. *PLoS One, 15*(9), e0238339. doi:10.1371/journal.pone.0238339

Meltzer, D. O., Best, T. J., Zhang, H., Vokes, T., Arora, V., & Solway, J. (2020). Association of Vitamin D Deficiency and Treatment with COVID-19 Incidence. *medRxiv*. doi:10.1101/2020.05.08.20095893

Merzon, E., Tworowski, D., Gorohovski, A., Vinker, S., Golan Cohen, A., Green, I., & Frenkel Morgenstern, M. (2020). Low plasma 25(OH) vitamin D level is associated with increased risk of COVID-19 infection: an Israeli population-based study. *FEBS J*. doi:10.1111/febs.15495

Meschia, J. F., Barrett, K. M., Brown, R. D., Jr., Turan, T. N., Howard, V. J., Voeks, J. H., . . . Brott, T. G. (2020). The CREST-2 experience with the evolving challenges of COVID-19: A clinical trial in a pandemic. *Neurology, 95*(1), 29-36. doi:10.1212/WNL.0000000000009698

Molloy, E. J., & Murphy, N. (2020). Vitamin D, Covid-19 and Children. *Ir Med J, 113*(4), 64.

Neher, R. A., Dyrdak, R., Druelle, V., Hodcroft, E. B., & Albert, J. (2020). Potential impact of seasonal forcing on a SARS-CoV-2 pandemic. *Swiss Med Wkly, 150*, w20224. doi:10.4414/smw.2020.20224

Nogués X., O. D., Quesada-Gomez J.M., Bouillon R. (2021). Calcifediol treatment and COVID-19-related outcomes.*]http://dx.doi.org/10.2139/ssrn.3771318*.

Okan, F., Okan, S., & Zincir, H. (2020). Effect of Sunlight Exposure on Vitamin D Status of Individuals Living in a Nursing Home and Their Own Homes. *J Clin Densitom, 23*(1), 21-28. doi:10.1016/j.jocd.2018.12.005

Osmancevic, A., Demeke, T., Gillstedt, M., Angesjo, E., Sinclair, H., Abd El-Gawad, G., & Landin-Wilhelmsen, K. (2016). Vitamin D treatment in Somali women living in Sweden-Two randomised, placebo-controlled studies. *Clin Endocrinol (Oxf), 85*(4), 535-543. doi:10.1111/cen.13097

Panagiotou, G., Tee, S. A., Ihsan, Y., Athar, W., Marchitelli, G., Kelly, D., . . . Quinton, R. (2020). Low serum 25-hydroxyvitamin D (25[OH]D) levels in patients hospitalised with COVID-19 are associated with greater disease severity. *Clin Endocrinol (Oxf)*. doi:10.1111/cen.14276

Pludowski, P., Holick, M. F., Grant, W. B., Konstantynowicz, J., Mascarenhas, M. R., Haq, A., . . . Wimalawansa, S. J. (2018). Vitamin D supplementation guidelines. *J Steroid Biochem Mol Biol, 175*, 125-135. doi:10.1016/j.jsbmb.2017.01.021

Quraishi, S. A., Bittner, E. A., Blum, L., McCarthy, C. M., Bhan, I., & Camargo, C. A., Jr. (2014). Prospective study of vitamin D status at initiation of care in critically ill surgical patients and risk of 90-day mortality. *Crit Care Med, 42*(6), 1365-1371. doi:10.1097/CCM.0000000000000210

Quraishi, S. A., De Pascale, G., Needleman, J. S., Nakazawa, H., Kaneki, M., Bajwa, E. K., . . . Bhan, I. (2015). Effect of Cholecalciferol Supplementation on Vitamin D Status and Cathelicidin Levels in Sepsis: A Randomised, Placebo-Controlled Trial. *Crit Care Med, 43*(9), 1928-1937. doi:10.1097/CCM.0000000000001148

Radujkovic, A., Hippchen, T., Tiwari-Heckler, S., Dreher, S., Boxberger, M., & Merle, U. (2020). Vitamin D Deficiency and Outcome of COVID-19 Patients. *Nutrients, 12*(9). doi:10.3390/nu12092757

Raisi-Estabragh, Z., McCracken, C., Bethell, M. S., Cooper, J., Cooper, C., Caulfield, M. J., . . . Petersen, S. E. (2020). Greater risk of severe COVID-19 in Black, Asian and Minority Ethnic populations is not explained by cardiometabolic, socioeconomic or behavioural factors, or by 25(OH)-vitamin D status: study of 1326 cases from the UK Biobank. *J Public Health (Oxf)*. doi:10.1093/pubmed/fdaa095

Rastogi, A., Bhansali, A., Khare, N., Suri, V., Yaddanapudi, N., Sachdeva, N., . . . Malhotra, P. (2020). Short term, high-dose vitamin D supplementation for COVID-19 disease: a randomised, placebo-controlled, study (SHADE study). *Postgrad Med J*, https://pmj.bmj.com/content/early/2020/2011/2012/postgradmedj-2020-139065 doi:10.1136/postgradmedj-2020-139065

Rhodes, J. M., Subramanian, S., Laird, E., & Kenny, R. A. (2020). Editorial: low population mortality from COVID-19 in countries south of latitude 35 degrees North supports vitamin D as a factor determining severity. *Aliment Pharmacol Ther, 51*(12), 1434-1437. doi:10.1111/apt.15777

Saaf, M., Fernell, E., Kristiansson, F., Barnevik Olsson, M., Gustafsson, S. A., & Bagenholm, G. (2011). Severe vitamin D deficiency in pregnant women of Somali origin living in Sweden. *Acta Paediatr, 100*(4), 612-614. doi:10.1111/j.1651-2227.2011.02134.x

Sabetta, J. R., DePetrillo, P., Cipriani, R. J., Smardin, J., Burns, L. A., & Landry, M. L. (2010). Serum 25-hydroxyvitamin d and the incidence of acute viral respiratory tract infections in healthy adults. *PLoS One, 5*(6), e11088. doi:10.1371/journal.pone.0011088

Shiravi, A. A., Saadatkish, M., Abdollahi, Z., Miar, P., Khanahmad, H., & Zeinalian, M. (2020). Vitamin D can be effective on the prevention of COVID-19 complications: A narrative review on molecular aspects. *Int J Vitam Nutr Res*, 1-13. doi:10.1024/0300-9831/a000676

Spiller, H. A., Good, T. F., Spiller, N. E., & Aleguas, A. (2016). Vitamin D exposures reported to US poison centers 2000-2014: Temporal trends and outcomes. *Hum Exp Toxicol, 35*(5), 457-461. doi:10.1177/0960327115595685

Stohs, S. J., & Aruoma, O. I. (2020). Vitamin D and Wellbeing beyond Infections: COVID-19 and Future Pandemics. *J Am Coll Nutr*, 1-2. doi:10.1080/07315724.2020.1786302

Story, M. J. (2021). Essential sufficiency of zinc, omega-3 polyunsaturated fatty acids, vitamin D and magnesium for prevention and treatment of COVID-19, diabetes, cardiovascular diseases, lung diseases and cancer. *Biochimie*. doi:10.1016/j.biochi.2021.05.013

Swami, S., Krishnan, A. V., & Feldman, D. (2011). Vitamin D metabolism and action in the prostate: Implications for health and disease. *Mol Cell Endocrinol*. doi:S0303-7207(11)00251-6 [pii]

10.1016/j.mce.2011.05.010

Tan, C. W., Ho, L. P., Kalimuddin, S., Cherng, B. P. Z., Teh, Y. E., Thien, S. Y., . . . Ng, H. J. (2020). Cohort study to evaluate the effect of vitamin D, magnesium, and vitamin B12 in combination on progression to severe outcomes in older patients with coronavirus (COVID-19). *Nutrition, 79-80*, 111017. doi:10.1016/j.nut.2020.111017

Temgoua, M. N., Kuate, L. M., Ngatchou, W., Sibetcheu, A., Toupendi, Z. N., Belobo, G., . . . Kingue, S. (2020). COVID-19 pandemic: do we need systematic screening of patients with cardiovascular risk factors in Low and Middle-Income Countries (LMICs) for preventing death? *Pan Afr Med J, 35*(Suppl 2), 11. doi:10.11604/pamj.2020.35.2.22947

Trivedy, C., Mills, I., & Dhanoya, O. (2020). The impact of the risk of COVID-19 on Black, Asian and Minority Ethnic (BAME) members of the UK dental profession. *Br Dent J, 228*(12), 919-922. doi:10.1038/s41415-020-1781-6

Vassiliou, A. G., Jahaj, E., Pratikaki, M., Orfanos, S. E., Dimopoulou, I., & Kotanidou, A. (2020). Low 25-Hydroxyvitamin D Levels on Admission to the Intensive Care Unit May Predispose COVID-19 Pneumonia Patients to a Higher 28-Day Mortality Risk: A Pilot Study on a Greek ICU Cohort. *Nutrients, 12*(12). doi:10.3390/nu12123773

Villamor, E., Villar, L. A., Lozano, A., Herrera, V. M., & Herran, O. F. (2017). Vitamin D serostatus and dengue fever progression to dengue hemorrhagic fever/dengue shock syndrome. *Epidemiol Infect, 145*(14), 2961-2970. doi:10.1017/S0950268817002059

Wang J, T. K., Feng K, X Lin, W Lv, K Chen, L Wang. (2020). High temperature and high humidity reduce the transmission of COVID-19. *SSRN Electron J, 19*(13), 1-13. doi:10.2139/ssrn.3551767

Wang, Z., & Wang, G. (2004). APD: the Antimicrobial Peptide Database. *Nucleic Acids Res, 32*(Database issue), D590-592. doi:10.1093/nar/gkh025

Wimalawansa, S. J. (2012). Vitamin D in the new millennium. *Curr Osteoporos Rep, 10*(1), 4-15. doi:10.1007/s11914-011-0094-8

Wimalawansa, S. J. (2020a). Achieving population vitamin D sufficiency will markedly reduce healthcare costs. *EJBPS, 7:3* 136-141.

Wimalawansa, S. J. (2020b). Commonsense approaches to minimising risks from COVID-19. *Open J Pulm Respir Med, 2*, 28-37, https://doi.org/10.36811/ojprm.32020.110010 doi:10.36811/ojprm.2020.110010

Wimalawansa, S. J. (2020c). COVID-19: Evolution and prevention. *Trends Telemed E-Health, 2*(3), 1-5. doi:10.31031/TTEH.2020.02.000539

Wimalawansa, S. J. (2020d). Global epidemic of coronavirus—COVID-19: What can we do to minimise risks? *European J. Biomed & Pharma Sci., 7*(3), 432-438. doi:https://storage.googleapis.com/journal-uploads/ejbps/article_issue/volume_7_march_issue_3/1584436192.pdf

Wimalawansa, S. J. (2020e). Modes of preventing secondary community spread and future epidemics of COVID-19. *J. Immuno Biol, 5*(1), 1-5. doi:10.37421/JIB.2020.5.147

Wimalawansa, S. J. (2020f). Reducing risks from COVID-19: Cost-effective ways of strengthening individual's and the population immunity with vitamin D. *J Endocrinol Sci, 2*(2), -13.

Wimalawansa, S. J. (2020c). Fighting against COVID-19: Boosting the immunity with micronutrients, stress reduction, physical activity, and vitamin D. *Nutrition and Food Science Journal (Sci Literature), 3(1)*(126), 1-4.

Wimalawansa, S. J., Razzaque, D. M.S, Al-Daghri, N.M. (2017). Calcium and Vitamin D in Human Health: Hype or Real? *J Steroid Biochem Mol Biol, 180*, 4-14. doi:10.1016/j.jsbmb.2017.12.009

Xu J, Y. J., Chen J, Luo Q, Zhang Q, Zhang H. (2017). Vitamin D alleviates lipopolysaccharide-induced acute lung injury via regulation of the renin-angiotensin system. *Mol Med Rep, 16*, 7432-7438

Yadaver, S. (2020). 57% of Mumbai slum dwellers were exposed to Covid, developed antibodies, finds sero survey. Retrieved from https://theprint.in/health/57-of-mumbai-slum-dwellers-were-exposed-to-covid-developed-antibodies-finds-sero-survey/470120/

Yousef, S., Elliott, J., Manuel, D., Colman, I., Papadimitropoulos, M., Hossain, A., . . . Wells, G. A. (2019). Study protocol: Worldwide comparison of vitamin D status of immigrants from different ethnic origins and native-born populations-a systematic review and meta-analysis. *Syst Rev, 8*(1), 211. doi:10.1186/s13643-019-1123-4

Zemb, P., Bergman, P., Camargo, C. A., Jr., Cavalier, E., Cormier, C., Courbebaisse, M., . . . Souberbielle, J. C. (2020). Vitamin D deficiency and the COVID-19 pandemic. *J Glob Antimicrob Resist, 22*, 133-134. doi:10.1016/j.jgar.2020.05.006

Zhu, Y., Xie, J., Huang, F., & Cao, L. (2020). Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China. *Sci Total Environ, 727*, 138704. doi:10.1016/j.scitotenv.2020.138704

Mitigation of post Covid-19 disorders and secondary infections by direct targeting of organ persisting pathogens and stimulation of human immunity via immunomodulatory nano-carriers enriched food formulations

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ABSTRACT

Excessive immunity triggering in human cells and tissues towards pathogenic infections are responsible for generating foreseeable impacts of Covid-19. Natural super functional foods modified with immune stimulants are capable of alleviating pathogenic persistence on human tissues which generate long term effects of Covid 19 while modulating immunity to avoid secondary infections. Objectives of this study is to review the reported research pathways of uplifting human immunity and suppressing pathogenic persistence on long-lived cells to mitigate post Covid 19 disorders by formulating functional foods enriched with immunomodulatory bioactive compound encapsulated nano-carriers. Major aspects in this review are; (a) uncontrolled immunity toward pathogenic persistence which damage specific organ tissues causing for disorders after Covid-19 infection (b) rapid, real-time, sensitive diagnosis of pathogenic persistence and eradication through recent advances in nanotechnology (c) oral delivery of bioactive compounds to definite targets by synthesizing biosensors toward persisted opportunistic pathogens using surface modified biodegradable nanoparticles (d) encapsulation of bioactive compounds in herbal extracts inside formulated foods in order to increase the bioavailability and regulate the dose- dependent release inside the human body. Major findings of this review are: Angiotensin-Converting Enzyme 2 (ACE2) specific binding of coronavirus has enhanced the pathogenic persistence in highly sensitive lungs, kidney, brain and neurons by least activation of immune responses. Unbalanced anti-inflammatory signals enhance secondary infection and excessive organ tissue damage. Combination of immunomodulatory compounds from foods in non-toxic doses have reduced health disorders, adverse effects of long term exposure and chemical reactions related to pharmaceutical delivery. Least bioavailable bioactive compounds can be orally delivered by encapsulation and slow releasing using biodegradable nano-materials that have site specific sensing toward persisting pathogens with suitable modifications. In conclusion, development of functional foods enriched with immune-stimulating bioactive compounds encapsulated nanoparticles will controls the pathogenic persistence on long-lived tissues thereby mitigating the human immunosuppression, and secondary infections which arise with Covid-19 exposure.

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Key words: Food formulations, Immune system, Nanoparticles, Post Covid-19 disorders

1. INTRODUCTION

Viruses are intercellular parasites, which survive and proliferate inside living cells, containing RNA or DNA and surrounded by a lipid- containing envelope or non-enveloped (Wagner, 2006). Viruses have significant impact on human health, ranging from severe life threatening illness to relatively mild and self-limiting or asymptomatic diseases (Barker *et al*., 2001). Since 1968, coronavirus family has been recognized as positive sense RNA viruses which infect the respiratory tract of mammals and birds with mild symptoms. Sever acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) disease or Covid- 19 starting from China, Wuhan in December 2019 with mild and sever lung infections in human has exhibited high rate of global spreading and high cumulative numbers of reported cases (~ 49.7 million) associated with moderate mortality rate (~2.3 %) and huge economic loss to date when compared to similar pandemics of Sever acute respiratory syndrome (SARS-CoV-1) in 2002 and Middle East Respiratory Syndrome (MERS) in 2012. The direct and indirect contact of a Covid-19 infected person may cause the development of mild and severe symptoms associated with lung infections and pneumonia starting from sore throat (28%), fever (46%), cough (46%), nasal congestion (10%), chest pain (10%), abdominal pain (4%), vomiting (5%), loss of taste (7%) and deaths after 2-14 days of exposure (Morris *et al*., 2020).

The human body has ultimate defense mechanisms against harmful infectious agents such as bacteria and viruses upon triggering the immunity system (Nicholson, 2016). Cell-mediated immunity produces cytokines pro-inflammatory factors such as interleukins (IL-1β, IL-6, IL-12), tumor necrosis factor (TNF), interferons (IFN-γ) and anti-inflammatory factors including interleukins (IL-4, IL-10, IL-13) and Growth Factor (TGF-β) (Chowdhury *et a*l., 2020). Over production of inflammatory cytokines, mainly interleukins in immune cells causes the cytokine storm syndrome thereby multi-organ failures referred as post Covid-19 disorders including silent heart failures, kidney damages, silent and sever pneumonia with lung damages, and neurological disorders such as chronic fatigue, lack of mental clarity, acute polyradiculopathy and dyspnea (Burling, 2020; Couzin-Frankel, 2020; Davido *et al*., 2020; Musker, 2020). Earlier, antiviral drug therapies and viral specific vaccines have shown significant mitigation toward infected and persisted pathogens. However, recently developed vaccine/drugs associated with unsolicited side effects such as over production of immune cytokines, muscle pain, and tenderness (Keech *et al*., 2020; WHO, 2020). Commercially available vaccines require cool or ultra-cool freezing conditions for long term storage until complete sequential vaccination (Mulligan *et al*., 2020). This continuous process acquires higher cost that cannot be tolerated by developing countries (WHO, 2020). In this world crisis situation, long/short term precautions to immunity triggering before infection and after infection is important. Most of the formulated vaccines against Covid-19 are under critical trails to evaluate protective efficacy on children, pregnant women and people with chronic diseases (Jackson *et al*., 2020; Zhang *et al*., 2020).Therefore, it requires very critical time to produce required doses of the vaccine to cover whole population in each country.

Maintaining the healthy nutrient status to support immunity function and prevent the onset of severe infections have been proved to be successive strategies toward Covid-19 (Zabetakis *et al*., 2020). The need for rapid remediation and extraordinary attempts and interventions toward post Covid-19 disorders and immune suppression with novel and specific site targeted nutrient delivery has been achieved by nanoparticles with nano-encapsulation of natural immunomodulatory compounds extracted from selected specific herbs, fruits, vegetables, spices and underutilized fruits. Direct targeting of body

persisted pathogens using surface modified nanomaterials can support and/or enhance the natural body defense. Surface modifications of nano-materials proven to overcome the limitation of biodegradation of bioactive compounds in oral delivery (Fadeel, 2019). Therefore, objectives of the present study is to review reported pathways of biosensing and direct targeting of pathogenic persistence to minimize post Covid-19 impacts and secondary infections by formulating super natural foods incorporated with immune stimulating compounds encapsulated nano-carriers.

2. EMERGENCE OF COVID-19, POST COVID-19 AND TRADITIONAL MITIGATION STRATEGIES

2.1. Severity of coronaviruses

Viruses, have high pathogenicity due to conserved receptor-binding in host entry and susceptibility to host defense (Jiang *et al*., 2012; Luo, 2008). In Baltimore classification, the nature of genome (DNA/RNA) categorized viruses in to seven groups (Mahmoudabadi & Phillips, 2018; Ryu, 2017).Among RNA viruses, Coronavirus, especially the family *Coronaviridae* exhibit specific spherical shape with bulbous distal ends of embedded envelope glycoproteins. Single stranded RNA viruses are considered as more susceptible to mutations than DNA viruses due to fragility of RNA and the tendency to break (Chaitanya, 2019). Until the emergence of SARS-CoV-1in 2002 and MERS in 2012 with higher deaths rates, scientists have not identified the virulence of coronavirus in humans (Fani *et al*., 2020). After the sever outbreak of SARS-CoV-2, scientists have discovered the genome stability, mutation rates of coronavirus and predicted genome sequence of novel coronavirus by comparing previous coronaviruses outbreaks (Sariol & Perlman, 2020). Strains of SARS-CoV-1, MERS and novel Covid-19 virus belong to the genus *Betacorona virus* which originated from wild bat ancestors (Eastern, 2003). The severity and virulence factors of SARS-CoV-2 depend on mutation rates and survival rates of different strains. It reveals 1,516 nucleotide-level variations and twelve deletion sites at different positions of whole genome in 120 SARS-CoV-2 strains in Japan, USA, England, Canada, Netherlands, China, and Australia. Amino acid substitution mutations are an example of non-synonymous mutations in genomic R203K and L3606F amino acids of SARS-CoV-2 strain in Europe (~43 %) and some temperate countries reported higher death rates when compared to Asia (~ 38 %) and North America (~ 26 %) (Islam *et al*., 2020).

2.2. Infection and spreading of Covid-19

Higher contagion of SARS-CoV-2 are due to high rate affinity of viral conserved spike (S) protein receptor-binding motif (RBM) toward human ACE 2 receptor and primer binding of cellular proteases like TMPRSS2 proteases (Estrada, 2020; Zheng, 2020). Infection efficacy of SARS-CoV-2 relies on the support of ACE 2 receptor to viral replication and localization (Chambers *et al*., 2020). Therefore, up-regulated expressions of ACE 2 receptor proteins at the sites of lungs, heart, cerebral cortex, thymus, testis, lymph node, and kidney may cause for Covid-19 spreading via human protein-protein interactions upon initial entry. According to Center of Disease (CDC), older adults in between 65 to 85+ years have the highest risk of hospitalization and deaths compared to younger adults in between 18- 29 years (States & June, 2020). In children and healthy people, ACE 2 modulates the renin–angiotensin system via cleaving angiotensin (Ang)-II to Ang-1–7 and protect from severe lung infections (Lee *et al*., 2020). People who suffer from chronic diseases are more vulnerable to viral infections. Reports have shown patient with type 1 and 2 diabetes has up-regulated expression of ACE2 viral receptors because of the drugs and treatments used for diabetes (Idampitiya *et al*., 2020). Diabetes and hypertension down regulate the host innate immune response by reduction of IFN-γ and interleukin synthesis (Chan *et al*., 2020).

2.3. Uncontrolled immunity and post Covid-19 disorders

Activation of the immunity system to fight against pathogenic infection is called immunity triggering (Choudhary & Singh, 2020). Immunity response to SARS-CoV-2 involves both cell-mediated immunity and antibody production. CD8+ or Cluster of Differentiation 8 glycoproteins positive T cells play a major role in Covid-19 virus clearance at the point of infection while Lymphocytes, CD4+ T cells, and B cells show significant inflammatory status (Perdomo-Celis *et al*., 2019; Wellinghausen *et al*., 2020). Elevated IgM antibody levels after 10-21 days of Covid-19 infection indicate the prolonged virus replication while IgG shows the persisted immune response (Wellinghausen *et al*., 2020). Unbalanced immune responses can be generated due to long term persistence of viruses inside human body and infected organs. Rapid virus replication in these sites causes cell pyroptosis or inflammatory form programmed cell death, immune evasion, and cell lysis in humans. Countries like China, Italy, USA, UK and regions of Asia have reported post COVID syndromes (Morris *et al*., 2020; Zhao *et al*., 2020). According to the American Society of Nephrology, survivors of serious COVID-19 needed dialysis, a process of kidney's blood-filtering using a machine, most probably forever (Burling, 2020). A study on SARS-CoV-1 in 2003 has shown lesions on lung after 1 year of infection which still remain. Neurological complications due to damages in brain cells lead to 'brain fog' or lack of mental clarity (Couzin-Frankel, 2020; Ellul *et al*., 2020). Infectious, Para-infectious and Post-infectious neurological damages of COVID-19 have developed encephalitis, acute disseminated encephalomyelitis and Guillain-Barré syndrome; an acute polyradiculopathy. Myocardial inflammations due to several viral infections; adenovirus, Corona virus show long term consequences of fatigue, shortness of breath and arrhythmias or abnormal heart beat which cause heart failures (Musker, 2020). Especially, SARS-CoV-2 infection has increased blood troponin levels in more than 75 % of tested patients who have risk of mortality by heart failures (Sariol & Perlman, 2020).

2.4. Medical treatments for Covid-19

Development of vaccines against SARS-CoV-2 is one such mitigation strategy and more than 50 vaccines are under trials to date (Ashford *et al*., 2020). Recently formulated, commercialized vaccines of Pfizer, Moderna's, Sinovac, and Novavax consist of mRNA part, spike protein of SARS- CoV-2, and whole viral particle that generate high or moderate efficacy toward Covid-19 by triggering immunity before severe infections and exhibit disadvantages (Table 1). Major limitation in Pfizer and Moderna's is the requirement of -20 ^{o}C to -70 ^{o}C freezing storage for storage until completing sequential vaccination (Mulligan *et al*., 2020). Evaluating the protective efficacy by three phase trials is a must in vaccine production to minimize the side effects and ensure safety of the whole population. However, increased severity of Covid-19 day by day, realizes the need of quick medication. Remdesivir, Dexamethasone and Hydroxychloroquine are recently recommended antiviral drugs for Covid-19.These drugs are not directly involved in enhancing the activity of human immunity. Although they have decreased the risk of Covid-19 by inhibiting the viral replication in the human body, they generate long term consequences on the human health including overproduction of cytokines (Table 1) (WHO, 2020). Apart from Western medicine, Sri Lanka, India, and China and other Asian countries that experience well balanced immunity have trailed on 'Ayurveda' syrups, powders, tables and tonics which are designed as food and herbal supplements which are not clinically cleared. Therefore, knowledge on valuable antiviral ingredients in foods and herbs may be critically important in developing and modifying food supplements with immune modulatory effects.

2.5. Foods for treating Covid-19

Maintaining healthy nutrient status to support immunity function and prevent the onset of severe infections has been proved to be successful strategies toward Covid-19. Food

Table 1. Strengths and weaknesses of formulated vaccines/drugs against Covd-19

	Commercial Name	Efficacy	Major Ingredient	Advantages	Limitations (To date)	References
Vaccines	Pfizer	~ 94 %	mRNA part of SARS- CoV-2	Trigger immunity before severe infections	Require ultra-cool freezing condition for storage	(Mulligan et al., 2020; WHO, 2020)
	Moderna's	~ 93 %	mRNA part of SARS- CoV-2	Preventing Covid-19 even in severe cases	Under critical trails to evaluate the safety in pregnancy and cancer patients	(Jackson et al., 2020; Mckeever, 2020)
	Sinovac	~ 50%	Inactivated viral particles of SARS-CoV-2	Trigger immunity before severe infections	Under phase 3 trial of protective efficacy	(Zhang et al., 2020)
	Novavax	-	Inactived Matrix-M spike protein 'rosettes'	Activate CD4+ immune cells	Unsolicited adverse events in 80% tested patients; muscle pain, fatigue	(Keech et al., 2020)
	Oxford-AstraZeneca	63.09%	SARS-CoV-2 spike protein	Causing the immune system to recognize artificially synthesized spike proteins and initiate an immune response	Short term fever, headache. Risk toward people with chronic diseases.	(WHO, 2020)
Drugs	Remdesivir	~ 65 %	*S*-acyl-2-thioethyl monophosphate	Inhibit coronavirus replication in human	More than 3000 dollars cost has acquired for 5 day treatments	(Eastman et al., 2020; WHO, 2020)
	Dexamethasone	-	Glucocorticoids	Decreased the risk of dying in hospitalized Covid-19 patients	Side effects on over production of immune cytokines	(Bordag et al., 2015; WHO, 2020)
	Hydroxychloroquine	-	Chloroquine	Avoid adverse outcomes of Covid-19 for rheumatic diseased patients	Little or no morality reduction in hospitalized COVID-19 patients	(Jorge, 2021; WHO, 2020)

bioactive compounds and phytochemicals in herbal plants are identified as natural antiviral and immunomodulatory compounds. Polyphenols in functional foods such as ginger, black pepper, garlic, turmeric, and sadikka has influenced the immune cell function by synthesis of pro-inflammatory cytokines and high antioxidant activity to inhibit of enzymes involved in the production of eicosanoid signaling molecules (Lange, 2020; Yahfoufi *et al*., 2018). Probiotics rich food supplements activate the multiple immune responses toward COVID 19 and decrease in the incidence of viral respiratory tract infections (King *et al*., 2014). Vitamin C rich fruits including citrus, pineapples, orange, grapes and under-utilized Nellie, Nami-nam have decreased the upper and lower respiratory tract COVID 19 viral persistence (Akhtar *et al*., 2020; Douglas *et al*., 2007).

A study on the treatment of children with zinc as supplement has showed a lower incidence (48%) of respiratory viral infections (Sazawal *et al*., 1998). Traditional and organic food consumption in Asian countries is at satisfactory levels when compared to European countries (Jensen *et al*., 2011; Narmilan & Sugirtharan, 2017; Nechaev *et al*., 2018). This evidence may be useful in the prediction of the relationship between morality of Covid-19 and healthy food consumption. Flavonoids and polyphenols in traditional herbal extracts including *Syzygium aromaticum*, *Piper nigrum, Curcuma longa* (curumin) with milk, *Tinospora cordifolia, Andrograhis paniculata, Arsenicum album,* and *Zizyphus jujube*are are identified as mediators of hyper responsiveness and nasal congestions in a COVID 19 infected person, blocked excessive cytokine release, and is recommended for COVID 19 due to immunomodulatory, anti-allergic and antioxidant activities (A. Omara et al., 2011; Kim & Lee, 2009; Rauš et al., 2015). Indigenous herbs and traditional foods and beverages have a strong relationship between maintaining health and prevention of non-communicable diseases in addition to delivering the required nutrition (Mihiranie *et al*., 2020). In Western medicine food is also considered as a medicine. It can be suggested that potential health effects and immunomodulation of food bioactive compounds are dependent on the digestion process which affects for the stability of bioactive compounds inside the human body until it can directly target the persisting pathogens or indirectly stimulate the human immune responsive cells against pathogens by a regulated mechanism of brain and the central nerve system. However, this harmony between natural defense mechanisms and food systems combined with indigenous medical system need to be further studied for the better clarification of novel nutraceutical delivery pathways and doses. There is a need for new recommendations of daily diets rich in immunomodulatory compounds making available such raw and herbal medicines based processed foods and implementing a national food consumption implementation plan. The process of commercialization of traditional medicine systems and herbal based formulated food products development is not an easy task. However, a speedy process to meet the urgent requirement of COVID 19 pandemic situation due to lack of national capacity for protective clinical trials in order to determine organ toxicity and pharmacokinetic studies for optimal dosage is essential. Therefore, competitiveness of indigenous medicines and herbal based immunomodulatory direct targeting food products are lagging behind to the requirements of local and global demand which are alternatives to Western medicines.

3. NOVEL ADVANCES IN NANOTECHNOLOGY AND BIOSENSING OF PATHOGENS

Rapid detection and the characterization of pathogenic microorganisms led to the advancement of biosensors. With the knowledge of nano-bio interference, nanomaterials have become prominent vehicles in specific and sensitive detection of pathogens as well as *in situ* eradication (Look *et al*., 2010). A biosensor consists of molecular recognition element and transducer to convert receptor-target element interaction into a measurable signal (Sposito *et al*., 2018). Nanoscale systems tend to enhance the diagnostic systems because of their size-dependent optical, electrical, physical, and

chemical properties (Hodak *et al*., 2000). Rapid detection of ultra-structures of bacteria, viruses, fungi including cell wall, capsid proteins, structures of cell membranes and their secondary metabolites is the major reason for using nanomaterials as biosensors (Ahmed *et al*., 2014; Shoieb *et al*., 2020). Recent reports on molecular docking have shown gold nano-rods designed for targeting heptad repeat 1 (HR1) and heptad repeat 2 (HR2) domains of coronavirus S spike proteins have successfully blocked the initial HR1/ HR2 mediated entry of coronavirus (Huang *et al*., 2019). Gold nanoparticles conjugated with citrate ions are used as colorimetric sensor for target SARS and MERS Viral RNA by using localized surface plasmon resonance principal (Medhi et al., 2020). After recognition of the pathogen and direct binding, some drug/ bio-chemical compounds encapsulated nanoparticles release the core material to (1). Fully/ partially inactivate pathogen, for example, β-cyclodextrin nanoparticles modified with graphene oxide and loaded with curcumin has fully inactivated the Respiratory Syncytial Virus (RSV) by attaching to the particle (Yang *et al*., 2017), and (2) regulating the immunity function in human. Inactivated Covid-19 viral mRNA part loaded lipid nanoparticles with cationic surface modifications trigger the immunity by direct binding to the immune responsive cells (Florindo *et al*., 2020). There is no clear evidence for total eradication/ killing of viruses and other pathogens by nano-biosensing.

4. TARGET ORIENTED ORAL DELIVERY OF IMMUNOMODULATORY COMPOUNDS

In oral delivery of immunomodulatory compounds, the major concerns are:(1) stability of bioactive compounds in the gastrointestinal tract, (2) delivery of bioactive compounds to the targeted site via body metabolic systems, and (3) the level of cytotoxicity. Novel fabrication strategies of nano-carrier development enhance the therapeutic effect, with non-toxic and edible platforms, to the human body. Nano-encapsulation protects the bioactive compounds from the enzyme of digestive system. Natural soy lipophilic protein nanoparticles (LPP) adorned with linoleic acid have been fabricated by ultra-sonication to increase the high loading capacity, oxidation protection, and sustained release inside the gastrointestinal tract (Gao *et al*., 2014). Polyethylene glycol (PEG) specific antibodies have been orally delivered using PEG-coated liposomes in order to provide a hydrophilic environment, thereby shielding them from immune recognition with 33% efficiency of a sustained transfer (Ramana *et al*., 2012). Surface modified nanoparticles have increased the trans-membrane absorption of released compounds with prolonged retention time at a specific site. Soybean lipid nano-emulsions loaded with curcumin and modified with arginine peptide increased accumulation in the liver and the lungs which suggests the potential application in liver and lung localized pathogens (Simion *et al*., 2016).

5. IMMUNOMODULATORY NANO-CARRIERS ENRICHED FOOD FORMULATIONS

Major advantage of enrichment of immunomodulatory nano- carriers into consumed foods is providing a carrier media for less bioavailable bioactive compounds until it reaches to the targeted organs or persisted pathogen. There are limited researches have conducted on bioactive compounds encapsulated nanoparticle incorporated foods (Ravichandran, 2010). Nano-encapsulation in to chitosan nanoparticles, beta-Lactoglobulin, and alginate has enhanced the stability and solubility of bioactive compounds such as mangiferin, curcumin, and folic acid inside hydrophobic/ hydrophilic nature of formulated foods (Table 2). Surface modified liposomes successfully overcome the limitation of toxicity and shelf life of nanomaterials and bioactive compounds in food products by preventing the undesirable interactions of chemical compounds with food matrix (Xia & Xu, 2005).

Table 2. Formulated foods with immunomodulatory nano-carriers

Nanomaterial	Encapsulated bioactive compounds	Incorporated foods	Advantages	References
β -Lactoglobulin–Chitosan nanoparticle	Mangiferin	Milk	Increase antioxidant capacity, lipid -peroxidation inhibition and protein -oxidation inhibition	(Samadarsi et al., 2020)
Egg lecithin and cholesterol liposome	Ferrous sulfate	Fluid milk	Prevent the undesirable interactions of ferrous ions	(Xia & Xu, 2005)
Alginate / poly(ethylene oxide)	Folic acid	-	Enhanced protection on folic acid in food products	(Alborzi et al., 2013)
beta-Lactoglobulin	Docosahexaenoic acid (DHA)	Non-fat drinks	Increase Solubilization and protection of DHA	(Zimet & Livney, 2009)

6. CONCLUSIONS

Human body system has direct or indirect pathogen targeting, natural bio-defense mechanism in order to inactive and/ or kill infected pathogens especially viruses. Repair the imbalance and/or enhance the natural defense of human have been achieved traditional medicine systems coupled with western medicine and by dietary foods with recommended dosages. Therefore, it is emphasized that formulation of novel national food programs and agenda for supply variety of balanced traditional foods and underutilized food diets support the long term immunity development and strength in human body.

Consumption of formulated foods consist with nano-encapsulated bioactive compounds and nano-carriers as well as natural dietary nutrients will be beneficial to enhance natural nutrient absorption through gastrointestinal pathway and direct targeting of persisted pathogens related to post Covid-19 disorders. Inactivation/ control of persisted pathogens may repair the disequilibrium of human immunity caused by long term persistence of Covid-19 virus and reduce the risk of present pandemic situation forthcoming viral pandemics.

REFERENCES

A. Omara, E., Kam, A., Alqahtania, A., M. Li, K., Razmovski-Naumovski, V., Nammi, S., Chan, K., D Roufogalis, B., & Q. Li, G. (2011). Herbal Medicines and Nutraceuticals for Diabetic Vascular Complications: Mechanisms of Action and Bioactive Phytochemicals. *Current Pharmaceutical Design*, *16*(34), 3776–3807. https://doi.org/10.2174/138161210794455076

Ahmed, A., Rushworth, J. V., Hirst, N. A., & Millner, P. A. (2014). Biosensors for whole-cell bacterial detection. *Clinical Microbiology Reviews*, *27*(3), 631–646. https://doi.org/10.1128/CMR.00120-13

Akhtar, S., Das, J. K., Ismail, T., Wahid, M., Saeed, W., & Bhutta, Z. A. (2020). Nutritional perspectives for the prevention and mitigation of COVID-19. *Nutrition Reviews*, *0*(0), 1–12. https://doi.org/10.1093/nutrit/nuaa063

Alborzi, S., Lim, L. T., & Kakuda, Y. (2013). Encapsulation of folic acid and its stability in sodium alginate-pectin-poly(ethylene oxide) electrospun fibres. *Journal of Microencapsulation*, *30*(1), 64–71. https://doi.org/10.3109/02652048.2012.696153

Ashford, J. W., Gold, J. E., Huenergardt, M. J. A., Katz, R. B. A., Strand, S. E., Bolanos, J., Wheeler, C. J., Perry, G., Smith, C. J., Steinman, L., Chen, M. Y., Wang, J. C., Ashford, C. B., Roth, W. T., Cheng, J. J., Chao, S., Jennings, J., Sipple, D., Yamamoto, V., … Earnest, D. L. (2020). MMR Vaccination: A Potential Strategy to Reduce Severity and Mortality of COVID-19 Illness. *American Journal of Medicine*, *2019*, 2019–2021. https://doi.org/10.1016/j.amjmed.2020.10.003

Bang, F. B. (1955). Morphology of viruses. *Annual Review of Microbiology*, *9*, 21–44. https://doi.org/10.1146/annurev.mi.09.100155.000321

Barker, J., Stevens, D., & Bloomfield, S. F. (2001). Spread and prevention of some common viral infections in community facilities and domestic homes. *Journal of Applied Microbiology*, *91*(1), 7–21. https://doi.org/10.1046/j.1365-2672.2001.01364.x

Bordag, N., Klie, S., Jürchott, K., Vierheller, J., Schiewe, H., Albrecht, V., Tonn, J. C., Schwartz, C., Schichor, C., & Selbig, J. (2015). Glucocorticoid (dexamethasone)-induced metabolome changes in healthy males suggest prediction of response and side effects. *Scientific Reports*, *5*(November), 1–12. https://doi.org/10.1038/srep15954

Burling, S. (2020). *The coronavirus is damaging kidneys*. https://medicalxpress.com/news/2020-08-coronavirus-kidneys-doctors-survivors-dialysis.html

Chaitanya, K. V. (2019). Structure and organization of Virus Genomes. In *Genome and Genomics*. https://doi.org/https://doi.org/10.1007/978-981-15-0702-1_1 1

Chambers, J. P., Yu, J., Valdes, J. J., & Arulanandam, B. P. (2020). SARS-CoV-2, Early Entry Events. *Journal of Pathogens*, *2020*, 1–11. https://doi.org/10.1155/2020/9238696

Chan, J. F. W., Yuan, S., Kok, K. H., To, K. K. W., Chu, H., Yang, J., Xing, F., Liu, J., Yip, C. C. Y., Poon, R. W. S., Tsoi, H. W., Lo, S. K. F., Chan, K. H., Poon, V. K. M., Chan, W. M., Ip, J. D., Cai, J. P., Cheng, V. C. C., Chen, H., … Yuen, K. Y. (2020). A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *The Lancet*, *395*(10223), 514–523. https://doi.org/10.1016/S0140-6736(20)30154-9

Choudhary, P., & Singh, I. (2020). Protective immunity against COVID-19: Unravelling the evidences for humoral vs. cellular components. *Travel Medicine and Infectious Disease*, *39*(January).

Chowdhury, M. A., Hossain, N., Kashem, M. A., Shahid, M. A., & Alam, A. (2020). Immune response in COVID-19: A review. *Journal of Infection and Public Health*, *13*(11), 1619–1629. https://doi.org/10.1016/j.jiph.2020.07.001

Couzin-Frankel, J. (2020). From 'brain fog' to heart damage, COVID-19's lingering problems alarm scientists. In *Science*. https://doi.org/10.1126/science.abe1147

Davido, B., Seang, S., Tubiana, R., & de Truchis, P. (2020). Post–COVID-19 chronic symptoms: a postinfectious entity? *Clinical Microbiology and Infection*, *26*(11), 1448–1449. https://doi.org/10.1016/j.cmi.2020.07.028

Douglas, R. M., Hemilä, H., Chalker, E., & Treacy, B. (2007). Vitamin C for preventing and treating the common cold. *Cochrane Database of Systematic Reviews*, *3*. https://doi.org/10.1002/14651858.CD000980.pub3

Eastern, M. (2003). *Coronaviruses*. 437–446. https://doi.org/10.1016/B978-0-12-375156-0.00031-X

Eastman, R. T., Roth, J. S., Brimacombe, K. R., Simeonov, A., Shen, M., Patnaik, S., & Hall, M. D. (2020). Remdesivir: A Review of Its Discovery and Development Leading to Emergency Use Authorization for Treatment of COVID-19. *ACS Central Science*, *6*(5), 672–683. https://doi.org/10.1021/acscentsci.0c00489

Ellul, M. A., Benjamin, L., Singh, B., Lant, S., Michael, B. D., Easton, A., Kneen, R., Defres, S., Sejvar, J., & Solomon, T. (2020). Neurological associations of COVID-19. *The Lancet Neurology*, *19*(9), 767–783. https://doi.org/10.1016/S1474-4422(20)30221-0

Estrada, E. (2020). Fractional diffusion on the human proteome as an alternative to the multi-organ damage of SARS-CoV-2. *Chaos*, *30*(8). https://doi.org/10.1063/5.0015626

Fani, M., Teimoori, A., & Ghafari, S. (2020). Comparison of the COVID-2019 (SARS-CoV-2) pathogenesis with SARS-CoV and MERS-CoV infections. *Future Virology*, *15*(5), 317–323. https://doi.org/10.2217/fvl-2020-0050

Florindo, H. F., Kleiner, R., Vaskovich-Koubi, D., Acúrcio, R. C., Carreira, B., Yeini, E., Tiram, G., Liubomirski, Y., & Satchi-Fainaro, R. (2020). Immune-mediated approaches against COVID-19. *Nature Nanotechnology*, *15*(8), 630–645. https://doi.org/10.1038/s41565-020-0732-3

Gao, Z. M., Zhu, L. P., Yang, X. Q., He, X. T., Wang, J. M., Guo, J., Qi, J. R., Wang, L. J., & Yin, S. W. (2014). Soy lipophilic protein nanoparticles as a novel delivery vehicle for conjugated linoleic acid. *Food and Function*, *5*(6), 1286–1293. https://doi.org/10.1039/c3fo60497g

Hodak, J. H., Henglein, A., & Hartland, G. V. (2000). Photophysics of nanometer sized metal particles: Electron-phonon coupling and coherent excitation of breathing vibrational modes. *Journal of Physical Chemistry B*, *104*(43), 9954–9965. https://doi.org/10.1021/jp002256x

Huang, X., Li, M., Xu, Y., Zhang, J., Meng, X., An, X., Sun, L., Guo, L., Shan, X., Ge, J., Chen, J., Luo, Y., Wu, H., Zhang, Y., Jiang, Q., & Ning,

X. (2019). Novel Gold Nanorod-Based HR1 Peptide Inhibitor for Middle East Respiratory Syndrome Coronavirus. *ACS Applied Materials and Interfaces*, *11*(22), 19799–19807. https://doi.org/10.1021/acsami.9b04240

Idampitiya, D., Narangoda, E., Pahalagamage, S., & Wijewickrama, A. (2020). COVID-19; Experience at the National Institute of Infectious Diseases, Sri Lanka. *Journal of the Ceylon College of Physicians*, *51*(1), 58. https://doi.org/10.4038/jccp.v51i1.7890

Islam, M. R., Hoque, M. N., Rahman, M. S., Alam, A. S. M. R. U., Akther, M., Puspo, J. A., Akter, S., Sultana, M., Crandall, K. A., & Hossain, M. A. (2020). Genome-wide analysis of SARS-CoV-2 virus strains circulating worldwide implicates heterogeneity. *Scientific Reports*, *10*(1), 1–9. https://doi.org/10.1038/s41598-020-70812-6

Jackson, L. A., Anderson, E. J., Rouphael, N. G., Roberts, P. C., Makhene, M., Coler, R. N., McCullough, M. P., Chappell, J. D., Denison, M. R., Stevens, L. J., Pruijssers, A. J., McDermott, A., Flach, B., Doria-Rose, N. A., Corbett, K. S., Morabito, K. M., O'Dell, S., Schmidt, S. D., Swanson, P. A., … Beigel, J. H. (2020). An mRNA Vaccine against SARS-CoV-2 — Preliminary Report. *New England Journal of Medicine*, *383*(20), 1920–1931. https://doi.org/10.1056/nejmoa2022483

Jensen, K. O. D., Denver, S., & Zanoli, R. (2011). Actual and potential development of consumer demand on the organic food market in Europe. *NJAS - Wageningen Journal of Life Sciences*, *58*(3–4), 79–84. https://doi.org/10.1016/j.njas.2011.01.005

Jiang, S., Lu, L., Liu, Q., Xu, W., & Du, L. (2012). Receptor-binding domains of spike proteins of emerging or re-emerging viruses as targets for development of antiviral vaccines. *Emerging Microbes and Infections*, *1*(March), 1–8. https://doi.org/10.1038/emi.2012.1

Jorge, A. (2021). Hydroxychloroquine in the prevention of COVID-19 mortality. *The Lancet Rheumatology*, *3*(1), e2–e3. https://doi.org/10.1016/S2665-9913(20)30390-8

Keech, C., Albert, G., Cho, I., Robertson, A., Reed, P., Neal, S., Plested, J. S., Zhu, M., Cloney-Clark, S., Zhou, H., Smith, G., Patel, N., Frieman, M. B., Haupt, R. E., Logue, J., McGrath, M., Weston, S., Piedra, P. A., Desai, C., … Glenn, G. M. (2020). Phase 1–2 Trial of a SARS-CoV-2 Recombinant Spike Protein Nanoparticle Vaccine. *New England Journal of Medicine*, *383*(24), 2320–2332. https://doi.org/10.1056/nejmoa2026920

Kim, S.-H., & Lee, Y.-C. (2009). Piperine inhibits eosinophil infiltration and airway hyperresponsiveness by suppressing T cell activity and Th2 cytokine production in the ovalbumin-induced asthma model. *Journal of Pharmacy and Pharmacology*, *61*(3), 353–359. https://doi.org/10.1211/jpp/61.03.0010

King, S., Glanville, J., Sanders, M. E., Fitzgerald, A., & Varley, D. (2014). Effectiveness of probiotics on the duration of illness in healthy children and adults who develop common acute respiratory infectious conditions: A systematic review and meta-analysis. *British Journal of Nutrition*, *112*(1), 41–54. https://doi.org/10.1017/S0007114514000075

Lange, K. W. (2020). Food science and COVID-19. *Food Science and Human Wellness*. https://doi.org/10.1016/j.fshw.2020.08.005

Lee, P. I., Hu, Y. L., Chen, P. Y., Huang, Y. C., & Hsueh, P. R. (2020). Are children less susceptible to COVID-19? *Journal of Microbiology, Immunology and Infection*, *53*(3), 371–372. https://doi.org/10.1016/j.jmii.2020.02.011

Look, M., Bandyopadhyay, A., Blum, J. S., & Fahmy, T. M. (2010). Application of nanotechnologies for improved immune response against infectious diseases in the developing world . *Advanced Drug Delivery Reviews*, *62*(4–5), 378–393. https://doi.org/10.1016/j.addr.2009.11.011

Luo, M. (2008). Assembly of Viruses: Nonenveloped Particles. *Encyclopedia of Virology*, 200–204. https://doi.org/10.1016/B978-012374410-4.00666-X

Mahmoudabadi, G., & Phillips, R. (2018). A comprehensive and quantitative exploration of thousands of viral genomes. *ELife*, *7*, 1–26. https://doi.org/10.7554/eLife.31955

Mckeever, A. (2020). *Latest_ FDA grants emergency authorization of Moderna's COVID-19 vaccine*. https://www.nationalgeographic.com/science/health-and-human-body/human-diseases/coronavirus-vaccine-tracker-how-they-work-latest-developments-cvd/#:~:text=On December 8%2C The Lancet,effective after one standard dose.

Medhi, R., Srinoi, P., Ngo, N., Tran, H. V., & Lee, T. R. (2020). Nanoparticle-Based Strategies to Combat COVID-19. *ACS Applied Nano Materials*, *3*(9), 8557–8580. https://doi.org/10.1021/acsanm.0c01978

Mihiranie, S., Jayasinghe, J. K., Jayasinghe, C. V. L., & Wanasundara, J. P. D. (2020). Indigenous and traditional foods of Sri Lanka. *Journal of Ethnic Foods*, *7*(1). https://doi.org/10.1186/s42779-020-00075-z

Morris, S. B., Schwartz, N. G., Patel, P., Abbo, L., Beauchamps, L., Balan, S., Lee, E. H., Paneth-Pollak, R., Geevarughese, A., Lash, M. K., Dorsinville, M. S., Ballen, V., Eiras, D. P., Newton-Cheh, C., Smith, E., Robinson, S., Stogsdill, P., Lim, S., Fox, S. E., … Godfred-Cato, S. (2020). Case Series of Multisystem Inflammatory Syndrome in Adults Associated with SARS-CoV-2 Infection — United Kingdom and United States, March–August 2020. *MMWR. Morbidity and Mortality Weekly Report*, *69*(40), 1450–1456. https://doi.org/10.15585/mmwr.mm6940e1

Mulligan, M. J., Lyke, K. E., Kitchin, N., Absalon, J., Gurtman, A., Lockhart, S., Neuzil, K., Raabe, V., Bailey, R., Swanson, K. A., Li, P., Koury, K., Kalina, W., Cooper, D., Fontes-Garfias, C., Shi, P. Y., Türeci, Ö., Tompkins, K. R., Walsh, E. E., … Jansen, K. U. (2020). Phase I/II study of COVID-19 RNA vaccine BNT162b1 in adults. *Nature*, *586*(7830), 589–593. https://doi.org/10.1038/s41586-020-2639-4

Musker, M. (2020). *What is post-viral fatigue syndrome, the condition affecting some COVID-19 survivors_*.

Narmilan, A., & Sugirtharan, A. (2017). Demand for Organic food Products in the urban areas of the Batticaloa District , Demand for Organic food Products in the urban areas of the Batticaloa District , Sri Lanka. *Research Journal of Agriculture and Forestry Sciences*, *3(11)* (December 2015), 21–26.

Nechaev, V., Mikhailushkin, P., & Alieva, A. (2018). Trends in demand on the organic food market in the European countries. *MATEC Web of Conferences*, *212*. https://doi.org/10.1051/matecconf/201821207008

Perdomo-Celis, F., Taborda, N. A., & Rugeles, M. T. (2019). CD8+ T-cell response to HIV infection in the era of antiretroviral therapy. *Frontiers in Immunology*, *10*(AUG). https://doi.org/10.3389/fimmu.2019.01896

Ramana, L. N., Sharma, S., Sethuraman, S., Ranga, U., & Krishnan, U. M. (2012). Investigation on the stability of saquinavir loaded liposomes: Implication on stealth, release characteristics and cytotoxicity Lakshmi. *International Journal of Pharmaceutics*, *431*(1–2), 120–129. https://doi.org/10.1016/j.ijpharm.2012.04.054

Rauš, K., Pleschka, S., Klein, P., Schoop, R., & Fisher, P. (2015). Effect of an Echinacea-Based Hot Drink Versus Oseltamivir in Influenza Treatment: A Randomized, Double-Blind, Double-Dummy, Multicenter, Noninferiority Clinical Trial. *Current Therapeutic Research - Clinical and Experimental*, *77*, 66–72. https://doi.org/10.1016/j.curtheres.2015.04.001

Ravichandran, R. (2010). Nanotechnology Applications in Food and Food Processing: Innovative Green Approaches, Opportunities and Uncertainties for Global Market. *International Journal of Green Nanotechnology: Physics and Chemistry*, *1*(2), P72–P96. https://doi.org/10.1080/19430871003684440

Ryu, W.-S. (2017). Part IV. RT Viruses. *Molecular Virology of Human Pathogenic Viruses*, 225. https://doi.org/10.1016/b978-0-12-800838-6.00045-x

Samadarsi, R., Mishra, D., & Dutta, D. (2020). Mangiferin nanoparticles fortified dairy beverage as a low glycemic food product: its quality attributes and antioxidant properties. *International Journal of Food Science and Technology*, *55*(2), 589–600. https://doi.org/10.1111/ijfs.14310

Sariol, A., & Perlman, S. (2020). Lessons for COVID-19 Immunity from Other Coronavirus Infections. *Immunity*, *53*(2), 248–263. https://doi.org/10.1016/j.immuni.2020.07.005

Sazawal, S., Black, R. E., Jalla, S., Mazumdar, S., Sinha, A., & Bhan, M. K. (1998). Zinc supplementation reduces the incidence of acute lower respiratory infections in infants and preschool children: A double-blind, controlled trial. *Pediatrics*, *102*(1 I), 1–5. https://doi.org/10.1542/peds.102.1.1

Shoieb, S. M., El-ghiaty, M. A., & El-kadi, A. O. S. (2020). *Targeting arachidonic acid – related metabolites in COVID-19 patients : potential use of drug-loaded nanoparticles*.

Simion, V., Stan, D., Constantinescu, C. A., Deleanu, M., Dragan, E., Tucureanu, M. M., Gan, A. M., Butoi, E., Constantin, A., Manduteanu, I., Simionescu, M., & Calin, M. (2016). Conjugation of curcumin-loaded lipid nanoemulsions with cell-penetrating peptides increases their cellular uptake and enhances the anti-inflammatory effects in endothelial cells. *Journal of Pharmacy and Pharmacology*, *68*(2), 195–207. https://doi.org/10.1111/jphp.12513

Sposito, A. J., Kurdekar, A., Zhao, J., & Hewlett, I. (2018). Application of nanotechnology in biosensors for enhancing pathogen detection. *Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology*, *10*(5), 1–22. https://doi.org/10.1002/wnan.1512

States, U., & June, A. (2020). *COVID-19 Mitigation Behaviors by Age Group —*. *69*(43), 1584–1590.

Wagner, E. K. (2006). *Basic Virology by Wagner*.

Wellinghausen, N., Plonné, D., Voss, M., Ivanova, R., Frodl, R., & Deininger, S. (2020). SARS-CoV-2-IgG response is different in COVID-19

outpatients and asymptomatic contact persons. *Journal of Clinical Virology*, *130*(June), 104542. https://doi.org/10.1016/j.jcv.2020.104542

WHO. (2020). *"Solidarity" clinical trial for COVID-19 treatments*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/global-research-on-novel-coronavirus-2019-ncov/solidarity-clinical-trial-for-covid-19-treatments

Xia, S., & Xu, S. (2005). Ferrous sulfate liposomes: Preparation, stability and application in fluid milk. *Food Research International*, *38*(3), 289–296. https://doi.org/10.1016/j.foodres.2004.04.010

Yahfoufi, N., Alsadi, N., Jambi, M., & Matar, C. (2018). The immunomodulatory and anti-inflammatory role of polyphenols. *Nutrients*, *10*(11), 1–23. https://doi.org/10.3390/nu10111618

Yang, X. X., Li, C. M., Li, Y. F., Wang, J., & Huang, C. Z. (2017). Synergistic antiviral effect of curcumin functionalized graphene oxide against respiratory syncytial virus infection. *Nanoscale*, *9*(41), 16086–16092. https://doi.org/10.1039/c7nr06520e

Zhang, Y., Zeng, G., Pan, H., Li, C., Kan, B., Hu, Y., & Mao, H. (2020). *Immunogenicity and Safety of a SARS-CoV-2 Inactivated Vaccine in Healthy Adults Aged 18-59 years: Report of the Randomized, Double-blind, and Placebo-controlled Phase Clinical Trial*.

Zhao, Y. miao, Shang, Y. min, Song, W. bin, Li, Q. quan, Xie, H., Xu, Q. fu, Jia, J. li, Li, L. ming, Mao, H. li, Zhou, X. man, Luo, H., Gao, Y. feng, & Xu, A. guo. (2020). Follow-up study of the pulmonary function and related physiological characteristics of COVID-19 survivors three months after recovery. *EClinicalMedicine*, *25*, 100463. https://doi.org/10.1016/j.eclinm.2020.100463

Zheng, J. (2020). SARS-coV-2: An emerging coronavirus that causes a global threat. *International Journal of Biological Sciences*, *16*(10), 1678–1685. https://doi.org/10.7150/ijbs.45053

Zimet, P., & Livney, Y. D. (2009). Beta-lactoglobulin and its nanocomplexes with pectin as vehicles for ω-3 polyunsaturated fatty acids. *Food Hydrocolloids*, *23*(4), 1120–1126. https://doi.org/10.1016/j.foodhyd.2008.10.008

The economics of COVID-19 in Sri Lanka: Direct and indirect costs

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ABSTRACT

All decisions should balance benefit to harm, and healthcare decision-making should consider resource availability, scarcity, opportunity-cost, and consequences and trade-offs arising through such decisions. A pandemic can cause widespread disease, disability, and even death. Labour productivity and human capital are directly affected by morbidity and mortality. This study assessed the direct and indirect costs incurred due to COVID-19 in Sri Lanka.

Scenario-based costing assessed the direct and indirect costs of COVID-19. Direct costs were calculated for four categories of patients Lost earnings due to COVID-19 (treatment and isolation) and indirect cost due to ceasing work was calculated based on lost working days and the income/ output lost. Cost data were obtained from the Medical-Supply's-Division(MSD), hospitals, and laboratories. Hospital and Quarantine hotel-cost per day was based on the WHO CHOICE model and adjusted for 2020, and the ICU bed cost per day was based on personal communications. Average stay per patient, days taken off work, and daily wage were from the literature. Microsoft Excel software was used for analysis.

The repeated PCR testing per patient for categories 1-4 was responsible for 22%, 21%, 18%, 3% of the total cost per stay. Other investigations for category 1-4 were accountable for 1.1%, 1.8%, 8.05%, 17.2% of the total costs. The revised PCR testing strategy per patient for categories 1-4 was responsible for 17%, 6.2%, 16.5%, 3% of the total cost per stay. Other investigations for category 1-4 were accountable for 0%, 0.8%, 9.7 %, 16.7% of the total costs.

The quarantine cost per day per patient is Rs.1610.00. The mean income loss due to hospitalization per patient for 14 days for the informal sector would be Rs. 13,800.00. Considering a government sector worker, the loss to the government would be 30,000.00 for 14 days.

The treatment costs among COVID-19 patients depended on the severity of illness. As the disease evolves, treatment and discharge guidelines must be revised considering the available recourses and the disease burden. Considerable fraction of the costs of COVID 19 is incurred in terms of lost earning/output and a further significant loss in terms of lifetime earning caused by mortality.

Key words: Economic impact, COVID-19, Healthcare costs, Opportunity cost/Trade-offs

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1. INTRODUCTION

Sri Lanka provides free healthcare at the point of service delivery, and the healthcare system is predominantly financed by tax revenue. The government allocations for healthcare are approximately half of the country's total health financing (Health expenditure to GDP is around 1.7%). Although there is a need to increase government allocations for health, the lack of fiscal space is a major constraint.

The SARS-COV2 virus, which is the causative agent of Coronavirus disease 2019 (known as COVID-19), continues to sweep the world, the disease burden, and prevention strategies resulting in adverse economic impacts, causing a substantial impact on human lives and even threatening global stability and security (International working group on financing preparedness, 2017). The COVID-19 pandemic, which is observed in various stages in different parts of the world, is a tremendous challenge for preventive health sectors globally.

Cost of illness analysis measures the medical and other costs incurred due to a specific disease or condition. Cost of illness (COI) studies provide policymakers with 1). How much is spent on a disease/ condition 2). It shows the major contributors/components of costs and the proportion of which, 3). Shows the societal impact due to disease 4). Helps healthcare allocations (Byford et al., 2000; Jo, 2014). Hence these are useful for gains inefficiency. In a COI study, an essential component is defining and classification of the costs. COI studies can be categorized into direct, indirect, and intangible costs. Considering COVID-19, the costs incurred can be classified as shown in Figure 1.

Being infected with COVID-19 would incur both direct and indirect costs from the system and the patient perspective. The direct treatment cost of a COVID-19 patient from a system perspective would consider medical care expenditures for diagnosis, treatment, and investigations, etc. The indirect costs due to hospitalization would be productivity losses due to morbidity and mortality.

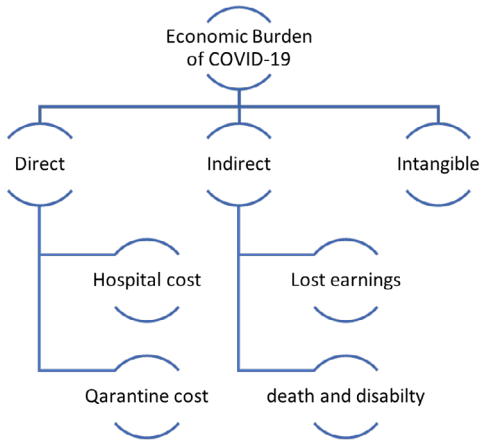

Figure 1. Costs associated with COVID-19

As a Public health and social measure (PHSM) government of Sri Lanka introduced quarantine for suspected exposure and all 'close contacts' of a COVID positive patient. The word 'quarantine' refers to the separation and /or restriction of movements of persons or communities, who are not symptomatic but have been exposed to an infectious disease to prevent or minimize the transmission of that disease (Centers for Disease & Prevention, 2003). Quarantine of a COVID-19 patient would incur both direct and indirect costs. Indirect costs are incurred due to implementation of the PHSM and measured through lost productivity that occur due to absenteeism (time lost from work), presenteeism (impaired time at work), productivity (time lost from work including impaired time at work), or premature retirement (Gamage & De Silva, 2020 ; Jo, 2014). Additionally, the indirect cost of absenteeism due to quarantine will affect the country's gross domestic product (GDP). Although quarantine causes direct and indirect costs, studies had reported that it is cost saving in the long term as it prevents adverse economic effects of disease spread (Gamage & De Silva, 2020). The indirect cost in this analysis looked at the work absenteeism contributing to GDP loss due to COVID-19 patients and the close contacts from the system perspective.

Treatment and disease control decisions made in any circumstance should also consider resource availability and scarcity, the opportunity cost of each decision, and the consequences and trade-offs that arise through such decisions. Such analysis is essential for ensuring the best use of scarce resources and enhancing efficiency (Donaldson & Mitton, 2020). An outbreak could result in high mortality and morbidity in the following ways: direct morbidity and mortality due to COVID-19 infection; indirect morbidity and mortality due to health systems being overwhelmed by COVID-19 care; indirect deaths due to the delay of services such as screening of non-communicable diseases etc. being adversely affected, or people not seeking healthcare due to the avoidance of hospitals; and most importantly adverse economic and societal impact leading to poverty and deprivation which is directly linked to ill health (Christopher, 2020). In Sri Lanka, no study assessed the economic impact of COVID-19 patients. This report focuses on the direct and indirect cost of treatment/isolation due to COVID-19 in Sri Lanka.

2. METHODS

Scenario-based COI analysis was conducted to assess the direct and indirect healthcare costs incurred by the government and households due to COVID-19 in Sri Lanka.

In analyzing the cost of treatment of a diagnosed COVID-19 patient were categorized based on the severity of the infection: 1. Asymptomatic, 2. Symptomatic with oxygen saturation (SPO2) >94%, 3. Symptomatic with oxygen saturation (SPO2) <94% and 4. Critical. It was assumed that the first three categories of patients were in the ward, and the critical cases were treated at the ICU with or without ventilation. The costing exercise consisted of 1. Identifying all resources used for an episode of hospitalization of a COVID-19 patient 2. determining the quantities of each resource needed 3. determine the value of each input (Annex 1).

2.1. Asymptomatic COVID patients:

These patients are (Polymerase chain reaction) PCR positive cases but with no symptoms reported at the point of diagnosis. After the initial assessment, the patient will be provided with a face mask and a kit that contains a set of clothes. Blood samples will be taken for Full blood count (FBC), C- Reactive Protein (CRP), Alanine transaminase (ALT), and Aspartate transaminase (AST). Peripheral oxygen saturation and temperature will be monitored daily.

As per the initial treatment guideline if a patient is asymptomatic, the blood investigations will be repeated on day 5 of admission. If a patient's clinical condition remains stable, the PCR test will be repeated on day 14, and if it is negative, the 2nd test will be done 24 hours after. If a patient's PCR test is positive, then the test will be repeated after five days. In the asymptomatic patients, only symptomatic treatment was given. As per the revised criteria, the asymptomatic patients are now admitted to intermediate care centers with monitoring facilities to assess the disease progression. No blood investigations or specific treatment would be done. If patients remain asymptomatic, they will be discharged from centers on day ten without doing 2nd PCR.

2.2. As per the initial guidelines, symptomatic COVID patients with SPO2 > 94% and stable vitals:

These patients have mild symptoms such as fever, dry cough, throat pain, and malaise. They will not have respiratory distress. Routine investigations and monitoring would be similar to an asymptomatic patient. Additionally, an ECG will be done before starting treatment. Hydroxy chloroquine is given as a treatment for symptomatic patients with 400 mg on day 1 and 200 mg twice a day from day 2 to 5. The blood tests will be repeated every other day or depending on the patients' condition. When a patient's clinical condition improves, PCR will be repeated on day 14, and if it is negative, the 2nd test will be done after 24 hours. If the patient's PCR test is positive, then the test will

be repeated after five days. As per the revised criteria, these patients will be admitted to intermediate care centers or level 2 centers, and their disease progression will be monitored. No specific investigations or treatment are given during their stay. Patients with co mobilities will be treated accordingly. If they recover, they will be discharged from the facility without doing 2nd PCR on day 10.

2.3. Symptomatic COVID with SPO2 <94%:

These patients may develop pneumonia and become Oxygen desaturated. They need oxygen therapy. High flow oxygen therapy or Non-invasive ventilation (NIV) will be used for these patients, with Hydroxy-chloroquine. Levofloxacin or doxycycline may be added when atypical infections are suspected. Additional investigations such as D-dimer, arterial blood gas analysis, and chest X-ray are necessary for these patients. These patients may progress into the critical stage. The revised criteria have been changed as follows: Hydroxychloroquine will be given only to selected patients. Additionally, dexamethasone 6 mg daily IV or oral will be added (for ten days duration) with antibiotics and supplement oxygen therapy. If a patient's D-Dimer is high, S/C Enoxaparin will be considered. These patients are managed in COVID tertiary care hospitals. Once the patient improves clinically with no fever for more than three days, their PCR will be repeated. 2 PCR tests will be done and must be negative 24 hours apart before discharge.

2.4. Critically ill:

5% of all COVID patients, who mostly have other co-morbidities, would progress into the critical stage. They would develop ARDS type of lung injury and need mechanical ventilation. They need more advanced monitoring and supportive treatment in an ICU. Apart from basic investigations, a wide range of investigations are necessary to manage these patients, including D-dimer, coagulation studies, IL 6 levels, and blood culture. Bacterial co-infection and sepsis may worsen the condition. The treatment for these patients may include IV dexamethasone, subcutaneous Enoxaparin, and broad-spectrum antibiotics with organ support. The Global data shows that the outcome of ventilated patients is poor.

2.5. A diagnosed COVID patient may progress from asymptomatic to symptomatic and may end up in a critical stage. The hospital stays for those patients may vary from a few days to several weeks.

Finally average cost per patient per day for each of the above scenario was calculated.

Diagnostic and discharge criteria and treatment for COVID-19 patients were as per the Ministry of Health Guidelines. Two calculations were conducted; 1. The initial guideline where PCR testing was done before discharging patients for categories 1 and 2 mentioned above and 2. The revised guideline on discharge criteria where only one PCR was done and for categories 1 and 2 mentioned above and no blood investigations were performed for asymptomatic patients at discharge. As per the revised discharge criteria issued in January 2021, the asymptomatic patient will be discharged in 10 days with an additional four days at home. The revised criteria, which mainly were on the PCR testing strategy and the number of days kept at the hospital, are summarized in Table 1. The changes applicable were mainly for the above-mentioned category 1 and 2 patients.

The direct costs data were obtained from the Medical Supply's Division (MSD), Hospitals, and laboratories. The hospital bed cost per day was based on the WHO CHOICE model and adjusted for the year 2020 (WHO, 2011), and the Intensive care Unit(ICU) bed cost per day was based on personal communication. Microsoft Excel software was used for data analysis. Data for the indirect costs were based on statistical sources and documents. A template of the cost sheet used is given in Annex 2. Duration of the clinical course (from the onset of the first clinical symptom or the laboratory confirmation of COVID-19 in asymptomatic patients until discharge from

Table 1. Summary of revised COVID-19 treatment guidelines

	Asymptomatic/ Symptomatic with SPO2 >94%,	**Symptomatic with SPO2 <94%**	**Critically ill**
Diagnostic PCR	1	01	01
Discharge PCR	0	02+	02+
Days spent in hospital	10	10+	10+

the hospital (or death) was obtained from published literature in Sri Lanka.

Calculation of direct and indirect cost of quarantine was done as follows; The number of work absent days due to being in quarantine and therefore the work loss was the number of days quarantined. The number of days quarantined for the patients and their first contacts were taken from guidelines of the Ministry of Health and Indigenous Medical Services Sri Lanka and other Sri Lankan literature. This is as follows; 1: All patients who will be discharged from hospitals following completion of treatment will be home quarantined for fourteen days (Lanka., 2020) 2: Asymptomatic contacts of COVID 19 will be quarantined for fourteen days at designated quarantine centers. Their quarantine period will be further extended for fourteen days if a COVID 19 positive patient is detected from the quarantine center from the date of detection of the case. They will also be subjected to mandatory home quarantine from the date released from the quarantine center (Kariyawasam et al., 2020). Hence the minimum period of quarantine will be 28 days, and the maximum period will be 42 days.

Calculation of first-degree contacts- As per literature, there are several methods to calculate the number of possible first-degree contacts of a COVID-19 patient. 1. The number of possible first-degree contacts for SARS had been calculated, assuming that an infected person contacts an average of twenty different people a day (Gupta et al., 2005). As the SARS-CoV-2 virus causes the novel coronavirus disease (COVID-19), the same assumption was applied to this study. Therefore, within the incubation period of 14 days, the index case could put 280 people at risk from the virus(Gupta et al., 2005). Evidence in Sri Lanka suggests that one person can infect an average of 5.4 people without mitigation, and one person can infect an average of 1.4 people with mitigation (LK, 2020). In our study, we calculated the number of possible first-degree contacts using the all three scenarios.

As of 31.01.2021, Sri Lanka is reported to be in cluster transmission of COVID-19. The clusters were the central municipal council (CMC), Sri Lankan Broad Casting cooperation (SLBC), Naval cluster, Sri Lanka Police, Special task force, garment factories, and the fish market cluster force. The numbers of patients in each cluster were obtained from data sources, and the possible contacts were calculated based on the methods given under "*Calculation of first-degree contacts*." To calculate the number of labor force participation of the patients and the contacts, the labor force participation rate (i.e., 51%) of Sri Lanka in the 1st quarter of the year 2020 was used (Finance., 2020).

The monthly salary was used to calculate per day income where relevant. Salaries for the naval base, Sri Lanka Police, and the Special Task Force were obtained from the Ministry of Public Administration and Management of Sri Lanka(Management., 2016). Sri Lanka Government offer's salary increases with increments with the service period. For the convenience of calculation, this study considered the average of the initial salary step (29540 LKR)and the maximum salary (55600 LKR). For the calculation of per day income of other personnel, the mean per capita income per month from the Household Income and Expenditure Survey 2016 in Sri Lanka was taken and corrected for 2020 (Department of Census and Statistics, 2016). After the correction, the informal sector's per day income was considered (Rs.) 19,710.

Indirect cost due ceasing to work

A person can be withdrawn from the workforce due to disability or death and would cease contributing to production. The average age of a person at retirement was taken as 60 years for a government sector worker and an informal sector worker 65 years. To give a monetary value to the number of person-years lost, the number of years that were lost was multiplied by the annual average wage rate of the said employee (Cost of loss of output due to COVID-19 or its complications = number of person-years lost x annual average wage rate of the patient). During the calculation, in addition to the above information, probability of being employed, probability of Survival, the annual growth rate (3.5% a year), 5% discount factor (the present value of all future earnings) were taken into consideration. Calculations were done assuming that due to COVID-19, an employee would have to withdraw from the work force at the age of 50.

3. RESULTS

The average hospital stay for categories 1-4 was 17, 17.5, 16.5, and 13.2 days, respectively(Ministry of Health and Indigenous Medical Services, 2020). The average costs per patient per day and per stay per the initial guideline were calculated and shown in Table 2. The cost calculations following the revised criteria are given in Table 3.

The repeated PCR testing per patient for categories 1-4 was responsible for 22%, 21%, 18%, 3% of the total cost per stay. Other investigations for category 1-4 were accountable for 1.1%, 1.8%, 8.05%, 17.2% of the total costs. Local evidence suggests that 56% of the cases are asymptomatic and that 5% would develop into a severe case of Covid-19. As of 31.01.2021, the total number of COVID-19 cases were 64157. Therefore, it can be approximated that 35,928 cases were asymptomatic and 3208 were critical.

The revised PCR testing strategy per patient for categories 1-4 was responsible for 17%, 6.2%, 16.5%, 3% of the total cost per stay. Other investigations for category 1-4 were accountable for 0%, 0.8%, 9.7 %, 16.7% of the total costs.

Table 2. Average cost per type of patient per day and per stay due to COVID-19

Category	Pricing per day per patient	Total cost per stay per patient
asymptomatic	7041.2	119700.42
symptomatic (SPO2>94%)	7143.5	125011.6
symptomatic (SPO2 <94%)	8743.9	144273.9
critical	69712.4	920203.5

Table 3. Average cost per type of patient per day and per stay due to COVID-19

Category	Pricing per day per patient	Total cost per stay per patient
asymptomatic	3865.0	38650.0
symptomatic (SPO2>94%)	5989.52	104816.6
symptomatic (SPO2 <94%)	9547.2	157529.1
critical	71594.0	945040.2

The direct cost of quarantine was Rs. 1610.00 per patient per day. In which the hotel cost accounted for 54% of the costs.

3.1. Loss of work and GDP

The loss to the society by an employee being sick and therefore production loss (GDP) and if an employee is removed from the workforce due to death and disability loss of income to the family was calculated.

Considering the indirect cost, the mean income loss due to hospitalization per patient for 14 days working in the informal sector would be Rs. 11,500.00. Considering a government sector worker, the loss to the government on average would be 30,000.00 for 14 days. Given that sick leave is granted, individuals face no lost earning but would be incurred by the government as loss of production (GDP).

Table 4 shows the loss of output due to being in quarantine. As described in the methods, this was done for being home

Table 4. Loss of work due to COVID-19 and the economic impact

	No of patients	Labour force participation	No of days quarantined.	Total cost (LKR)
Patients being home quarantined after discharge from the hospital.	63293	33043	14	316,577,058.00
Contacts if an index case put 280 people at risk	17,722,040	9,038,240	28	166,267,470,398.40
Without mitigation (5.4)	4,784,951	2,440,325	28	37,300,854,283.76
With mitigation (1.4)	1,240,543	632,677	28	11,638,722,964.68

quarantined for 14 days after being discharged and considering three exposure scenarios.

Based on the calculations (Table 4), due to patients being home quarantined for 14 days after discharge from the hospital, the monetary value of loss of output would be Rs.316 million.

Loss of output due to putting the primary contacts of the index case in quarantine if he puts 280 people at risk would amount to Rs. One hundred sixty-six billion and putting the primary contacts of the index case in quarantine if R0 5.4 would account to Rs 37 billion and if R0 is 1.4 would account to Rs. 11 billion.

Table 5 and Table 6 show the calculations on lost earnings for a government sector and informal sector worker, incorporating probabilities of Survival and employment if he/she is withdrawn from the workforce due to disability or death and would cease to contribute in the production. For a government sector worker and an informal sector worker, the total lost earnings would be Rs. 4.5 million and Rs. 3 million respectively.

4. DISCUSSION

The treatment costs among COVID-19 patients depended on the severity of illness. This suggests that early diagnosis, allowing for symptomatic treatment, could have been essential in keeping healthcare costs low, in addition to enhancing their probability of Survival. As per the initial treatment guidelines, the per-day cost for an asymptomatic patient is Rs.7041.2 per day, while the treatment of a critically ill patient needing ICU care is, on average, Rs. 70,000.00 per day. As per the revised guideline, the treatment costs for asymptomatic and symptomatic with >94%SPO2 were reduced. This was mainly due to the revised PCR strategy and the introduction of an "intermediate treatment center" for asymptomatic patients and the duration of hospital stay. The cost of treatment for COVID-19, particularly the need for ICU care, and the cost of treating ICU patients were linked to co-morbidities. This once again supports the prevailing policy recommendations in the country for better diagnosis and management of NCDs.

Table 5. Calculating lost earnings for a government sector office

Age	Income	Annual income	Probability of Survival	Income if Alive	Probability of Employment	Expected Income	Discount 5%	Discounted Income
50	42570	510840	0.922	470994.48	1	470994.5	1	470,994.48
51	44102.5	529230	0.88	465722.4	1	465722.4	1.05	443,545.14
52	45690.2	548282.4	0.88	482488.512	1	482488.5	1.10	437,631.30
53	47335.1	568021.2	0.88	499858.656	1	499858.7	1.16	431,796.70
54	49039.1	588469.2	0.88	517852.896	1	517852.9	1.22	426,038.86
55	50804.5	609654	0.88	536495.52	1	536495.5	1.28	420,358.28
56	52633.5	631602	0.824	520440.048	1	520440.0	1.34	388,360.38
57	54528.3	654339.6	0.824	539175.8304	1	539175.8	1.41	383,182.20
58	56491.3	677895.6	0.824	558585.9744	1	558586.0	1.48	378,072.97
59	58525	702300	0.824	578695.2	1	578695.2	1.55	373,032.09
60	60631.9	727582.8	0.824	599528.2272	1	599528.2	1.63	368,058.32
								4,521,070.72

Table 6. Calculating lost earnings for an informal sector worker

Age	Income	Annual income	Probability of Survival	Income if Alive	Probability of Employment	Expected Income	Discount Rate	Discounted Income
50	19,710	236520	0.922	218071.4	0.918	200189.5819	1	200189.6
51	20419.6	245035.2	0.88	215631.0	0.918	197949.236	1.05	188523.1
52	21154.7	253856.4	0.88	223393.6	0.918	205075.3542	1.10	186009.4
53	21916.2	262994.4	0.88	231435.1	0.918	212457.3961	1.16	183528.7
54	22705.2	272462.4	0.88	239766.9	0.918	220106.0252	1.22	181081.8
55	23522.6	282271.2	0.88	248398.7	0.918	228029.9662	1.28	178667.4
56	24369.4	292432.8	0.824	240964.6	0.918	221205.5278	1.34	165067.0
57	25246.7	302960.4	0.824	249639.4	0.918	229168.9413	1.41	162866.1
58	26155.6	313867.2	0.824	258626.6	0.918	237419.1938	1.48	160694.7
59	27097.2	325166.4	0.824	267937.1	0.918	245966.2703	1.55	158552.1
60	28072.7	336872.4	0.824	277582.9	0.918	254821.0633	1.63	156438.0
61	29083.3	348999.6	0.824	287575.7	0.918	263994.4654	1.71	154352.1
62	30130.3	361563.6	0.824	297928.4	0.918	273498.2771	1.80	152294.1
62	31215	374580	0.824	308653.9	0.918	283344.2986	1.89	150263.5
64	32338.7	388064.4	0.824	319765.1	0.918	293544.3302	1.98	148259.8
65	33502.9	402034.8	0.824	331276.7	0.918	304111.9878	2.08	146283.1
								2,673,070.35

PCR testing and investigations are responsible for a considerable amount of the costs incurred during the hospital stay. PCR testing is an essential strategy in prevention, and since PCR testing can lead to segregation of even asymptomatic patients is an essential strategy for limiting contacts, while community PCR testing is an important strategy for disease surveillance. The other investigations carried out regularly during the hospital stay are important for patient monitoring. As there are differences in treatment costs at the different stages of the illness, such management strategies could be important economically and from the patients' wellness perspective. As resources are limited, and every decision has a trade-off, it is recommended that further research be carried out to carefully analyze such trade-offs to ensure the best use of publicly funded resources. As the disease evolves, treatment and discharge guidelines may have to be revised considering the country's available resources and the disease burden. The Antigen (Ag) and Antibody (Ab) testing is currently being implemented in Sri Lanka. However, they are not widely used as these tests are only available in a few hospitals. Therefore, we have not estimated such costs in this exercise, so this could be considered a limitation of the study.

Many studied have pointed out that direct costs account for only a portion of the total health and productivity-related expenditure. Productivity related costs are much more important from an employer's societal perspective and should be considered in policy debates and decision making. Tracing and placing people in quarantine is a useful measure in reducing transmission. It can be argued that with proper mitigation (i.e., given that R0 is 1.4), the numbers exposed and therefore quarantined could be reduced, and therefore the productivity loss could be minimized. If an employee is removed from the workforce and the productivity loss, the training cost for that particular employee to perform in that field is wasted and a loss. Additionally, the government has to spend on the training of a similar employee.

5. CONCLUSION AND RECOMMENDATION

- The treatment costs among COVID-19 patients depended on the severity of their illness.
- PCR testing and investigations accounted for a considerable amount of systemic costs.
- The cost estimates can be considered in the healthcare planning and budgeting process. As the disease evolves, treatment and discharge guidelines may have to be

revised considering the availability of resources and the disease burden.

- Considerable fraction of the costs of COVID 19 is incurred in terms of lost earnings/output.
- Enhanced mitigation would lead to reduced loss of output.
- There will be a significant loss in terms of lifetime earning caused by mortality.
- Households would have incurred a high magnitude of psychic costs, but this was too complex to measure in this context.

REFERENCES

Gamage, A. & De Silva, A. (2020). Public health interventions and economic implications due to COVID-19. *Journal of the College of Community Physicians of Sri Lanka,, 26 (5)*. doi:DOI: http://doi.org/10.4038/jccpsl.v26i5.8355

Byford, S., Torgerson, D. J., & Raftery, J. (2000). Economic note: cost of illness studies. *BMJ (Clinical research ed.), 320*(7245), 1335-1335. doi:10.1136/bmj.320.7245.1335

Centers for Disease, C., & Prevention. (2003). Use of quarantine to prevent transmission of severe acute respiratory syndrome--Taiwan, 2003. *MMWR. Morbidity and mortality weekly report, 52*(29), 680-683. Retrieved from http://europepmc.org/abstract/MED/12881699

Christopher, W. (2020). *COVID-19. An initial view.* Paper presented at the Gresham College Lectures Gresham College, .

Department of Census and Statistics. (2016). *Household Income and Expenditure Survey 2016.* Retrieved from Colombo Retrieved from http://www.statistics.gov.lk/HIES/HIES2016/HIES2016_FinalReport.pdf

Donaldson, C. & Mitton, C. (2020). Coronavirus: Where Has All the Health Economics Gone? *International Journal of Health Policy and Management*, -. doi:10.34172/ijhpm.2020.108

Finance., D. O. C. S. M. o. (2020). QUARTERLY REPORT OF THE SRI LANKA LABOUR FORCE SURVEY 2020- First Quarter. Retrieved from http://www.statistics.gov.lk/LabourForce/StaticalInformation/QuarterlyReports/1stQuarter2020

Gupta, A. G., Moyer, C. A., & Stern, D. T. (2005). The economic impact of quarantine: SARS in Toronto as a case study. *The Journal of infection, 50*(5), 386-393. doi:10.1016/j.jinf.2004.08.006

International working group on financing preparedness. (2017). *From Panic and Neglect to Investing in Health Security:Financing Pandemic Preparedness at a National Level*. Retrieved from

Jo, C. (2014). Cost-of-illness studies: concepts, scopes, and methods. *Clinical and molecular hepatology, 20*(4), 327-337. doi:10.3350/cmh.2014.20.4.327

Kariyawasam, M., Wickramasinghe, S., Ginige, S., Samaraweera, S., Palihawadana, P., Ruwanpathirana, T., . . . Gamage, D. (2020). *Epidemiological Characteristics of COVID-19 and Efforts to Prevent Community Transmission: The Sri Lankan Experience*.

Lanka., M. o. H. a. I. M. S. S. (2020). Sri Lanka Preparedness & Response Plan. Retrieved from http://www.health.gov.lk/moh_final/english/public/elfinder/files/news/2020/FinalSPRP.pdf

LK, C. (2020). Coronavirus (COVID-19) Sri Lanka - Analytics Dashboard- Spread Probability in Sri Lanka Before vs After Lockdown [Internet]. . Retrieved from https://covid.iq.lk/

Management., M. o. P. A. a. (2016). Revision of the Salaries in Public Service - 2016. 2016;. Retrieved from http://www.museum.gov.lk/web/images/stories/Circulars/2016/English/03_2016e.pdf

Ministry of Health and Indigenous Medical Services. (2020). *Clinical and Epidemiological Characteristics of the Confirmed COVID-19 Patients in Sri Lanka. Status Report Based on the Interim Analysis of the First 100 COVID-19 Patients Following Hospital Discharge or Death*. Retrieved from Colombo:

WHO. (2011). Country-specific unit costs. *Choosing Interventions that are Cost Effective (WHO-CHOICE).* Retrieved from https://www.who.int/choice/country/country_specific/en/

ANNEX

Annex 1. Template of cost data extraction sheet

Cost category	Cost per item	Value of each input (cost per item * quantity)
Diagnosis		
PCR		
Investigations		
FBC		
CRP		
ALT		
AST		
ECG		
S. Creatinine		
INR		
BU		
D- Dimer		
ECG		
CXR		
ESR		
Treatment		
PCM 1 tab		
HCQ 200 mg		
Levofloxacin 500 mg		
Meropenem 1 g		
Saline I pint		
Oxygen		
mask for Oxygen		
Intubation and Ventilation		
Hospital bed/day		
ICU bed/ day		
Protective equipment		
Mask		
gloves		
Gown		
full PPE (N 95, boots, D gloves, cap, kits, surgical mask, shield, apron)		
Staff/day		
Consultant		
Doctor		
Nurse		
Minor staff		
Meals		
Breakfast		
Lunch		
Dinner		
Refreshments		
Tea		
Kanji/ Light meal		
Others		
Transport cost /Km		

Annex 2. Costing template for indirect cost assessment

Total number of 1st contacts	No of days quarantined			Daily income	Per day loss per person	Total loss due to 14 days quarantine	GDP loss due to 14 days quarantine	1/4 of workers in SL are daily wage earner (Economist Lanka)	1/24 will lose employment (Economist Lanka)
assumes that a person contacts an average of 20 different people a day. The incubation period of 14 days would be used in calculation. Therefore, the index case could put 280 people at risk from the virus.	To	From	Total					(Total infected + 1st contacts) x 1/4 = daily wage earners	(Total infected + 1st contacts) x 1/24 = will lose employment
Total infected x 280= total 1st contacts									
Total infection x Ro									

Knowledge, attitudes and practices on COVID-19 among medical students in Sri Lanka

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ABSTRACT

The recent coronavirus disease (COVID-19) pandemic is associated with increasing morbidity and mortality and has impacted the global population. Human behavior and knowledge assessment during the crisis are critical in the overall efforts to contain the outbreak. We carried out study to assess knowledge, attitude, perceptions towards COVID-19 medical students in Sri Lanka

Methods: We planned a cross-sectional descriptive study conducted between April-June 2020. Participants were students enrolled at Faculty of Medical Sciences University of Sri Jayewardenepura. A questionnaire posted on online platforms was used for data collection. The questionnaire consisted of three main sections: knowledge, attitudes, and practices regarding COVID-19.

Results: We found 73.9% had overall good knowledge about COVID. Majority lacked knowledge in areas such as specimen storage and transportation. Males and pre intern students had more knowledge. Majority believed that they have a chance of getting infected with COVID and were worried of the social stigmatization of their family members. Most are willing to accept isolation in health care facility in case of COVID infection. Relatively low knowledge in the sequence followed when wearing Personal Protective Equipment (PPEs) and removal of a used mask with correct response rates of 51.91% and 53.05% respectively. But the majority showed a good overall practice score.

Conclusion: Medical students showed expected level of knowledge about the COVID-19 virus, but require more training in usage of PPE and mask hygiene. Measures should be taken to address social stigmatization of health care professionals and their family members.

Key words: Attitudes, COVID, Knowledge, Medical students, Practices

1. INTRODUCTION

Coronavirus disease 2019 (COVID-19 or Covid-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Culp, 2020). It was first identified in December 2019 in the capital of China's Hubei province, Wuhan. Since then it has spread globally as a pandemic 2019-2020 (Zhu et al., 2020). The actual origin of COVID 19 is unknown, but the spread of infection was almost entirely driven by human-to-human transmission(Surveillances, 2020).Typical presentations include fever, cough, and shortness of breath. Furthermore, fatigue, muscle pain, diarrhea, sore throat, and abdominal pain are also recognized as less common symptoms(Numbers, 2020). There are more than ten million cases have been reported across 185 countries and territories, resulting in

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more than 511,545 deaths and the global death-to-case ratio, is 4.87% (511,545/10,487,022) as of first of July 2020 based on Johns Hopkins University statistics (John Hopkins Corona Virus Resource Center, n.d.). The number may vary by region.

The frontline health professionals had been performing an outstanding role in treatment of COVID confirmed and suspected cases. This pandemic has made a huge impact as never before towards the mental health of the health care professionals. Doctors, nurses and other personnel who are involved in direct patient care mostly were subjected to quarantine process and were deprived of visiting their own family and had to limit their social interactions (Tan et al., 2020; Tsamakis et al., 2020; Varshney et al., 2020).

Apart from the knowledge about the corona virus, the attitudes and practices adopted by health care professionals during this hard time determined the success of the control programs. The assessment of knowledge and behavior patterns adopted by the public towards this pandemic is of vital importance especially due to the large amount of misconceptions and false information that are bombarded upon population by social media and other means of platforms regarding transmission of the disease and methods of acquisition(Olum et al., 2020). This is of importance to healthcare professionals, service providers and medical students. Such assessments would be useful as an important means in the education and raising awareness of best practice. The utility of such information has proven benefits in successful control of previous viral outbreaks including Severe Acute Respiratory syndrome(SARS), Middle East Respiratory Syndrome (MERS), and Ebola (Holakouie-Naieni et al., 2015; Jalloh et al., 2017; Van Velsen et al., 2014).

Sri Lanka during the study period had reported 2048 patients with a total death toll of 11 (Bereau, n.d.). The country successfully controlled the spread of the virus with continuous awareness programs and tightly monitored quarantine process. Its nine medical schools and parent universities have been closed for nearly three months rendering a huge impact on the academic career of medical students (Matthias et al., 2013). Medical students are a source of information to public and their families and some even have volunteered to serve in the front line at the peak of the pandemic. Assessing the level of their knowledge and attitude on COVID-19 would reflect to a fair degree the level of knowledge attitude, practices of the general population. The sample also included graduates awaiting their internship appointments who will soon serve as first contact doctors in hospitals. The level of their knowledge, attitudes and practices would influence their contributions in future as members of the health care teams to contain the pandemic successfully.

2. MATERIALS AND METHODS

This study was a cross sectional descriptive study conducted among 523 medical students from first year to final year following MBBS degree at Faculty of Medical Sciences, University of Sri Jayewardenepura, Sri Lanka. University of Sri Jayewardenepura is one of the leading universities in Sri Lanka with a large number of students dispersed among 6 faculties (Dqg, 2018). The medical faculty is attached to three major hospitals in the country as it's teaching hospitals. Colombo South Teaching hospital, Homagama Base Hospital and Sri Jayewardenepura General Hospital with bed capacity 1093, 426 and 1066 respectively (Matthias et al., 2013)(Medical Statistics Unit, 2008). These hospitals are receiving Corona patients and have separate wards to treat COVID suspected cases. Homagama Base Hospital which had been operating as a teaching hospital for medical students was converted to a specialized hospital to treat COVID confirmed cases with effect from 12th of April 2020.

The convenient sampling method was used. The data was collected using an online self-administered questionnaire distributed via e-mail and other social media platforms to 650 students. The questionnaire consisted of two parts: demographics and KAP. According

to guidelines for clinical and community management of COVID-19 by the Ministry of health and WHO a COVID-19 knowledge questionnaire was developed by the authors. WAS THIS VALIDATED? The questionnaire had 10 questions (Table 1): These questions were answered on a true/false basis with an additional "I don't know" option. A correct answer was assigned 1 point and an incorrect/ unknown answer was assigned 0 points. The total knowledge score ranged from 0 to 10, with a higher score denoting a better knowledge of COVID-19. Attitudes towards COVID-19 were measured by five questions. The assessment of respondents' practices was composed of six questions (Table 5) and each correct answer was given 1 point each and an incorrect/unknown answer was assigned 0 points. The total practice score ranged from 0 to 6, with a higher score denoting adaptation to better practices of COVID-19.

3. STATISTICAL ANALYSIS

Frequencies of correct answers for each of the three sections: Knowledge, Attitudes, Practice were described. Mann- Whitney U test was used to assess the statistical difference between knowledge score and gender. Both Kolmogorov-Smirnov and Shapiro-Wilk tests suggest that our dependent variable (knowledge score) is not distributed normally among the academic years hence the non-parametric test 'Kruskal Wallis" has been used in order to assess the significance of the mean scores with respect to each academic year. Multivariable linear regression analysis using gender and academic year as independent variables and knowledge score as the outcome variable was conducted to identify factors associated with knowledge. Furthermore, multiple logistic regression was used to assess the association with attitudes. Similar to analysis of knowledge, practice section was analyzed. A p-value <0.05 was used to indicate statistical significance.

4. RESULTS

4.1. Demography

A total of 523 completed the questionnaire with a response rate of 80.4% A vast majority of the participants were female (n =353, n = 67.5%).

4.2. Knowledge

The overall mean knowledge score was 7.11±1.19, and 387/523 (74%) of the participants scored 70% or more and were considered to have sufficient knowledge. Only 136 participants scored below 70%. Out of 170 males, 113 had scored above 7 and showed good knowledge. 81 females out of 353 had poor knowledge.

The comparison of mean knowledge score with regard to gender and academic knowledge is shown in Table 2.

Table 1. Questions for knowledge and frequencies of correct responses.

Question	Correct response
The origin of COVID-19 is not clear but it appears to have been transmitted to human by sea food, snakes or bats.(T)	398/523(76.09%)
Its common symptoms are fever, cough and shortness of breath but nausea and diarrhea are reported. (T)	471/523(90.05%)
It can be diagnosed by PCR test on sample collected from nasopharyngeal and oropharyngeal discharge or from sputum and bronchial washing. (T)	494/523(94.45%)
It is transmitted through respiratory droplets during coughing and sneezing. (T)	521/523(99.61%)
It is transmitted during close contacts with an infected person (especially in family, crowded places and health care institutions). (T)	518/523(99.04%)
The specimens collected from patients should ideally be transported within 48 hours(T)	244/523(46.65%)
In case of a delay of more than 48 hours, samples should be stored in -70 Celsius(T)	86/523(16.44%)
Patients suffering from chronic diseases are more vulnerable to severe complications from COVID(T)	510/523(97.5%)
The disease can be treated by usual antiviral drugs(F)	370/523(70.74%)
The incubation period of corona virus is up to 14 days with a mean of 5 days(T)	454/523(86.80%)

Table 2. Demographic characteristics of participants and knowledge score of COVID-19 by demographic variables

Characteristics		Number of participants (%)	Mean knowledge score (mean ± standard deviation)	P value
Gender	Male	170(32.5)	7.17±1.31	0.020
	Female	353(67.49)	6.5±1.23	
Academic year	1st year	109(20.84)	6.49±1.21	0.000
	2nd year	24(4.58)	6.62±1.31	
	3rd year	148(28.29)	7.21±1.23	
	4th year	23(4.39)	7.26±0.81	
	5th year	128(24.47)	7.38±1.05	
	Pre intern	91(71.09)	7.41±1.02	

Males have a higher mean score than females. The Mann-Whitney U test found that there was a significant statistical difference between the male and female knowledge scores. Pre interns showed the highest mean score while first year students have shown lowest mean score. The Kruskal- Wallis test showed that there is a statistically significant difference in knowledge scores between the different academic years at 95% significance level. Neither the gender nor the academic year of the students were significantly associated with lower knowledge score at a 95% significance level (using multiple linear regression analysis) (Table 3)

4.3. Attitudes

Multiple logistic regression analysis found that COVID-19 knowledge score (OR: 1.176, P < 0.05), the 3rd academic year (vs 6th year, OR: 2.601, P < 0.05) and the 4th academic year (vs 6th year, OR: 2.09, P < 0.05) were significantly associated with the disagreement in believing to have a chance of getting infected.Furthermore, Multiple logistic regression analysis found that only the COVID-19 knowledge score (OR: 1.561, P < 0.05) was significantly associated with the disagreement in accepting isolation in a health care institution. See Table 4.

4.4. Practices.

Practices score was assessed based on the answers provided by respondents for 6 questions. A score out of 6 was calculated and 453(86.61%) respondents scored more than 4. The mean practice score was 4.639 The mean practice score of females was 4.702±1.055 and males' is 4.511±1.078. See Table 5.

Multiple linear regression analysis showed that neither the gender nor the academic year of the students were significantly associated with lower practice score at a 95% significance level. (Table 6).

Table 3. Results of multiple linear regression on factors associated with poor COVID-19 knowledge

Variable	Estimated Coefficient (95% CI)	Standard error	t- value	P-value
Gender (Female vs. Male)	0.114919 (-0.173, 0.4032)	0.145703	0.789	0.432
Academic year(1st year vs pre interns)	-0.263548 (-0.7519, 0.2248)	0.246822	-1.068	0.288
Academic year(2nd year vs pre interns)	0.008208 (-0.608, 0.6239)	0.311178	0.026	0.979
Academic year(3rd year vs pre interns)	-0.332133 (-0.8615, 0.1972)	0.267562	-1.241	0.217
Academic year(4th year vs pre interns)	0.259432 (-0.6705, 1.1893)	0.470004	0.552	0.582
Academic year(5th year vs pre interns)	-0.092281 (-0.6598, 0.47526)	0.286852	-0.322	0.748

Table 4. Attitudes towards COVID-19 by demographic variables

Characteristics		Attitudes (%)									
		Do you think you have a chance of getting infected?		Are you worried that one of your family members may get the illness?		If you get infected with COVID, would you accept isolation in a heath care facility?		Are you worried about your family members getting stigmatized for having contracted COVID?		The disease can be prevented by avoiding close contacts disinfection.	
		yes	no	yes	no	yes	no	yes	no	yes	no
Gender	Male	157	13	157	13	167	3	107	63	170	0
	Female	318	35	328	25	342	11	192	161	353	0
Academic year	1st year	99	10	95	14	107	2	66	43	109	0
	2nd year	23	1	18	6	21	3	18	6	24	0
	3rd year	136	12	136	12	144	4	90	58	148	0
	4th year	19	4	23	0	22	1	12	11	23	0
	5th year	107	11	120	8	127	1	78	50	128	0
	Pre intern	81	10	87	4	91	0	37	54	91	0

Table 5. Questions to assess practices and frequencies of correct responses.

Question	Frequency
What is the correct sequence of wearing PPE?	51.91%
The mask should be carefully placed to cover mouth and nose and tied securely to minimize any gaps between the face and the mask	93.51%
Masks should be replaced with new clean, dry masks as soon as they become damp/humid	78.63%
Re-use of the single-use masks is acceptable	84.92%
When the mask is being removed, the correct practice is to remove the front part of the mask first and then the lace behind.	53.05%
Repeated touching of the mask while in use should be avoided	97.71%

Table 6. Results of multiple linear regression on factors associated with poor COVID-19 knowledge.

Variable	Estimated Coefficient (95% CI)	Standard error	t- value	P-value
Gender (Female vs. Male)	0.05285 (-0.1503, 0.2560)	0.10304	0.513	0.6086
Academic year(1st year vs 6th year)	-0.16048 (-0.544, 0.2233)	0.19461	-0.825	0.4106
Academic year(2nd year vs 6th year)	-0.45821 (-0.969, 0.0522)	0.25884	-1.770	0.0782
Academic year(3rd year vs 6th year)	-0.24237 (-0.6142, 0.1295)	0.18859	-1.285	0.2002
Academic year(4th year vs 6th year)	0.01561 (-0.7629, 0.7942)	0.39484	0.040	0.9685
Academic year(5th year vs 6th year)	-0.25382 (-0.6674, 0.1598)	0.20975	-1.210	0.2276

5. DISCUSSION.

To our knowledge, this is the first study in Sri Lanka assessing the KAP towards COVID-19 among Sri Lankan Medical students. The novelty of this disease, along with its uncertainties, make it critical for health authorities to plan appropriate strategies to prepare and manage the public. It is therefore of utmost importance that the knowledge, attitudes and practices of the population, health care professionals and medical students be studied to guide these efforts towards successful management of the epidemic.

The distribution of the sociodemographic characteristics of the respondents showed a high percentage of females and first academic year participants. Knowledge of the etiology and clinical presentation of the disease are considered as the first step of patient education and enable better understanding of disease transmission and preventive measures . Our

study showed markedly higher knowledge in modes of transmission and clinical manifestation of COVID.

Significantly low knowledge was found in areas such as specimen storage and sample transportation. This is of concern due to overwhelmed laboratories there may be a need to store specimens before being sent for processing, an essential piece of knowledge that should be possessed by doctors (WHO, 2020)(European Society of cardiology, 2020). Majority (97.5%) of medical students were aware that patients with underlying chronic diseases are at a higher risk of increased mortality.

A study conducted in China among Chinese residents in the peak of COVID outbreak has shown that knowledge scores significantly differed across genders, age-groups, categories of marital status, education levels, and residence places($P<0.001$). Our study revealed a similar finding with regard to gender and academic year (P 0.020 and P 0.000 respectively). Chinese study found out that male gender (vs. female, β: -0.284, $P<0.001$), age-group of 16-29 years (vs. 30-49 years, β: -0.302, $P<0.001$), marital status of never-married (vs. married, β: -0.215, $P<0.001$), education of bachelor's degree or lower (vs. master degree and above, β: -0.191 ~ -1.346, $P<0.001$), and occupations of unemployment (β: -0.158, $P=0.040$) and students (β: -0.234, $P<0.001$) (vs. mental labor) were significantly associated with lower knowledge score. Multiple linear regression analysis carried out for our study showed that neither the gender nor the academic years is significantly associated with lower knowledge score ($P< 0.05$). The difference observed between these two studies may be attributed to the fact that our study was conducted among medical students who have a similar basic educational qualification and have faced same entry exam. Therefore, gender or current academic year are not factors that lead to lower knowledge score.

Majority of the medical students (90.8%) believe that they have a higher chance of getting infected due to frequent close exposure to patients but almost all believed that avoiding close contacts and frequent disinfection would help in the prevention. A similar study conducted in Chinese health care workers, the percentage population that had the same belief amounted to 82.3%. In a study conducted in Jordan among medical and non-medical students around 90% of the participants believed that despite their strong immunity and beliefs, they can contract infection from COVID-19 patients (Alzoubi et al., 2020). Social stigma, in the context of health, is the negative association related to people or a group who have a specific disease in common. In an epidemic, this may mean that people are labelled, stereotyped, and discriminated against because of a perceived link to the epidemic. This is more critical when dealing with a contagious disease like Corona. This can lead to higher rates of stress and burnouts among health care professionals. This stigmatization can even be seen in their own families. Majority of the study population were afraid that their family members might catch the illness and a similar figure were worried of their family members getting stigmatized for catching the illness.

In the past Sri Lanka has experienced a similar infectious pandemic back in 1918-1919, which was the influenza pandemic. Total loss of population by it was 307 000 or approximately, 6.7% of the population (Chandra & Sarathchandra, 2014). The Sri Lankan doctors or medical students were not given a training on donning and doffing off of PPE except for the ones working in the front line. Therefore, it was the first encounter with PPE for most of the medical doctors. Though the medical students once/twice in their academic carrier have received a training on PPE, much emphasis was not given, as Sri Lanka was not a frequent victim of infectious diseases such as SARS and MERS. Therefore, correct response rate for practice questions regarding correct sequence of PPE is low as 51.91%. CDC guidelines has published a guideline as "How to Put On (Don) PPE Gear" (Centre for Disease Control and Prevention, 2020)and it has described the parts of the attire as well as the sequence to be followed. It is crucial for medical students and health care professionals to be thorough with

these protective gear as Sri Lanka is at a risk of a second wave. As the COVID outbreak continued, various professional colleges and the Health promotion bureau put out instructional videos about PPE (Unit et al., n.d.)and it is clear that medical students need to learn about PPE from these videos as educational institutions will restart academic activities and hospital teaching in the coming months in Sri Lanka with necessary precautions in place. Most Sri Lankan University students are hostellers while minority are day scholars(Perera, n.d.). Maintenance of social distancing in University hostels and privately owned boarding places is hard and rapid spread of this highly contagious virus is inevitable in that setting. In addition, day scholar students might act as carriers to spread the infection to their own family members and public due to close contacts and frequent use of public transport. Therefore, it's essential for medical students to follow PPE training programs conducted by various responsible authorities.

The medical students showed good knowledge on mask hygiene. The correct response rate was above 80%, but the correct response rate was low as 53% for the question that tested the correct way of removing the mask. WHO had published a statement on how to remove the used face mask correctly, which emphasizes the need of removing the mask from behind first. Although the local media, Social scientists, especially those in public health and health communication, are working continuously on cost effective public health campaigns and education programs to increase the awareness among general public and medical professional about the importance of a face mask, our study in fact, exposes the need for more comprehensive education programs on mask hygiene. It is commendable what the authorities, ministry of health and professional colleges have done so far in combatting the COIVID 19 outbreak so far. For further improvement of correct practices, it is essential to focus on consistency of information given out by the government authorities. COVID-19 education efforts should take a proactive approach and focus on dispelling misinformation in the form of conflicting opinions, old wives' tales and incorrect information. Due to higher usage of levels of media by Sri Lankan society the authorities would benefit from utilizing both mainstream and social media in disseminating these messages to the society effectively.

6. CONCLUSION

Medical students showed expected level of knowledge about the COVID-19 virus, but require more training in usage of Personal protective equipment and mask hygiene. Measures should be taken to address social stigmatization of health care professionals and their family members.

REFERENCES

Alzoubi, H., Alnawaiseh, N., Al-Mnayyis, A., Abu-Lubad, M., Aqel, A., & Al-Shagahin, H. (2020). Covid-19—Knowledge, attitude and practice among medical and non-medical university students in Jordan. *Journal of Pure and Applied Microbiology*, *14*(1), 17–24. https://doi.org/10.22207/JPAM.14.1.04

Bereau, H. promotion S. L. (n.d.). *Daily update*.

Centre for Disease Control and Prevention. (2020). Use Personal Protective Equipment (PPE) When Caring for Patients with Confirmed or Suspected COVID-19. *Centre for Disease Control and Prevention Guidelines*, 1–2.

Chandra, S., & Sarathchandra, D. (2014). The influenza pandemic of 1918-1919 in Sri Lanka: Its demographic cost, timing, and propagation. *Influenza and Other Respiratory Viruses*, *8*(3), 267–273. https://doi.org/10.1111/irv.12238

Culp, W. C. (2020). Coronavirus Disease 2019. *A & A Practice*, *14*(6), e01218. https://doi.org/10.1213/xaa.0000000000001218

Dqg, H. (2018). Department of Decision Sciences and Information Management (Kbi). *Erasmus*, 0–15.

European Society of cardiology. (2020). *ESC Guidance for the Diagnosis and Management of CV Disease during the COVID-19 Pandemic*. 1–115.

Holakouie-Naieni, K., Ahmadvand, A., Raza, O., Assan, A., Elduma, A. H., Jammeh, A., Kamali, A. S. M. A., Kareem, A. A., Muhammad, F. M., Sabahat, H., Abdullahi, K. O., Saeed, R. A., & Saeed, S. N. (2015). Assessing the knowledge, attitudes, and practices of students regarding ebola virus disease outbreak. *Iranian Journal of Public Health*, *44*(12), 1670–1676.

Jalloh, M. F., Sengeh, P., Monasch, R., Jalloh, M. B., DeLuca, N., Dyson, M., Golfa, S., Sakurai, Y., Conteh, L., Sesay, S., Brown, V., Li, W., Mermin, J., & Bunnell, R. (2017). National survey of Ebola-related knowledge, attitudes and practices before the outbreak peak in Sierra Leone: August 2014. *BMJ Global Health*, *2*(4). https://doi.org/10.1136/bmjgh-2017-000285

John Hopkins Corona Virus Resource Center. (n.d.). *No Title*. John Hopkins Corrona Virus Resource Center.

Matthias, A. T., Nagasingha, P., Ranasinghe, P., & Gunatilake, S. B. (2013). Neurophobia among medical students and non-specialist doctors in Sri Lanka. *BMC Medical Education*, *13*(1). https://doi.org/10.1186/1472-6920-13-164

Medical Statistics Unit. (2008). *Sri Lanka Health at a Glance*. 1–12.

Numbers, S. I. N. (2020). *Coronavirus disease 2019 (COVID-19). 2019*(March). https://doi.org/10.1056/NEJMc2004973

Olum, R., Chekwech, G., Wekha, G., Nassozi, D. R., & Bongomin, F. (2020). Coronavirus Disease-2019: Knowledge, Attitude, and Practices of Health Care Workers at Makerere University Teaching Hospitals, Uganda. *Frontiers in Public Health*, *8*(April), 1–9. https://doi.org/10.3389/fpubh.2020.00181

Perera, M. A. N. R. (n.d.). *Sociological Analysis of University Students ' Accommodation Issues in Sri Lanka*. 63–94.

Surveillances, V. (2020). The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China. *Zhonghua Liu Xing Bing Xue Za Zhi = Zhonghua Liuxingbingxue Zazhi*, *41*(2), 145–151. https://doi.org/10.3760/cma.j.issn.0254-6450.2020.02.003

Tan, B. Y. Q., Chew, N. W. S., Lee, G. K. H., Jing, M., Goh, Y., Yeo, L. L. L., Zhang, K., Chin, H.-K., Ahmad, A., Khan, F. A., Shanmugam, G. N., Chan, B. P. L., Sunny, S., Chandra, B., Ong, J. J. Y., Paliwal, P. R., Wong, L. Y. H., Sagayanathan, R., Chen, J. T., … Sharma, V. K. (2020). Psychological Impact of the COVID-19 Pandemic on Health Care Workers in Singapore. *Annals of Internal Medicine*, *16*(April), 5–7. https://doi.org/10.7326/m20-1083

Tsamakis, K., Rizos, E., Manolis, A., Chaidou, S., Kympouropoulos, S., Spartalis, E., Spandidos, D., Tsiptsios, D., & Triantafyllis, A. (2020). [Comment] COVID-19 pandemic and its impact on mental health of healthcare professionals. *Experimental and Therapeutic Medicine*, 3451–3453. https://doi.org/10.3892/etm.2020.8646

Unit, E., Services, I. M., & Lanka, S. (n.d.). *Rational use of PPE and Infection Prevention and Control of COVID-19 Health care settings in Sri Lanka*.

Van Velsen, L., Beaujean, D. J. M. A., Van Gemert-Pijnen, J. E. W. C., Van Steenbergen, J. E., & Timen, A. (2014). Public knowledge and preventive behavior during a large-scale Salmonella outbreak: Results from an online survey in the Netherlands. *BMC Public Health*, *14*(1). https://doi.org/10.1186/1471-2458-14-100

Varshney, M., Parel, J. T., Raizada, N., & Sarin, S. K. (2020). Initial psychological impact of COVID-19 and its correlates in Indian Community: An online (FEEL-COVID) survey. *PLoS ONE*, *15*(5), 1–10. https://doi.org/10.1371/journal.pone.0233874

WHO. (2020). Laboratory testing for coronavirus disease 2019 (COVID-19) in suspected human cases. *Interim Guidance*, *March*, 1–7.

Zhu, H., Wei, L., & Niu, P. (2020). The novel coronavirus outbreak in Wuhan, China. *Global Health Research and Policy*, *5*(1), 2019–2021. https://doi.org/10.1186/s41256-020-00135-6

Annex 1. Abbreviations

Abbreviation	**Expansion**
PPE	Personal Protective Equipment
SARS	Severe Acute Respiratory syndrome
MERS	Middle East Respiratory Syndrome
CDC	Center for Disease Control and Prevention

Establishment of healthcare facility at Iranawila, Puttlam for COVID-19 patients: First ever conversion of non-health facility to an infectious disease hospital in Sri Lanka‡

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ABSTRACT

Puttlam was identified as a vulnerable district for COVID- 19 as there were many returnees from Italy by March 2020. The abandoned Ex-Voice of America building at Iranawila was selected to re-furbish and convert to a 40 bedded hospital to manage COVID-19 patients. Ministry of Health took over the building on 20th March 2020. There were several issues in the building such as no electrical supply, blocked drainage system and not functioning tube well. Removal of unwanted structures and partitioning of new isolation cubicles were to be done.

The project was designed by a medical and architect team. Local politicians, religious priests, provincial and district health authorities extended their support. Army personnel completed civil constructions. Data was gathered using qualitative and quantitative techniques,

It was shown that electricity was supplied with a new transformer, existing generator and submersible pump of the tube well were repaired. Air-conditioning system was renovated. The building was refurbished with proper isolation facilities within 14 days and declared open by the Hon. Minister of Health. Project review was conducted after four months duration. Number of patients' admissions was 144 and 341 samples were taken for COVID-19 Reverse transcriptase Polymerase Chain Reaction (RT-PCR) testing.

This hospital has contributed to manage COVID-19 patients up to now. It was recommended as an exemplary model for many other COVID- 19 hospitals (Intermediate Care Centres) later developed in Sri Lanka.

Key words: COVID 19 patients, Ex-voice of America building, Iranawila, Puttlam district, RT-PCR testing

1. INTRODUCTION

The COVID-19 pandemic in Sri Lanka is part of the worldwide pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The first case of the virus was confirmed in Sri Lanka on 27 January 2020, after a 44-year-old Chinese woman from Hubei Province in China was admitted to the National Institute of Infectious Diseases (Colombo Page News Desk, 2020).

‡ **Short Communication**

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COVID-19 was declared as public health emergency of international concern (PHEIC) by World Health Organization (WHO) on 30th of January 2020 as it was spreading all over the world. On 3 March 2020, the first reported case involving a Sri Lankan was reported in Italy (World Health Organization, 2020).

Ministry of Health embarked several preventive and curative sector strategies to combat COVID 19 (Health Promotion Bureau, 2020). Early detection and containment of the patients in isolation centre was a pivotal factor for source reduction. In accordance with this epidemiological principle, Ministry of Health has initiated conversion of several hospitals such as Base Hospital Homagama and Colombo East Base Hospital, Mulleriyawa for admitting of COVID 19 confirmed cases (Ministry of Health Sri Lanka, 2020). The Ministry of Health (MoH) of Sri Lanka felt the need of being prepared early to successfully contain the pandemic which could pose a significant threat to the nation as there were 70 total COVID-19 patients by 20th of March, and most of the confirmed cases (37) were reported from Gampaha, Colombo and from Puttlam districts (Health Promotion Bureau Sri Lanka, 2020).

1.1. Justification

Considering the epidemiological pattern of the disease transmission, Puttlam district was identified as a vulnerable area by the district health authorities as there were 1423 Returnees from Italy to this district by 20th of March 2020. MoH recognized the urgent need of establishing a health care facility which is dedicated for isolation and management of COVID- 19 suspected patients in the area. The abandoned Ex-Voice of America building premises at Iranawila was selected as the project location for this purpose after conducting SWOT analysis.

1.2. Objective

The project aimed at re-furbishing the existing building of Ex-Voice of America building at Iranawila in Puttlam district to a 40 bedded hospital to manage COVID-19 patients.

2. METHODOLOGY

Director General of Health Services of the Ministry of Health nominated a team to conduct a feasibility study of the project. This team included Director, Healthcare Quality and Safety, Director, Primary Healthcare Services, and the Regional Director of Health Services, Puttlam and the Consultant physician of Base Hospital Marawila.

This premises belongs to the Ministry of Finance and Policy Development and they agreed to hand over this building for the

Strengths Ex VOI premises spreads over 490 acres of land which belong to the Ministry of Finance, Economy and Policy Development and consented to hand over the keys of the building to the Ministry of Health. Being located in isolated area from the local community, it was suitable for conversion to an Infectious disease hospital	**Opportunities** Strong political leadership and commitment of provincial and district level authorities Strong support from the religious leaders of the community
Weaknesses There may be difficulty in mobilizing healthcare staff due to lack of transport facilitates No pipe borne water supply. But there was only a tube well. High voltage electrical supply which has already been disconnected.	**Threats** Possibility of project failure due to unforeseen events 2. Need to fix a transformer to get a new connection from the Ceylon Electricity board with in limited time

Figure 1. SWOT Analysis conducted at the EX-Voice America Building Premises

purpose of establishing a COVID treatment centre. Based on the recommendation of the feasibility assessment, the Director General of Health Services took over the building on 20th March 2020 by virtue of the power vested with him as the proper authority under Quarantine and Preventing Disease Ordinance of 1987 of Sri Lanka ("QUARANTINE AND PREVENTION OF DISEASES ORDINANCE," 1987). Project was to be completed during the period of 20th March 2020 to 07th April 2020.

A situation analysis was conducted and responsibilities were allocated to solve the priority issues during preliminary visit of project team. (Figure 2)

The project design was guided by the three consultants namely, a microbiologist, an anaesthetist and a physician and qualified architect. The principal author was the project coordinator.

One adjacent building was supplied with electricity with a generator and transformed into a conference room with air-conditioning facilities. Next meeting was held with all the stakeholders and it was a crucial one. The project stakeholders had alternative opinions on how to supply electricity and water. Best possible options were agreed upon and following decisions were made.

1. Fixation of a 600 KVA capacity transformer to the premises
2. Repair of the submersible pump of the tube well
3. Renovation of the existing air conditioning system of the main building
4. Refurbishment of the building by the army personnel

Provincial health authorities, local politicians, district secretary of Puttlam district, divisional secretary, water board and electrical engineers and the religious priests of the area involved in the decision-making process throughout the implementation of the project.

Data was collected from observational visits, Key informant interviews. Patients data was extracted from available registers for successive four months period and analysed.

3. RESULTS

Existing generator was repaired. A transformer and panel boards were fixed in the premises by the Ceylon Electricity Board. The existing submersible water motor was repaired. Air-conditioning system was renovated. Existing building was partitioned with proper isolation facilities. Army personnel of Engineering service finished the civil works, plumbing and electrical wiring to complete this project with in two weeks period. Ante-rooms, donning rooms and doffing rooms were established according to the infection control standards.

Robot operated drug dispensing trolley, autoclaving facilities and other essential facilities such as a backup generator, supply of electricity, purified water supply, separate sewerage system, an ambulance and transport facilities for laboratory samples were established.

Issues	Activity to be done	Responsibility
Full of dust inside the building and weeds in the garden	Cleaning of the building and the premises	Pradeshiya Saba representatives and the community
No Electricity. High voltage lines were disconnected	Provision of Generator as an urgent short-term measure and Supply of electricity with a transformer proper voltage	Ceylon Electricity Board
No water supply to the building	Cleaning of tube well and purification of water	Water board
All drainage lines were blocked	Cleaning of drains	Municipal council

Figure 2. Preliminary Issues Identified and the Preliminary Activities conducted at the EX-Voice America Premises

A medical officer in-charge with two acting consultant physicians were assigned by the Ministry of Health. Other categories of staff including nursing staff were mobilized by the district health authorities. Necessary biomedical equipment was also provided.

The centre was declared open for patient care on 7th of April 2020 enabling accommodation of asymptomatic COVID-19 patients. Patients in quarantine centres or in any other setting were transferred to this hospital for further management. The workload in first four months after the commencement of this facility is depicted in Table 1.

RT- PCR samples were obtained and transported to other laboratories during the 1st wave of COVID-19. Moreover, it was revealed that no health staff became COVID infected at Iranawila hospital due strict infection control measures which have been adopted since inception of the hospital.

4. DISCUSSION

It was a well-coordinated project, managing triple constraints (Cost, Quality and Time). As provision of safe care is the one of the most important domains of quality of healthcare (Agency for Healthcare Research and Quality, 2020), safe design of the hospital was a critical consideration.

It was revealed that COVID 19 patients were treated in a safe environment with skilful staff at Iranawila hospital ensuring both patient and health worker safety. As this hospital accommodate only diagnosed COVID patients, it allows other hospitals of the district to provide routine patient care services. Reduction of overcrowding of other hospitals and reduction of risk of health workers of other hospitals in the district were benefits of the project.

Table 1. Number of Admissions and Number of RT-Polymerase Chain Reaction (RT-PCR) tests performed up to July 2020

Month	Number of admitted patients	Number of RT-PCR tests done
April	23	23
May	52	56
June	30	157
July	39	105
Total	144	341

The project sustainability was achieved with wider stakeholder participation. Yet, there were some issues. District health authorities were concerned that a considerable proportion of funds allocated for health services of the whole district, had been spent for a 40 bedded treatment centre to manage COVID-19 patients. Some of the staff were needed to be transported daily to Iranawila for duty shifts to minimize their exposure to Covid19 infection.

Four (04) medical officers from Primary Care Medical Units (PMCU) of the Puttlam district were deployed to Iranawila to cater the services for COVID 19 patients. It affected the proper functioning of these PMCUs, resulting patients who seek primary care to find another health facility.

5. CONCLUSIONS

This was the first ever converted non-health facility to accommodate COVID-19 patients in the country. The project contributed to manage this pandemic handling 144 admissions within four months of implementation. The best practices of this centre have been shared to many other healthcare facilities of the country.

It is considered as a benchmark hospital which ensures healthcare worker safety and recommended as an exemplary model for many other COVID- 19 hospitals (Intermediate Care Centres) later developed in Sri Lanka.

REFERENCES

Agency for Healthcare Research and Quality. (2020). *Six Domains of Health Care Quality | Agency for Healthcare Research and Quality*. https://www.ahrq.gov/talkingquality/measures/six-domains.html

Colombo Page News Desk, S. L. (2020, January 27). First patient with coronavirus reported in Sri Lanka. *Colombo Page News Desk, Sri Lanka*. http://www.colombopage.com/archive_20A/Jan27_1580144354CH.php

Health Promotion Bureau. (2020). *Health Promotion Bureau COVID-19 Updates*. https://www.hpb.health.gov.lk/en/covid-19

Health Promotion Bureau Sri Lanka. (2020). *HPB | Live updates on New Coronavirus (COVID-19) outbreak*. https://www.hpb.health.gov.lk/en

Ministry of Health Sri Lanka. (2020). *Guidance for intermediate care centres on management of COVID-19 positive individuals* (p. 6). https://www.epid.gov.lk/web/images/pdf/Circulars/Corona_virus/Guidance_for_intermediate_care_centers_on_management.pdf

QUARANTINE AND PREVENTION OF DISEASES ORDINANCE. (1987). In *Chapter 553*.

World Health Organization. (2020). Public Health Emergency of International Concern (PHEIC). In *World Health Organization*. https://www.who.int/publications/m/item/covid-19-public-health-emergency-of-international-concern-(pheic)-global-research-and-innovation-forum

NATIONAL SCIENCE FOUNDATION

Section 3

Mental Health and Wellbeing

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Mental Health and Wellbeing: Introduction

Enoka Wickramasinghe

The World Health Organization (2004) defines mental health as not merely the absence of a mental disorder, but a state where a person is self aware, able to cope with daily stresses effectively, and while being productive will contribute to the society. Pandemic COVID-19 has taken the world by storm as it continues to impact the majority of countries across globe including Sri Lanka. With the increase in physical health related risks there is an increase in the risk placed on the mental health and wellbeing too.

Due to the novelty of COVID-19 pandemic, the response strategies were completely new, imposing inevitable uncertainty and hardships to all categories of people in varying degrees in Sri Lanka and the world. To curb the spread of this highly contagious deadly infection, government of Sri Lanka declared island wide curfew for nearly three months initially and time to time lock downs and travel restrictions thereafter since March 2020. These elements of infection control affected the mental health status among all categories of people in different degrees due to the effect on livelihood, economy, social life and educational needs. The mental wellbeing during these phases depended on the pre-COVID health status, particularly the mental health status, family cohesion, financial stability, employment, housing conditions, social networks and personal wellbeing. Similar to any other disaster a small proportion of people may need specific psychological and social services while majority needed some form of psychosocial support, imposing additional demand and burden for the mental health service providers and policy makers in the country.

To make evidence based informed decisions on mental health service provision, it is imperative to conduct scientific research in the field of mental health across its broad spectrum. The five short manuscripts published under the mental health track in this volume are based on original research conducted during the period of COVID-19 across a range of important mental health themes. The risk perception and adherence to COVID preventive measures; effect of non-availability of alcohol and tobacco on the use and the perceptions of wives; availability of personal protective equipment and depressive symptoms among nurses; effects of lockdown and household characteristics on continued education, and exploration of reach of a awareness campaign on violence against women (VAW) and toxic masculinity have been assessed scientifically for further action. Using online methods of data collection in majority of these projects showcase the optimal utilization of contextual opportunities and continued scientific enthusiasm during this challenging time.

Gunawardena and the team from University of Peradeniya give evidence on the association between locus of control and self efficacy to risk perception; and self efficacy and accessibility to adherence to COVID-19 related safety measures among university undergraduates. Vital insights are produced on how mental processes such as risk perception, personality factors, and availability and accessibility to sanitary products impact the adherence behaviours to COVID-19 preventative measures among young students. With the possibility of continued pandemic for more than another three years, this research provides an eye opener for educational policy makers to ensure safety within universities, when those are re-opened. Also the findings pave path to further explore feasibility of re-opening when recommendations of this study are implemented, and impact of lockdowns on continued undergraduate education.

Chandrasekara, Weerasinghe and Basnayake provide evidence on the negative impact of COVID-19 outbreak on education and the mental perception of undergraduates in Kelaniya University. Loss of jobs of family members, home violence, and having to assist cultivation activities decided students online lecture attendance. Poor internet connectivity, lack of IT facilities were the other reasons, though overall knowledge on IT use has increased. Existence of negative concerns of

mental healthiness and suicidal thoughts also needs prompt attention. For continued and effective university education, it is important that these students are given necessary support by the higher education authorities. Similar studies are needed in all 16 universities, and also in schools and pirivens in Sri Lanka, because relevant national level policy decisions can only be taken if the broader picture is well explored and understood.

Pandemic COVID-19 greatly impacted all occupations and livelihoods, of which healthcare providers faced the highest workload and risk. Wickramarachchi, and the group's effort on how availability of personal protective equipment (PPE) affect the depressive symptoms among nursing officers provides insights into how feeling of protection affect psychological states at times like present. According to the study majority of nursing officers experienced depressive symptoms and PPE were not available adequately during the first phase of the pandemic in Sri Lanka. The psychological burden of COVID-19 on other formal and informal occupations is worth studying, as mental health and wellbeing of workers are important because those are key determinants of work performance and thereby the national economy.

In Sri Lanka the prevalence of alcohol and tobacco consumption is more than 20%. The manuscript on alcohol and tobacco consumption during the COVID-19 restrictions in Sri Lanka by De Seram, Bandara Tenna, Sumanasekara and Ranchigoda, provides valuable findings for substance use prevention programs. The project spanned across all districts in Sri Lanka, found that reduced availability of alcohol and tobacco during the curfew period led to reduced consumption. As high as 80% alcohol users and 68% smokers reduced the consumption. Moreover, 48% wives felt reduction of family problems, and expenditure with increased family savings. Paper showcases how situational influences provided the alcohol and tobacco users an opportunity to experience benefits of being free from use. Hence, the paper emphasizes the importance of reduced availability of addictive substances nationwide, if we are to halt these unhealthy practices.

Finally the manuscript on Mitigating the 'Shadow Pandemic' of COVID-19 a project by De Soyza and the group from Faculty of Medicine, Colombo identified how being confined to home with the violent partner made it harder for women to seek support at times of violence. Using multiple modes of dissemination, the project focused on raising public awareness to end such violence. Increased knowledge leads to willingness to change attitudes and behaviors. This timely effort managed to impart knowledge, and condemn toxic masculine attitudes and behaviors that contributed to VAW. Formal evaluation of effects of awareness campaigns on VAW and toxic masculine behaviours would be beneficial to plan and implement effective preventative interventions.

The findings of these five projects provide information for national level policy decisions and mental health promotion interventions, and will open doors for future research on effects of the pandemic on important themes among vulnerable populations, informal work settings and low socioeconomic groups as the degree of the impact on mental health varies across categories. Exploring magnitude of stigma and discrimination also cannot be forgotten in addressing mental wellbeing as those are important negative behaviours coined with mental disorders.

The impact of personality dimensions and associated factors on COVID-19 pandemic related risk perception and adherence behaviour among university undergraduates

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ABSTRACT

The outbreak of COVID-19 around the world has posed a severe threat to public health and wellbeing. Individual responses to the COVID-19 pandemic depend on a variety of factors. The present study aimed to identify the impact of personality dimensions: Locus of control (LOC), and self-efficacy (SE), and socio-demographic factors on the perceived risk perception and adherence behavior related to COVID-19.

The study sample consisted of 371 undergraduate students from the Faculty of Arts, University of Peradeniya. Content and consensual validated online questionnaires were circulated among consenting undergraduates during the lockdown period from March to April 2020. The online questionnaires assessed LOC, SE, COVID-19 related risk perception, accessibility to sanitary products relating to COVID-19 and adherence to COVID-19 related safety measures.

External LOC, (r= .147, p=.004), SE, (r = -.313, p=.000) and adherence to safety measures, (r = .102, p= .049), reported positive, negative and positive significant associations respectively with COVID-19 related risk perception. SE (r =.290, p= .000), and accessibility to sanitary products (r (369) = .102, p=.049) was significantly positively associated with adherence to COVID-19 related safety measures. A statistically significant predictive relationship was found between external LOC and COVID-19 related risk perception. Accessibility to sanitary facilities marginally significantly predicted adherence to safety measures, $F(1,369) = 3.885$, $p < 0.01$ $R2 = .010$.

External LOC has a significant role to play in perception of risk among the undergraduate study sample. Increasing SE levels and provisions for free hygiene facilities will aid in increasing adherence to COVID-19 safety measures.

Key words: COVID-19, Risk perception, Adherence behavior, Undergraduates, Personality

1. INTRODUCTION

The COVID-19 pandemic has taken the world by storm as it continues to impact the majority of countries in the world. There have been large numbers dying due to the virus with the death toll at 8th January 2021 standing at 1,906,770 (Worldometer, 2021). It is predicted that there are long term physical effects due to COVID-19 (Centre for Disease Control USA, 2020). With the increase in physical health related risk there is an increase in the risk placed on the development of mental health problems. A cross sectional survey conducted in

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December 2020 depicted a higher incidence of suicidal thoughts globally (Rathod et al., 2020). Health care workers particularly have displayed higher incidence of anxiety and depression. With the first transmission of COVID-19 in Sri Lanka in April 2020 there was a prediction of an increase in cases of depression, anxiety, grief, substance related disorders due to COVID 19 and an increased risk for acute stress disorder, post-traumatic stress disorder, substance abuse and dependence, anxiety and depression due to quarantine situations (Ellepola & Rajapakse, 2020).

The likelihood of contracting the COVID-19 virus is reported to be higher for the aged (above 60 years of age) and for those with underlying health conditions (Miller & Englund, 2020). However when psychological and social impacts of COVID-19 are considered the line between who gets affected and who does not is less pronounced as the imposition of quarantine and the uncertainty related anxiety and stress has led to various groups of people experience a deterioration in psychological wellbeing (Zhang et al., 2020; Alkhamees et al., 2020; Morelli et al., 2020).One such sub population that has had to face drastic changes in their day to day life and also their psychological health is the student population in the world (Adnan & Anwar, 2020; Dhawan, 2020; Moawad, 2020)

Health behavior related research has indicated that risk perception is a key psychological factor which determines whether individuals would implement protective behaviors which in-turn influences the likelihood of contracting the disease (Brewer et al., 2007; Dionne et al., 2007). Studies conducted among university students, have found students who are living closer to high-risk areas, female students, non-medical students and who have higher knowledge levels relating to COVID-19 report higher levels of risk perception (Ding et al, 2020). The importance of having a certain level of risk perception is highlighted by the fact that individuals who do not perceive adequate levels of risk are more likely to repeatedly engage in behavior that would put other individuals at risk by non-adherence to safety precautions (Ferrer & Klein, 2015).The convergence of both affective and deliberative risk perception is seen to increase the likelihood of selecting and acting based on a health promoting behavior (Ferrer et al., 2011). Another important finding based on previous research is the fact that affective risk perception which manifests itself as incessant worry about the likelihood of the occurrence of an event, can also lead to individuals not engaging in preventive behaviors (Ferrer et al., 2013).

Adherence to safety precautions is a key behavioral component that plays a role in mitigating health related risks and in the context of a pandemic it becomes a vital point when it comes to health promotion campaigns. Many countries around the world have implemented preventive strategies such as social distancing, use of protective gear and encouraging and providing facilities for basic hand hygiene related activities and "stay at home" policies (Hale et al., 2020).

Risk perception is influenced by the control one has of one's situation which is termed locus of control (LOC) and this connection is found to be stronger in the context of life threatening situations (Armas et al., 2017). LOC is divided into two main components; internal LOC and external LOC. People with internal LOC assume responsibility and influence what happens to them and are therefore self-reliant when in their responses to difficult situations while people with external LOC rely on the environment and other people and objects to solve their problems for them. Individuals with internal LOC have a higher chance of engaging in active coping strategies (Valentiner et al., 1994). There are contradictory findings however, in connection with the relationship between LOC and risk perception with some studies concluding that there is a positive correlation between internal LOC and general risk perception (Kallmen, 2000) and another study finding a positive relationship between external LOC and risk perception (Armas et al., 2017).

Several studies have found that the odds of healthy/adherence behaviour were greater

among individuals with an internal LOC (Ozcakir et al., 2014)

Furthermore, another study conducted in Germany found that students engaged more strongly in unhealthy behaviour if they believed luck determines health (Helmer et al., 2012). Although this study does not directly measure the LOC, the basic idea can be closely associated

A study conducted in Poland concludes that the internal dimension of health control has the greatest impact on health in the group studied. This study does not measure health behaviour in terms of adherence. However it can be concluded that good health is an indicator of positive health behaviour and adherence to health guidelines (Deluga, 2018).

Self-efficacy (SE) refers to an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments (Bandura, 1977, 1986, 1997 as cited in Muretta, 2005). COVID-19 related SE looks at how much one believes in one's capability to protect oneself from getting infected with the COVID-19 virus (Yildirim & Guler, 2020) SE has been found to have a negative relationship with risk perception (Schaninger, 1976). A cross-sectional study conducted in Iran during March and April 2020 which measured risk perception (efficacy, defensive responses, perceived treat) related to the COVID-19 shows more than half of all participants were motivated by danger control. This research also indicated that more than half of participants had high perceived efficacy which comprised of SE and response efficacy (Jahangiry, 2020). However a contradictory finding has been found in another study where teacher's risk perception was assessed along with their SE levels and response efficacy and approach to disease prevention during the COVID-19 pandemic in Taiwan. Results showed that teachers with a higher risk perception and lower SE levels showed a stronger adoption of disease prevention measures (Tang et al., 2020).

Early literature shows SE play a significant role in health behavior and adherence to preventive programs (O'Leary, 1985). There are few researches on SE and adherence during COVID-19.

There are many psychological pathways of promote *adherence behaviors like SE in controlling the spread of the COVID-19. However a relatively limited number of studies have explored these relationships in connection with COVID-19.*

As health adherence, there are many factors affecting COVID-19 related health behaviors. Many studies show that risk perception of COVID-19 one of the most important component for behavior change as well as the existence of positive correlation between perceived risk and protective, health related behavior (Dolinski et al., 1987). There is a significant relationship between risk perception and SE as a predictive factor when it comes to using health information and promoting health behaviors. A study done by Rimal (2001) aimed at finding out the effects of risk perception and SE on individuals' motivation to think about heart disease. Results show that there is a significant interaction between risk perception and SE on individuals' decision to undertake preventive behaviors when it comes to health related conditions.

Several studies have found a relationship between risk perception and adherence to preventive health behavior. Data from two studies with U.S. respondents revealed an ideological divide in adherence to social distancing guidelines during the COVID-19 pandemic. Differences in reported social distancing were mediated by divergent perceptions of the health risk posed by COVID- 19 which was explained by differences in self-reported knowledge of COVID-19 and perceived media accuracy in covering the pandemic. The politicization of COVID-19 may have prompted conservatives to discount mainstream media reports of the severity of the virus, leading them to downplay its health risks and consequently adherence less to social distancing protocols (Rothgerber, 2020). In a study conducted in Italy exploring the degree of the adherence to quarantine restrictions

and other factors associated with self-reported adherence levels, found that individuals who perceived higher risk, were more anxious and were also more likely to adhere to quarantine guidelines. Furthermore, results showed significant differences among demographic groups in tendency to comply with quarantine orders, with women, more educated people, residents of Southern Italy (despite recording fewer number of positive cases), middle-aged individuals, and health workers more likely to adhere to quarantine guidelines (Carlucci et al., 2020) .

Accessibility to safety products is also a factor that plays a role when it comes to determining the level of risk that one is in as well as the ability to adhere to safety methods. A study conducted in Netherlands during the A (H1N1) pandemic found perceived vulnerability and the intention to adopt protective measures increased during the pandemic. Higher levels of intentions to receive vaccination were associated with increased perceived vulnerability (Van der Weerd et al., 2011). Another study in Netherlands on monitoring of risk perceptions and correlates of precautionary behavior related to human Avian influenza during 2006-2007 conducted found perceived severity appeared to be high and remained over time for people who followed less precautions (de Zwart et al., 2010). Research data from a study conducted on perception of risk regarding the use of medications and other exposures during pregnancy confirmed women overestimated the risk of drugs and other exposures during pregnancy. The way pregnant women perceived teratogenic risk is directly associated with their drug use during pregnancy (Nordeng, 2009).

In a study conducted to measure the effects of pharmacy care program on medication adherence depicted that specific pharmacy care program led to increase the medical adherence ,medication persistence and clinically meaningful reduction in blood pressure. The discontinuation of the program was associated with decreased medication adherence and persistence (Lee et al., 2006). From a meta- analysis done on health beliefs, disease severity and patient adherence showed clearly lower adherence is related to severity of patients disease conditions (Dimatteo et al., 2007).

Though some studies have been conducted globally about risk perception and adherence related behavior during the COVID-19 pandemic many such studies have been conducted taking a general population into account. Moreover there is a dearth of such research looking at the combination of personality dimensions such as LOC and SE as well as accessibility to safety measures as determinant factors for the development of risk perception and adherence to safety precautions in the Sri Lankan context. Moreover generally there is relatively less number of such researches conducted taking into consideration the student population in tertiary education. This research aims to fulfill this gap and thereby also seeks to identify whether interventions targeting prevention of the spread of COVID-19 should focus on manipulating personality related factors and accessibility to safety products related to COVID-19 as a means of changing perception of risk related to COVID-19 and COVID-19 related adherence behavior.

The first objective of the study was to explore whether personality related dimensions namely, LOC and SE affect risk perception and adherence to safety measures. The second objective was to assess the predictive nature of personality dimensions on COVID-19 related risk perception and adherence to safety measures.

The research hypotheses were,

H1: External LOC will have a positive relationship with COVID-19 risk perception

H2: Higher SE levels will lead to lower COVID-19 related risk perception

H3: External LOC will have a negative relationship with adherence to COVID-19 related safety measures

H4: SE will have a positive relationship with adherence to COVID-19 related safety measures.

H5: Adherence to COVID-19 related safety measures will have an effect on COVID-19 related risk perception

H6: Accessibility to COVID-19 related safety products will have an impact on adherence to COVID-19 related safety measures.

2. METHODOLOGY

2.1. Participants

The study sample consisted of 371 undergraduate respondents from the Faculty of Arts, University of Peradeniya. The convenience sampling method was used to recruit the sample. There were 64.4% first year students, 14.4% second year, 12.9% third year and 8.4% fourth year students in the total sample. The majority in the sample were females (90.6%). The sample was equally representative of all socioeconomic groups and all provinces except for the Northern Province.

2.2. Materials and Procedure

LOC was measured using a nine-item scale developed by Fritzberg et al., (2019). This scale measures both internal and external LOC. An overall scale score can also be calculated by reversing the external LOC scale item scores to indicate increasing internal LOC.

SE was measured by using an item used in a study conducted by Yildirim and Guler (2020) in Turkey. The item consisted of asking participants "How confident are you that you can prevent getting COVID-19 in case of an outbreak?". The likert type response item requires participants to give a rating from 1= not confident to 5= very confident. A higher score indicates higher SE

COVID-19 related risk perception was assessed using an eight item scale adapted and developed by Yildirim and Guler (2020). The scale was adapted and developed based on a scale initially developed relating to SARS (Brug et al., 2004).The likert type scale measures both cognitive risk perception and emotional risk perception relating to COVID-19.Higher scores on each dimension is reflective of higher personal risk relating to COVID-19.

A six item likert type scale was developed to measure adherence to safety measures relating to COVID-19. The scale was developed using the COVID-19 related safety guidelines issued by the Government of Sri Lanka.

A socio demographic information sheet was developed to capture the age, gender, socioeconomic status, residential province as well as the level of accessibility to safety products relating to COVID-19

As the preliminary stage of this study the three questionnaire measuring LOC, self-esteem and COVID-19 related risk perception were carried through the forward and backward translation process to ensure the conceptual meaning of the questionnaires are retained. Thereafter to content and consensually validate the questionnaires a five member Delphi panel was consulted. The pre-finalized version was edited based on feedback received from the Delphi panel.

During the second stage of the study the questionnaires were compiled into a Google form which comprised of Sinhala and English versions. Google forms were then circulated via email among the undergraduate students. Participation in the survey was entirely voluntary and personal information was not recorded during data collection. The participants also had the right to withdraw during the answering of the questionnaire or within a two weeks period after the submission of their questionnaire if they experienced any kind of discomfort when taking part in the survey. Participants were also given information relating to accessing relevant mental health related services in case of distress experienced during the study.

3. RESULTS AND DISCUSSION

The student sample displayed on average higher levels of emotional risk perception (*M=12.30, SD=4.69)* in comparison with

cognitive risk perception *(M=7.04.SD=3.166).* Adherence to safety measures were also at a higher level when considering at overall total adherence score of 30 (*M=25.04, SD=3.573).* Based on demographic information based analysis it was seen that females reported significantly higher levels of adherence to COVID-19 related safety measures in comparison to the males *t (369) = -3.196 p=0.002.* The sample displayed marginally higher external LOC levels *(M= 16.34, SD=7. 082)* than internal LOC *(M=15. 26, SD=4.107)*. The SE levels were also marginally higher in the total sample *(M=. 40, SD= .846)*.

No significant differences were found in risk perception based on gender, year of study, socioeconomic status, and residential province. There was no significant difference in adherence to COVID-19 safety measures based on year of study, socio economic status and residential province.

Inferential statistics based analysis conducted on the two personality dimensions of LOC and SE revealed the following results: External LOC reported a positive significant correlation with COVID-19 related risk perception *(r = .147, p=.004)* and a significant negative relationship was reported between SE and COVID-19 related risk perception *(r=-.313, p=.000).*Therefore hypothesis 1 and 2 were supported by these findings. The positive correlation between external LOC and Covid-19 related risk perception could be due to the fact that individuals with external LOC being more depended on the healthcare system to intervene in their illness rather than taking responsibility themselves which enhances risk perception (Macaden & Clarke, 2006). The present study findings relating to a university student sample finds results similar to the ones found by Armas et al., (2017) where they too found a positive relationship between external LOC and risk perception relating to exposure to a llife-threatening situation such as an earthquake. The negative correlation between SE and COVID-19 risk perception has been reported in earlier studies as well as when your feel you have lesser ability to protect oneself by initiating different mechanisms the risk perception would increase (Schaninger, 1976). SE level directly influences ones response efficacy. Therefore, when it is at a lower level there is a likelihood of risk perception increasing (Jahangiry, 2020). However when SE levels are low thereby increasing risk perception, there could also be an increase in disease prevention measures which could be one positive effect of having low SE levels during the a pandemic situation (Tang et al., 2020).

In terms of behavioural responses adherence to COVID-19 related safety measures and COVID-19 related risk perception was positively correlated *(r= .102, p= .049)* supporting hypothesis 5. This positive correlation is in concordance with another study done using a sample from the general population where a positive correlation was found (Rubin, 2009). One study conducted in Italy found that this higher adherence level is triggered by the anxiety that individuals with higher risk perception experience (Calrucci et al., 2020). The same study found females adhering more to the safety measures than males which is also similar to the findings from the university sample of the current study where females were more likely to adhere to safety precautions as opposed to the males. This gender wise difference where females are more likely engage in preventive and avoidant behaviors during COVID-19 has been found in other research as well (Chen et al., 2020, Wenham et al., 2020). Men are typically more likely to engage in risky behaviour than women (Cobey et al., 2013).

As predicted by hypothesis 3 external LOC reported a negative relationship with adherence to COVID-19 safety measures (r=-0.057, p=0.275). However this correlation was not at a significant level. The negative correlation found in the present study is similar to the findings of a study conducted in Germany among a student population) where students were found to engage in more unhealthy behaviour and adhere less to healthy behaviour if they believed luck determines health outcomes (Helmer et al., 2012).

Supporting hypothesis 4 the personality dimension of SE was also positively correlated to adherence to COVID-19 related safety measures (*r = .290, p = .000*).SE has been found to be a strong predictor of health behavior (Alshammari, 2018). It also plays an essential role in motivating individuals to engage in protective practices (Aghababaei et al., 2020). Accessibility to sanitary products was also significantly positively associated to adherence to COVID-19 related safety measures *(r =.102, p=.049).* A reduction in accessibility to precautionary measures either through the increase in cost or lack of supply leads to a drop in adherence to healthy behavior (Qeadan, 2020).

As shown in Table 1 self-esteem (β= -.220, p< 0.05) and external LOC (β=.131, p<0.05) were found to be predictive of COVID-19 related risk perception. The overall regression equation was also significant (F (4,366) = 6.594, p< 0.000) with an R^2 of .067. However when considering individual contributions of variables to the overall model internal LOC and adherence to safety measures were not predictive of COVID-19 related risk perception. Overall the carryover effects of the significant external LOC and SE can be seen in the same two variables being predictive of COVID-19 related risk perception. LOC especially external LOC is a possible factor that should be focused on when conducting intervention relating to increasing risk perception as a mechanism to encourage preventive behavior. Higher SE levels lead to higher danger control which is in turn predictive of the level of risk perception that they display (Jahangiry, 2020).

When looking at which variables are predictive of adherence to COVID-19 related safety procedures (Table 2) it was found that SE (β= .227, p< 0.05) and accessibility to COVID-19 related safety methods (β=.075, p< 0.05) were predictive of adherence to COVID-19 related safety measures. As SE directly considers one's capability to protect one- self from getting infected with COVID-19 it has also been found to be predictive of adherence behavior relating to COVID-19. In the context of accessibility to COVID-19 related safety products previous research has found that when freely accessible precautionary methods are not provided or is once provided and then is stopped adherence behavior also drops (Lee et al, 2006).

Table 1. *Multiple regression analysis for main predictors and their effect on COVID-19 related risk perception*

Model	Unstandardized Coefficients		Standard Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	21.223	2.799		7.582	.000
SE	-1.698	.407	-.220	-4.167	.000
External LOC	.120	.049	.131	2.450	.015
Internal LOC	.032	.085	.020	.378	.705
Adherence to COVID-19 related safety measures	.098	.097	.054	1.012	.312

Dependent variable: COVID-19 related Risk Perception

Table 2. *Multiple regression analysis for main predictors and their effect on Adherence to COVID-19 related Safety measures.*

Model	Unstandardized Coefficients		Standard Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	18.786	1.239		15.15	.000
SE	1.171	.211	.277	5.551	.000
External LOC	-0.030	.026	.059	-1.127	.260
Internal LOC	.075	.045	.086	1.642	.101
Accessibility to COVID-19 related safety products	.248	.164	.075	1.508	.045

Dependent variable: Adherence to COVID-19 related safety measures

4. CONCLUSION

Based on this study it can be concluded that external LOC and SE play an influencing predictive role when it comes to risk perception. SE and accessibility to play a predictive role in adherence to COVID-19 related safety measures. Adherence to safety measures should be encouraged more specially among male students through prevention and promotion programs. Implementing programs to increase SE by providing free sanitary products relating to COVID-19 would also be a mechanism that can be implemented within the University set up with the intention of increasing adherence. Interms of limitations this study only accessed students who have access to internet facilities. This would have excluded students who did not have internet accessibility. Moreover the study findings can only be generalized to students in the Arts faculty. As coming into direct contact with the illness plays a role in risk perception as well as the adherence levels displayed by students, future research should also focus on students in other faculties who might come into contact with the virus due to clinical training processes. This would make it more possible to general findings to a wider student base.

REFERENCES

Adnan,M., & Anwar, K. (2020). Online Learning amid the COVID-19 Pandemic: Students' Perspectives. *Online Submission*, *2*(1), 45-51. DOI: 10.33902/JPSP. 2020261309

Aghababaei, S., Bashirian, S., Soltanian, A., Refaei, M., Omidi, T., Ghelichkhani, S., & Soltani, F. (2020). Perceived risk and protective behaviors regarding COVID-19 among Iranian pregnant women. *Middle East Fertility Society Journal*, *25*(1), 1-9.doi: https://doi.org/10.1186/s43043-020-00038-z

Alkhamees, A. A., Alrashed, S. A., Alzunaydi, A. A., Almohimeed, A. S., & Aljohani, M. S. (2020). The psychological impact of COVID-19 pandemic on the general population of Saudi Arabia. *Comprehensive psychiatry*, *102*, 152192. https://doi.org/10.1016/j.comppsych.2020.152192

Alshammari, F. (2018). Knowledge and perception of health practitioners towards MERS-CoV in hail region, Kingdom of Saudi Arabia. *American Journal of Nursing Research*, *6*(1), 12-17. DOI:10.12691/ajnr-6-1-2

Armaș, I., Cretu, R. Z., &Ionescu, R. (2017). SE, stress, and locus of control: The psychology of earthquake risk perception in Bucharest, Romania. *International journal of disaster risk reduction*, 22, 71-76.https://doi.org/10.1016/j.ijdrr.2017.02.018

Brewer, N. T., Chapman, G. B., Gibbons, F. X., Gerrard, M., McCaul, K. D., & Weinstein, N. D. (2007). Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. *Health psychology*, *26*(2), 136. doi:10.1037/0278-6133.26.2.136

Brug, J., Aro, A. R., Oenema, A., De Zwart, O., Richardus, J. H., & Bishop, G. D. (2004). SARS risk perception, knowledge, precautions, and information sources, the Netherlands. *Emerging infectious diseases*, *10*(8), 1486. doi: 10.3201/eid1008.040283

Carlucci, L., D'Ambrosio, I., & Balsamo, M. (2020). Demographic and attitudinal factors of adherence to quarantine guidelines during COVID-19: The Italian Model. Frontiers in Psychology, 11, 2702. https://doi.org/10.3389/fpsyg.2020.559288

Chen, N., Zhou, M., Dong, X., Qu, J., Gong, F., Han, Y., et al. (2020). Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan. *Chin. Descript. Stud. Lancet* 395, 507–513. DOI: 10.1016/s0140-6736(20)30211-7

Cobey, K. D., Laan, F., Stulp, G., Buunk, A. P., and Pollet, T. V. J. E. P. (2013). Sex differences in risk taking behavior among Dutch cyclists. *Evol. Psychol.* 11, 350–64. https://doi.org/10.1177/147470491301100206

Worldometer. (2021, January 8). Coronovirus Death Toll, https://www.worldometers.info/coronavirus/coronavirus-death-toll/

de Zwart, O., Veldhuijzen, I. K., Richardus, J. H., & Brug, J. (2010). Monitoring of risk perceptions and correlates of precautionary behaviour related to human avian influenza during 2006-2007 in the Netherlands: results of seven consecutive surveys. *BMC Infectious Diseases*, *10*(1), 114. https://doi.org/10.1186/1471-2334-10-114

Deluga, A., Bogdańska, P., Dobrowolska, B., Slusarska, B., Bartoszek, A., & Szczekala, K. (2018). The Health Locus of Control and Health Behaviours Declared by Students of Health Sciences. Nursing in the 21st Century. 17. 10-17. 10.2478/pielxxiw-2018-0002.

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems*, *49*(1), 5-22. https://doi.org/10.1177/0047239520934018

Dolinski, D., Gromski, W., & Zawisza, E. (1987). Unrealistic pessimism. *The Journal of Social Psychology*, *127*(5), 511-516. https://doi.org/10.1080/00224545.1987.9713735

DiMatteo, M. R., Haskard, K. B., & Williams, S. L. (2007). Health beliefs, disease severity, and patient adherence: a meta-analysis. *Medical care*, 521-528. https://www.jstor.org/stable/40221467

Ding, Y., Du, X., Li, Q., Zhang, M., Zhang, Q., Tan, X., & Liu, Q. (2020). Risk perception of coronavirus disease 2019 (COVID-19) and its related factors among college students in China during quarantine. *PloS one*, *15*(8), e0237626. https://doi.org/10.1371/journal.pone.0237626.

Dionne, G., Fluet, C., & Desjardins, D. (2007). Predicted risk perception and risk-taking behavior: The case of impaired driving. *Journal of risk and uncertainty*, *35*(3), 237-264. https://doi.org/10.1007/s11166-007-9023-8.https://doi.org/10.1007/s11166-007-9023-8

Ellepola, A. & Rajapakse, R.P.S.S. (April 2020). The foreseeable psychological impact of COVID 19 in Sri Lanka. DOI: 10.13140/RG.2.2.26156.21120.

Ferrer, R. A., & Klein, W. M. (2015). Risk perceptions and health behavior. *Current opinion in psychology*, *5*, 85-89. https://doi.org/10.1016/j.copsyc.2015.03.012

Ferrer, R. A., Hall, K. L., Portnoy, D. B., Ling, B. S., Han, P. K., & Klein, W. M. (2011). Relationships among health perceptions vary depending on stage of readiness for colorectal cancer screening. *Health Psychology*, *30*(5), 525. DOI: 10.1037/a0023583

Ferrer, R. A., Portnoy, D. B., & Klein, W. M. (2013). Worry and risk perceptions as independent and interacting predictors of health protective behaviors. *Journal of health communication*, *18*(4), 397-409. https://doi.org/10.1080/10810730.2012.727954

Hale, T., Petherick, A., Phillips, T., & Webster, S. (2020). Variation in government responses to COVID-19. *Blavatnik school of government working paper*, *31*. https://www.bsg.ox.ac.uk/sites/default/files/2020-04/BSG-WP-2020-032-v5.0_0.pdf

Helmer, S. M., Krämer, A., & Mikolajczyk, R. T. (2012). Health-related locus of control and health behaviour among university students in North Rhine Westphalia, Germany. *BMC research notes*, *5*(1), 703. https://doi.org/10.1186/1756-0500-5-703

Jahangiry, L., Bakhtari, F., Sohrabi, Z., Reihani, P., Samei, S., Ponnet, K., & Montazeri, A. (2020). Risk perception related to COVID-19 among the Iranian general population: an application of the extended parallel process model. *BMC public health*, *20*(1), 1-8. https://doi.org/10.1186/s12889-020-09681-7

Kallmen, H. (2000). Manifest anxiety, general self-efficacy and locus of control as determinants of personal and general risk perception. *Journal of risk research*, 3(2), 111-120.https://doi.org/10.1080/136698700376626

Lee, J. K., Grace, K. A., & Taylor, A. J. (2006). Effect of a pharmacy care program on medication adherence and persistence, blood pressure, and low-density lipoprotein cholesterol: a randomized controlled trial. *Jama*, *296*(21), 2563-2571. doi:10.1001/jama.296.21.joc60162

Centre for Disease Control USA (2020, November 13). Long-Term Effect. https://www.cdc.gov/coronavirus/2019-ncov/long-term-effects.html

Macaden, L. & Clarke, C.L. (2006) Risk perception among older South Asian people in the UK with type 2 diabetes. International Journal of Older People Nursing 1(3), 177–181. doi:10.1111/j.1748-3743.2006.00026.x.

Miller, R., & Englund, K. (2020). Transmission and risk factors of OF COVID-19. *Cleveland Clinic journal of medicine*. DOI: 10.3949/ccjm.87a.ccc029

Moawad, R. A. (2020). Online Learning during the COVID-19 Pandemic and Academic Stress in University Students. *Revista Românească pentru Educație Multidimensională*, *12*(1 Sup2), 100-107. https://doi.org/10.18662/rrem/12.1sup2/252

Morelli, M., Cattelino, E., Baiocco, R., Trumello, C., Babore, A., Candelori, C., & Chirumbolo, A. (2020). Parents and Children During the COVID-19 Lockdown: The Influence of Parenting Distress and Parenting Self-Efficacy on Children's Emotional Well-Being. *Frontiers in Psychology*, *11*, 2584. https://doi.org/10.3389/fpsyg.2020.584645

Muretta Jr, R. J. (2005). *Exploring the four sources of self-efficacy* (Doctoral dissertation, ProQuest Information & Learning).

Nordeng, H., Ystrøm, E., & Einarson, A. (2010). Perception of risk regarding the use of medications and other exposures during pregnancy. *European journal of clinical pharmacology*, *66*(2), 207-214. https://doi.org/10.1007/s00228-009-0744-2

O'Leary, A. (1985). Self-efficacy and health. *Behaviour research and therapy*, *23*(4), 437-451. https://doi.org/10.1016/0005-7967(85)90172-X

Ozcakir, A., Dogan, F.O., & Bayram, N. & Bilgel, N. (2014). *Health Locus of Control, Health Related Behaviors and Demographic Factors: A Study in*

a Turkish Population. https://doi.org/10.9734/BJMMR/2014/9440

Qeadan, F., Akofua Mensah, N., Tingey, B., Bern, R., Rees, T., Talboys, S., ... & Shoaf, K. (2020). What protective health measures are Americans taking in response to COVID-19? Results from the COVID Impact Survey. *International Journal of Environmental Research and Public Health*, *17*(17), 6295. https://doi.org/10.3390/ijerph17176295

Rathod, S., Pallikadavath, S., Young, A. H., Graves, L., Rahman, M. M., Brooks, A., ... & Phiri, P. (2020). Psychological impact of COVID-19 Pandemic: Protocol and Results of first three weeks from an international cross-section survey-focus on health professionals. *Journal of Affective Disorders Reports*, *1*, 100005.

Rimal, R. N. (2001). Perceived risk and self-efficacy as motivators: Understanding individuals' long-term use of health information. *Journal of Communication*, *51*(4), 633-654.

Rothgerber, H., Wilson, T., Whaley, D., Rosenfeld, D. L., Humphrey, M., Moore, A. L., & Bihl, A. (2020, April 22). Politicizing the COVID-19 Pandemic: Ideological Differences in Adherence to Social Distancing. https://doi.org/10.31234/osf.io/k23cv

Rubin, G. J., Amlôt, R., Page, L., & Wessely, S. (2009). Public perceptions, anxiety, and behaviour change in relation to the swine flu outbreak: cross sectional telephone survey. *Bmj*, *339*, b2651. doi: 10.1136/bmj.b2651

Schaninger, C. M. (1976). Perceived risk and personality. *Journal of Consumer Research, 3*(2), 95–100. https://doi.org/10.1086/208656

Tang, J. S., Chen, C. L., Lin, C. H., & Feng, J. Y. (2020). Exploring teachers' risk perception, self-efficacy and disease prevention measures during the outbreak of 2019 novel coronavirus disease in Taiwan. *Journal of Infection and Public Health*

Valentiner, D. P., Holahan, C. J., & Moos, R. H. (1994). Social support, appraisals of event controllability, and coping: An integrative model. *Journal of Personality and Social Psychology*, *66*(6), 1094. https://doi.org/10.1037/0022-3514.66.6.1094

Van der Weerd, W., Timmermans, D. R., Beaujean, D. J., Oudhoff, J., & van Steenbergen, J. E. (2011). Monitoring the level of government trust, risk perception and intention of the general public to adopt protective measures during the influenza A (H1N1) pandemic in the Netherlands. *BMC public health*, *11*(1), 575. https://doi.org/10.1186/1471-2458-11-575

Wenham, C., Smith, J., and Morgan, R. (2020). COVID-19: the gendered impacts of the outbreak. *Lancet* 395, 846–848. doi: 10.1016/s0140-6736(20)30526-2

Yıldırım, M., & Güler, A. (2020). Factor analysis of the COVID-19 perceived risk scale: A preliminary study. *Death Studies*, 1-8.https://doi.org/10.1080/07481187.2020.1784311

Zhang, H., Shi, Y., Jing, P., Zhan, P., Fang, Y., & Wang, F. (2020). Posttraumatic stress disorder symptoms in healthcare workers after the peak of the COVID-19 outbreak: A survey of a large tertiary care hospital in Wuhan. *Psychiatry research*, *294*, 113541. https://doi.org/10.1016/j.psychres.2020.113541

Alcohol and tobacco consumption during the COVID-19 restrictions in Sri Lanka

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ABSTRACT

Introduction: COVID-19 prevention measures in Sri Lanka led to closure of alcohol outlets between mid-March to May 2020 and restrictions in cigarette sales, thus reducing availability. Evidence suggests reduced availability of alcohol and tobacco results in reduced consumption. The Alcohol and Drug Information Centre (ADIC) – Sri Lanka conducted this study on alcohol (legal and illegal) users and tobacco smokers, and their families, to ascertain changes in alcohol and tobacco consumption during the COVID-19 situation in Sri Lanka, aiming to inform ADIC policy advocacy and community interventions.

Method: Data was collected from a sample of 2019 individuals from all 25 districts of Sri Lanka, using the snowball sampling method between 1st to 10th of May 2020, through a questionnaire developed by ADIC and administered by trained data collectors. Data analysis was conducted using Microsoft Excel software. As the study was routine work of ADIC ethical approval was not obtained.

Results: Findings from 2019 study participants (58% male, 42% female) suggest that during the COVID-19 situation in Sri Lanka, out of the 58% male alcohol users, 80% reduced alcohol consumption and 68% reduced tobacco smoking. Other notable results include the willingness of those who quit/reduced alcohol, tobacco use during COVID-19 to continue their change and the benefits to the family such as decreased problems, increased savings, and happiness.

Conclusion: The results of this study indicated that restricted availability of alcohol and tobacco led to users reducing/ quitting use of these two substances. Reasons are discussed including situational influences providing a chance to experience benefits of being free from use.

Key words: Alcohol consumption, Availability, COVID-19, Health policy, Tobacco smoking

1. INTRODUCTION

COVID-19 was first reported on 31st December 2019 from Wuhan City in Hubei Province of China and was diagnosed as "Novel Corona Virus" on 7th January 2020. On 30th January 2020, the World Health Organization (WHO) declared it as a Public Health Emergency of International Concern (PHEIC). On 11th February 2020, the WHO renamed the disease as COVID-19 and on 11th of March 2020 declared it as a pandemic (WHO, 2020). The government of Sri Lanka implemented an island-wide curfew and a range of restrictions to curb the spread of COVID-19 within the country from mid-March 2020 to May 2020. Among the restrictions implemented were a temporary closure of all bars, taverns, and liquor stores (PMD News, 2020). After a brief

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opening of these alcohol outlets between 19th to 21st April 2020 they were closed again and remained closed till 13th May 2020. Additionally, expert recommendation advised halting sales of tobacco products specifically, cigarettes within the country given the negative effects of smoking related to COVID-19 (CCT, 2020).

Due to the island-wide curfew which was in operation for about two months and the afore mentioned restrictions, access to alcohol and tobacco reduced within the country. Thus, reducing availability of these products. Restricting availability of health harmful products such as alcohol and tobacco is a WHO recommended measure to reduce consumption of these substances and their harm, thereby elevating population health. Such availability restriction measures are outlined in the WHO SAFER package for alcohol control (WHO, 2020) and the WHO Framework Convention on Tobacco Control (WHO, 2005). Restricting availability of harmful products is specifically recommended for low- and middle-income countries as a best buy policy measure to reduce the non-communicable disease (NCD) burden (World Economic Forum, 2011). Alcohol use and tobacco use are two of the leading risk factors for the growing global NCD burden.

Alcohol use has been found to increase in the aftermath of traumatic incidents. A Meta-analysis by DiMaggio, Galea and Li (2009) found that 7.3% of a population can be expected to report increased alcohol consumption in the first two years following a terrorist event. They predicted a 20% probability that the prevalence will be as high as 14%. Furthermore, the Ministry of Health in Japan reports an increase in consultations provided for alcohol use issues in crisis regions following the great east Japan earthquake in 2011 (Movendi International, 2021). However, as Sugarman and Greenfield (2020) notes, COVID-19 is no ordinary traumatic event. It is unique due to the ongoing, prolonged nature of the trauma, the significant loss of life resulting in grief, the social disruption and isolation.

Early evidence suggests that alcohol use increased in several countries during COVID-19. Pollard, Tucker and Green (2020) found alcohol use frequency increased in an American population during COVID-19. Their results found that on average, alcohol was consumed one day more per month by three of four adults. Similarly in Australia a survey found one in five people reported having increased their alcohol use since the pandemic (Tran et al., 2020). A study in the United Kingdom found more than one in six people increased their alcohol use during COVID-19 lockdown (Jacob et al., 2021).

Restricting access to alcohol was found to have positive effects in South Africa which implemented temporary alcohol sales bans as a COVID-19 prevention and control measure (Movendi International, 2021). A recent analysis of trauma cases in a South African hospital found that there was a 59–69% decrease in trauma volume following the first temporary alcohol sales ban and a 39–46% decrease following the second ban. When each of the bans were lifted trauma volume increased, finally returning to pre-COVID-19 levels with complete lifting of the alcohol sales ban.

In terms of tobacco use, the increased risk of Coronavirus infection and its complications from smoking was found to lead to quitting cigarette use and increase motivations to quit. Klemperer and colleagues (2020) found about a quarter of their survey respondents quit tobacco cigarette and electronic cigarette use due to the pandemic. A third of the respondents increased their motivations to quit following COVID-19.

Previous research suggests restricting availability of health harmful products lead to reduced consumption of these products. Meanwhile, there is evidence that trauma inducing crisis events can increase alcohol use among people. In the COVID-19 context, restricting alcohol use was found to have positive effects in South Africa. In terms of tobacco use, previous research shows quitting

cigarette smoking and motivations to quit increased with the pandemic.

As an organization conducting alcohol, tobacco and other drug prevention and policy advocacy in Sri Lanka, research into the trends and changes of alcohol and tobacco use within the country is an important aspect for the Alcohol and Drug Information Centre (ADIC) – Sri Lanka. Therefore, ADIC wanted to learn the answer to the research question "Did the reduced availability of alcohol and tobacco due to the COVID-19 curfew situation have an effect on consumption of alcohol and tobacco in Sri Lanka?".

2. METHODOLOGY

Data for this study was collected between the 1st to 10th May 2020 from a sample of 2019 individuals covering all 25 districts of Sri Lanka.

In the sample selection process, two divisional secretariat areas were randomly selected from each district. However, the survey could not be administered in certain randomly selected divisional secretariat areas due to practical difficulties, in this event these areas were replaced with a convenient divisional secretariat area to administer the survey. Data was collected from 40 to 50 people in each divisional secretariat area.

Inclusion criteria were Sri Lankan adults (over 18 years) who reported consuming any alcohol before the COVID-19 pandemic.

In the selected divisional secretariat areasdata was collected from individuals in three to four villages and snowball sampling method was used to find individuals fitting the inclusion criteria. Data was collected through trained data collectors of ADIC by administering a questionnaire developed by ADIC to individuals physically or via telephone. Specifically, in Colombo, Gampaha, Kaluthara and Puttlam Districts data was collected through telephone interviews.

When collecting data from married men, qualitative data was collected from their wives on how their husbands' reduction or quitting alcohol and tobacco use was beneficial to them and their families.

Data analysis was conducted using Microsoft Excel software. The study was conducted as routine work of ADIC, and hence ethical approval was not obtained.

All COVID-19 protection measures such as mask use and physical distancing was employed when questionnaires were administered to participants physically.

3. RESULTS

3.1. Demographic data

Data was collected from a total of 2019 individuals out of which 58% (n = 1171) were males who identified as consuming alcohol from before the COVID-19 pandemic, 42% (n = 848) were female spouses (wives) of these males. Age distribution was as follows, 23% (n = 470) respondents were between 21 to 24 years, 47% (n = 953) were between 25 to 40 years, and 30% (n = 596) were above 40 years.

3.2. Alcohol consumption during COVID-19

In this study all the males (58%) reported alcohol consumption before COVID-19. Among the males who were married, their spouses (42%) were included in the study but none of them reported any alcohol use (Figure 1 & Figure 2).

The study found that during the COVID-19 situation out of the 58% male respondents who reported consuming alcohol before the pandemic, 80% reported a reduction in their alcohol consumption (Figure 3).

3.3. Reasons for reducing/ quitting alcohol consumption during COVID-19

Out of the 80% male respondents who quit or reduced alcohol consumption during

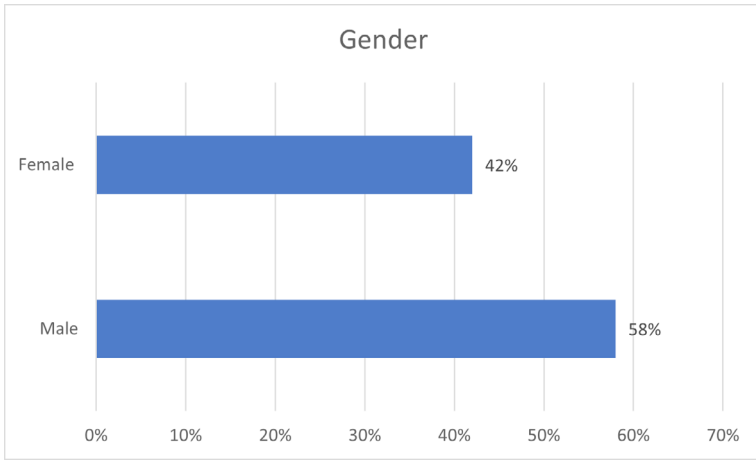

Figure 1. Gender distribution of survey participants

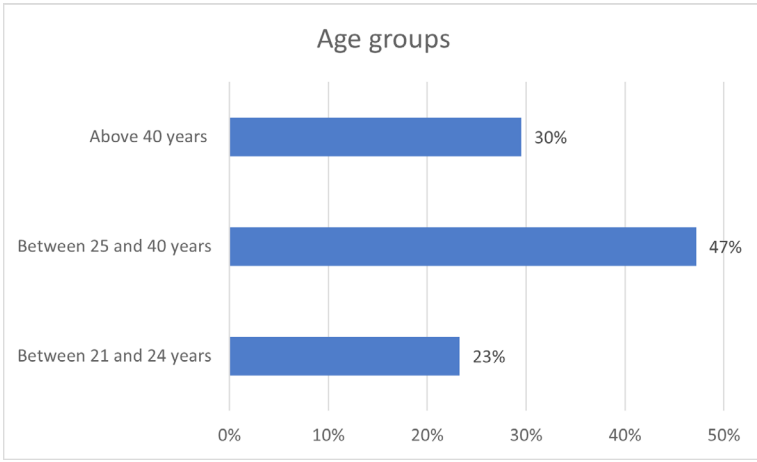

Figure 2. Age distribution of survey participants

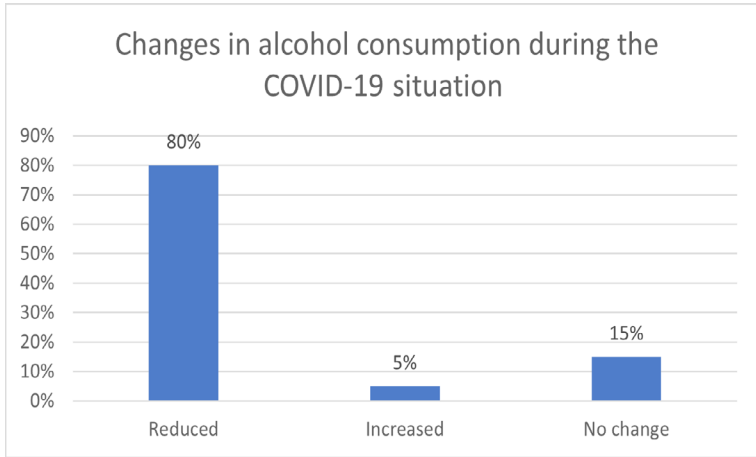

Figure 3. Changes in alcohol consumption during the COVID-19 situation

COVID-19, 54% reported "closure of alcohol outlets" as the reason for their change in consumption (Figure 4).

Opinions of Respondents Who Consume Alcohol on Whether Restrictions on Alcohol Availability Benefits Quitting/Reducing Alcohol Consumption

Out of the 80% male respondents who quit or reduced alcohol consumption during COVID-19, the opinion of 84% were that restrictions on alcohol availability was helpful in quitting/reducing their alcohol consumption.

Only 16% of the 80% male respondents who quit or reduced alcohol consumption during COVID-19, claimed the restrictions did not help them to quit or reduce their alcohol consumption (Figure 5).

3.4. Benefits of husband quitting/ reducing alcohol use as reported by their wives

According to the responses of 848 (42%) wives of men who reduced alcohol consumption, 49% reported a reduction in family problems and, 40% reported an increase in family savings, due to husband reducing alcohol use (Figure 6).

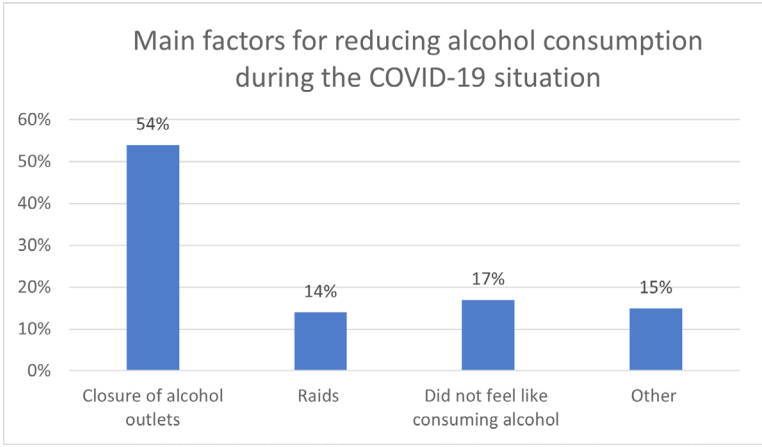

Figure 4. Main factors for reducing alcohol consumption during the COVID-19 situation

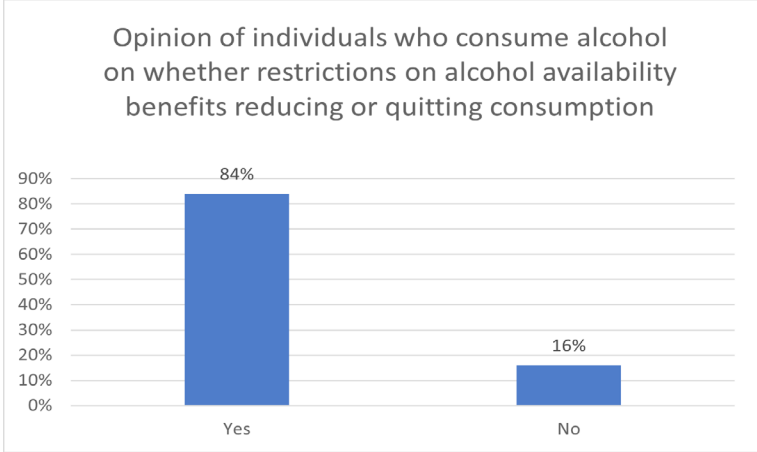

Figure 5. Opinion of individuals who consume alcohol on whether restrictions on alcohol availability benefits reducing or quitting consumption

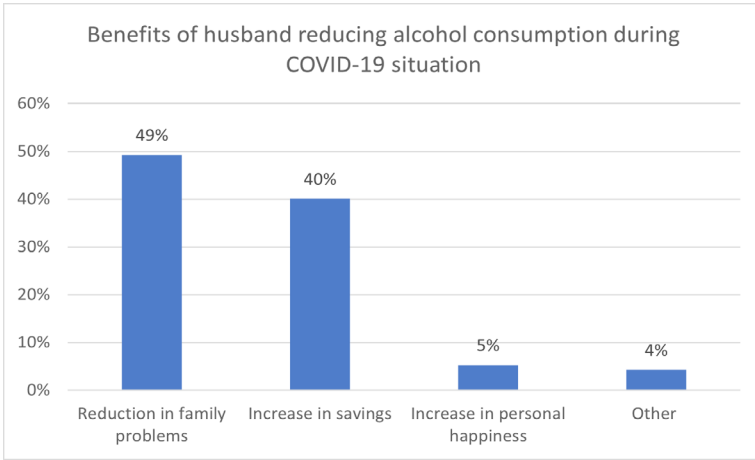

Figure 6. Benefits of husband reducing alcohol consumption during COVID-19 situation reported by their wives

3.5. Respondents' willingness to maintain reducing alcohol consumption during COVID-19 in future

Out of the 80% males who reported reducing alcohol consumption during the COVID-19 period 37% were prepared to continue the change in future, while 13% reported they will start consuming alcohol as before COVID-19 and 42% could not say what they would do in future (Figure 7).

3.6. Tobacco Consumption During COVID-19

In this study, out of the 1171 (58%) males who consumed alcohol from before the pandemic 54% respondents reported smoking tobacco from before COVID-19. None of the wives of the males reported smoking tobacco.

The study found that out of 54% respondents who were smoking tobacco, a majority of 68% reduced/quit their tobacco smoking during the COVID-19 situation. Among them, 48% have reduced tobacco smoking while 20% quit smoking tobacco (Figure 8).

3.7. Respondents' Willingness to Maintain Quitting/Reducing Tobacco Smoking During COVID-19 in Future

The study found that, 51% out of those who reduced/ quit tobacco smoking during COVID-19 reported they are prepared to continue this change in the future even after the situation normalizes (Figure 9).

4. DISCUSSION

While it may be difficult to quit/ reduce use and experience its benefits under normal circumstances, this study shows that the situational influences during COVID-19 provided a chance to experience the benefits of being free from use. The findings further indicate many secondary positive influences on families from reduction of alcohol consumption by the husband/father.

It must be noted that respondents were more willing to maintain the reduction/quitting of tobacco use than of alcohol consumption. It is possible that the public health awareness interventions regarding tobacco harms have been successful in increasing willingness among those who smoke to quit/reduce their use. Meanwhile, the myths and norms associated with alcohol are more pervasive and hence challenging to break down with public health awareness interventions. Additionally, the alcohol industry strategies to increase

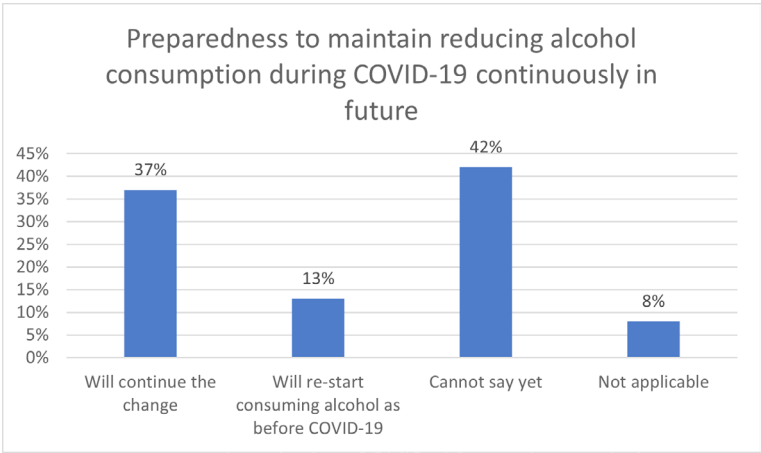

Figure 7. Preparedness to maintain reducing alcohol consumption during COVID-19 continuously in future

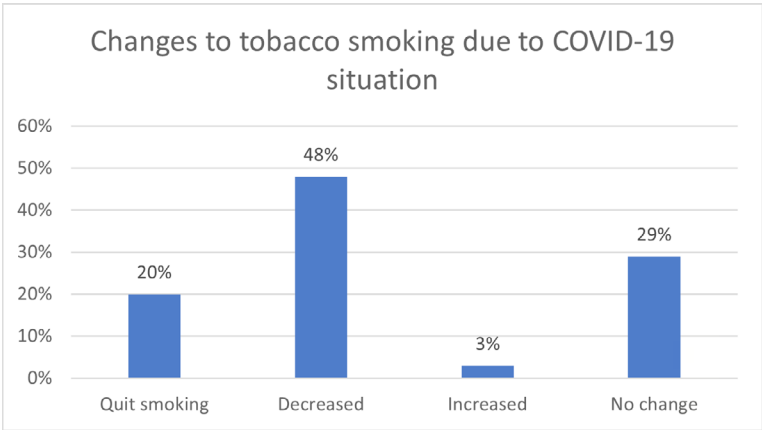

Figure 8. Changes to tobacco smoking due to COVID-19 situation

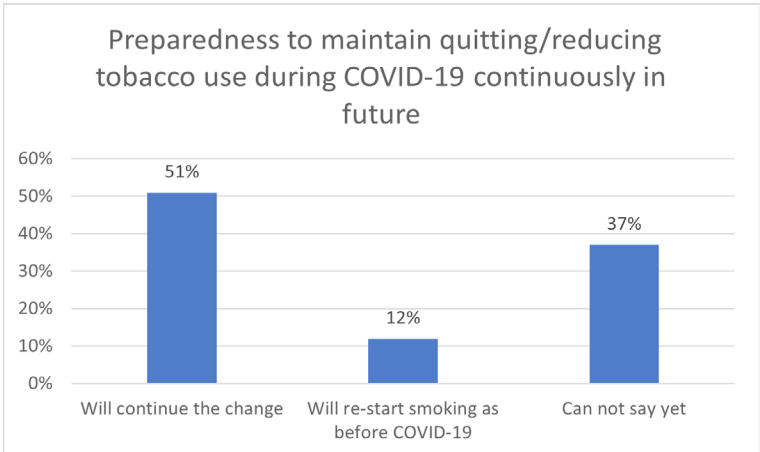

Figure 9. Preparedness to maintain quitting/reducing tobacco use during COVID-19 continuously in future

consumption are more subtle hence escape being identified by the general public. These reasons could have led to more participants being uncertain of maintaining their change in reduction of alcohol consumption.

Globally, the alcohol and tobacco industries are against sales restrictions and reduced availability of their products because users will quit use by realizing that they can live without these substances and specifically by understanding that it is more comfortable to live free from these substances.

4.1. Limitations

Several limitations of the study must be noted. The sample is not representative therefore, findings cannot be generalized to the entire population. Population and racial differences in each district and divisional secretariat area were not taken into consideration in sample selection and use of snowball sampling may have led to a homogenous sample non-representative of differences in the population. As with all self-reported surveys the answers by the respondents may have been affected by social desirability bias due to the public opinion that it is beneficial to not use alcohol or smoke tobacco during COVID-19. The respondents may have also withheld reporting about illicit alcohol consumption.

Many practical limitations were faced due to the COVID-19 pandemic and curfew measures across the country.

5. CONCLUSION

The overall results of the study found during the COVID-19 situation in Sri Lanka alcohol consumption among 80% of alcohol users reduced and smoking among 68% of tobacco smokers reduced.

Out of the individuals who quit/reduced alcohol consumption during the COVID-19 situation 37% claimed they were prepared to continue their change in future even after the situation normalizes.

Out of individuals who quit/reduced tobacco smoking during COVID-19 situation 51% claimed they were prepared to continue their change in future even after the situation normalizes.

Among the wives of men who consume alcohol, 49% reported family problems reduced due to husband quitting alcohol consumption. A further 40% reported there was an increase in family savings.

In conclusion, the results of this study suggest that restricted availability of alcohol and tobacco led to users' reducing/ quitting use of these two substances.

ACKNOWLEDGEMENTS

The Alcohol and Drug Information Centre (ADIC) – Sri Lanka acknowledges with gratitude the financial support provided by the IOGT-NTO Movement, Sweden.

REFERENCES

Centre for Combating Tobacco. (CCT, 2020). A letter to HE the president, Sri Lanka requesting to ban tobacco sales during the COVID-19 Epidemic. (2021). [online] Available at: <http://cct.lk/?p=1784> [Accessed 6 January 2021].

Chu, K., Marco, J., Owolabi, E., Duvenage, R., Londani, M., Lombard, C. and Parry, C., 2021. Trauma trends during COVID -19 alcohol prohibition at a South African regional hospital. Drug and Alcohol Review.

DiMaggio, C., Galea, S. and Li, G., 2009. Substance use and misuse in the aftermath of terrorism. A Bayesian meta-analysis. Addiction, 104(6), pp.894-904.

Jacob, L., Smith, L., Armstrong, N., Yakkundi, A., Barnett, Y., Butler, L., McDermott, D., Koyanagi, A., Shin, J., Meyer, J., Firth, J., Remes, O., López-Sánchez, G. and Tully, M., 2021. Alcohol use and mental health during COVID-19 lockdown: A cross-sectional study in a sample of UK adults. Drug and Alcohol Dependence, 219, p.108488.

Movendi International. 2021. Japan: Crisis Regions Show Greater Alcohol Use Disorder Numbers Years Later - Movendi International. [online] Available at: <https://movendi.ngo/news/2021/02/15/japan-crisis-regions-show-greater-alcohol-use-disorder-numbers-years-later/> [Accessed 6 June 2021].

Movendi International. 2021. South Africa and COVID-19: Alcohol Sales Bans Were Widely Successful - Movendi International. [online] Available at: <https://movendi.ngo/news/2021/04/02/south-africa-and-covid-19-alcohol-sales-bans-were-widely-successful/> [Accessed 6 June 2021].

Klemperer, E., West, J., Peasley-Miklus, C. and Villanti, A., 2020. Change in Tobacco and Electronic Cigarette Use and Motivation to Quit in Response to COVID-19. Nicotine & Tobacco Research, 22(9), pp.1662-1663.

PMD News. (2020). Announcement on curfew - President's Media Division. [online] Available at: <https://www.pmdnews.lk/%E0%B6%87%E0%B6%B3%E0%B7%92%E0%B6%BB%E0%B7%92-%E0%B6%B1%E0%B7%93%E0%B6%AD%E0%B7%92%E0%B6%BA-%E0%B6%9A%E0%B7%8A%E2%80%8D%E0%B6%BB%E0%B7%92%E0%B6%BA%E0%B7%8F%E0%B6%AD%E0%B7%8A%E0%B6%B8%E0%B6%9A/> [Accessed 22 December 2020]

Pollard, M., Tucker, J. and Green, H., 2020. Changes in Adult Alcohol Use and Consequences During the COVID-19 Pandemic in the US. JAMA Network Open, 3(9), p.e2022942.

Sugarman, D. and Greenfield, S., 2020. Alcohol and COVID-19: How Do We Respond to This Growing Public Health Crisis?. Journal of General Internal Medicine, 36(1), pp.214-215.

Tran, T., Hammarberg, K., Kirkman, M., Nguyen, H. and Fisher, J., 2020. Alcohol use and mental health status during the first months of COVID-19 pandemic in Australia. Journal of Affective Disorders, 277, pp.810-813.

World Economic Forum. (2011). From Burden to "Best Buys": Reducing the Economic Impact of Non-Communicable Diseases in Low- and Middle-Income Countries. [online] Available at: <https://www.who.int/nmh/publications/best_buys_summary.pdf> [Accessed 22 December 2020]

World Health Organization. (WHO, 2020). Timeline: WHO's COVID-19 response. [online] Available at: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/interactive-timeline#event-4> [Accessed 22 December 2020]

World Health Organization. (WHO, 2020). Strengthen restrictions on alcohol availability. [online] Available at: < https://www.who.int/substance_abuse/safer/s/en/> [Accessed 22 December 2020]

World Health Organization. (2020) WHO | Tobacco control measures. <https://www.who.int/tobacco/control/measures/en/> [Accessed 22 December 2020]

World Health Organization. (2005) WHO Framework Convention on Tobacco Control. WHO Press.

Nurses' experiences of the availability of personal protective equipment and depressive symptoms during COVID-19: Points to ponder

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ABSTRACT

Background: Availability of personal protective equipment (PPE) is crucial to improve the morale and work efficiency of nurses especially during pandemics like COVID-19. This study investigated the availability of PPE for nurses working in different healthcare settings during the COVID-19 and to elucidate the impact of this occupational health issue on their psychological well-being.

Methods: A descriptive online survey was conducted in May, 2020 using a sample of nurses in Sri Lanka. The Center for Epidemiologic Studies Depression Scale-Revised (CESD-R – 10) was used to assess depressive symptoms.

Results: The mean age of the participants (N= 386) was 37.8 years (SD = 9.6 years). About 57% of the participants were on the opinion that they were not given full protection against COVID-19 in their workplaces. Of the total, 64.5% (n=249) reported that they did not have adequate PPE in their workplaces. Slightly higher percentage of nurses who did not work with COVID-19 confirmed or suspected patients at the time of the survey reported having had no adequate PPE compared to those of other nurses (70.7% versus 62.4%, p = 0.13). Mean scores of the CES-D were 10.46 (SD = 5.4) and 11.01 (SD = 5.2) for the two groups who reported having had adequate PPE and inadequate PPE respectively (p=0.33).

Conclusion: The availability of PPE for nurses during the initial months of COVID-19 was not satisfactory. However, provision of PPE was not associated with the development of depressive symptoms in them. This is probably because nurses are inclined to work for the good of their patients, at the expense of themselves. However, further research is needed to confirm our assertions. Enhancement of the notions of social responsibility among nurses may assist them to provide needed services during unprecedented pandemics like COVID-19.

Key words: COVID-19, Nurses, Occupational safety, Personal protective equipment, Sri Lanka

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1. INTRODUCTION

The World Health Organization declared the outbreak of a novel corona virus (COVID-19) as a pandemic on 11th March 2020 (Lambert et al., 2020; World Health Organization (WHO), 2020). By 3rd June, 2021, globally, there were 172,671,166 confirmed cases and 3,771, 679 deaths, and the rates continue to rise (Worldometers, 2021). Health care systems all over the world are overburdened as a result of this pandemic, and healthcare workers were forced to work incessantly, sometimes beyond their capacity, to manage the pandemic. According to the International Council of Nurses (ICN), as of 31 December 2020, the cumulative number of reported COVID-19 deaths in nurses in 59 countries was 2,262 (International Council of Nurses, 2020). The growth of COVID-19 cases and deaths has caused intense anxiety and distress among healthcare professionals in Sri Lanka (Chandradasa et al, 2020). The paucity of information regarding the risk of acquiring the infection, the non-availability of a clinically proven treatment or a vaccine during the initial months of the pandemic, and stigmatization were the main reasons found for the psychological problems observed in healthcare workers across the world (Lai et al, 2020; Lambert et al, 2020; The Lancet, 2020). Nurses are the biggest health care group suffered from physical and psychological problems related to COVID-19 because nursing professionals are the key health care givers at the frontline for detecting, treating, and caring the people infected with COVID-19 (Nie et al, 2020; Galehdar et al, 2020). The COVID-19 is highly contagious and spreads very fast and therefore the patients are treated in isolation. Thus, safe work place and personal protective equipment (PPE) are essential to improve the morale and work efficiency of nurses working with COVID-19 patients.

In Sri Lanka, the government health care system is the main body responsible for testing, contact tracing, institutional quarantine and providing care to confirmed cases. All confirmed cases are admitted to state-hospitals and treated under specialized care team in the initial months of the pandemic. Nurses had to work long hours under direct contacts with confirmed patients during this period and therefore they were more vulnerable than other health care workers to get infected (Isa et al, 2019; Ministry of Health, Sri Lanka, 2020). Compulsory precautionary measures including wearing personal protective equipment (PPE), and continuous training and guidance on safety measures were given by the government for healthcare workers. Nurses' role in managing COVID-19 is mainly concentrated on prevention and control of infection, sample collection, care of patients with mild to moderate symptoms and management of care of the critically ill patients. A key feature of caring for COVID-19 is prevention of cross infection. Nurses who are working with COVID-19 cases were provided with additional measures to control the disease by increasing working staff at a given time, providing PPE for them and scheduling and facilitating resting hours and leave. Infectious Disease Hospital (IDH), Colombo workflow was usually followed by the nurses for caring, which was developed based on institutional infection control policy.

It was not known in the initial months of the pandemic whether N95 respirators, regular hand hygiene or facemasks had protective effect against COVID-19 pandemic as had been observed in recent outbreaks of SARS and influenza. These uncertainties and seriousness of this new pandemic had raised concerns about occupational health safety issues of frontline healthcare workers and effective healthcare delivery mechanism for patients with COVID-19 in the first half of the year 2020. An online survey using a sample of 512 healthcare professionals was conducted in May, 2020 to identity psychological issues encountered by them during the pandemic (Perera et al., 2021). In this paper, using a sub sample of that research, we investigated the availability of PPE for nurses working in different healthcare settings during the initial months of the pandemic and how this occupational health issue had affected psychological well-being of the nurses.

2. METHODS

In this descriptive research, an online survey was conducted from 1 May, 2020 to 22 May 2020 using a sample of 386 nurses in Sri Lanka. The online survey form included demographic and psychosocial questions. The Center for Epidemiological Studies Depression Scale Revised (CESD-R – 10) was used to assess depressive symptoms (Eaton et al, 2004). The CESD-R – 10 has 10 questions on a four-point Likert scale (0–3) and the total score ranges from 0 to 30 where higher scores indicate higher depressive symptomatology. The CESD-R – 10 is a reliable and valid tool to assess depressive symptoms among healthcare workers. The availability of PPE was asked using a single question "Do you have adequate personal protective equipment to work with COVID-19 patients?". The answers for the question were dichotomous, "yes" or "no.". We used the English versions of the scales.

2.1. Ethical Clearance

Participation of the study was completely voluntarily. Ethical approval was obtained from the Ethics Committee, Faculty of Allied Health Sciences, University of Ruhuna, Galle, Sri Lanka.

2.2. Data Collection Procedure

Government Nurses who were working in hospital during the survey period were contacted through various means such as personal contacts, social media, information available in telephone directories, and health websites. Contacted individuals were explained the purpose of the survey and anonymity, emphasizing that their participation was completely voluntary. Online survey was conducted using Google form based questionnaire. The submitted online questionnaires automatically generated excel worksheets and forwarded such data sheets directly to one of the investigators of the research team.

3. RESULTS

A total of 386 nurses participated in the study (Table 1). The mean age was 37.8 years (*SD* = 9.6 years). The mean number of years worked was 12.9 years (*SD* = 10.1 years). The majority (63.7%) were working in teaching hospitals followed by 7.5% in general, 18.9% in base and the rest (9.9%) in other peripheral healthcare settings. Of the total, 74.4% were working with COVID-19 confirmed or suspected patients at the time of the survey. A majority of the participants (57.3%) were on the opinion that they have had not adequate PPE to work as healthcare workers during the COVID-19. Out of the total of 386 participants, 249 (64.5%) reported that they did not have adequate PPE in their workplaces. Although no significant difference was found, a slightly higher percentage of nurses who did not work with COVID-19 confirmed or suspected patients at the time of the survey reported that they had no adequate PPE compared to nurses

Table 1. Distribution of demographic and work-related information of the participants (n = 386)

Variable		Number (%)
Gender	Male	52 (13.5%)
	Female	334 (86.5%)
Type of hospital	Teaching	246 (63.7%)
	General	29 (7.5%)
	Base	73 (18.9%)
	District	13 (3.4%)
	Other	25 (6.5%)
Work experience	≤ 1 year	29 (7.5%)
	2 – 5 years	93 (24.1%)
	5 – 10 years	74 (19.2%)
	≥ 10 years	190 (49.2%)
Working with COVID 19 suspected or confirmed patients	Yes	285 (73.8%)
	No	101 (26.2%)
Have adequate PPE in the workplace	Yes	137 (35.5%)
	No	249 (64.5%)
Have you given full occupational safety against COVID 19	Yes, very much	43 (11.1%)
	Yes, considerable	96 (24.9%)
	Yes, somewhat	164 (42.5%)
	No, not at all	83 (21.5%)

Note: PPE refers to personal protective equipment

who did work with COVID-19 confirmed or suspected patients at the time of the survey (70.7% versus 62.4%, p = 0.13). Two hundred and fifteen participants (55.7%) have had elevated depressive symptoms. Mean scores of the CES-D were 10.46 (*SD* = 5.4) and 11.01 (*SD* = 5.2) for the two groups who reported having had adequate and inadequate PPE respectively, no significant difference was found (p =0.33).

4. DISCUSSION AND CONCLUSION

Since December, 2019, the COVID-19 pandemic has made a serious of adverse consequences on world population, and at the end of 2020, nearly about 1.8 million COVID-19 deaths were reported globally (Down to Earth, 2020), and the figure has increased to 3.7 million in May, 2021. The rates continue to rise (Worldometers, 2021). People in all age and occupational categories are endangered due to COVID-19 but healthcare professionals remain the most vulnerable population group to contaminate with COVID-19, a deadly and a highly transmitted disease. Normal functioning of any healthcare system will shatter when there is a shortage of protective equipment and when the workplace becomes unsafe for the employees. Since healthcare professionals face a very high risk of infection while giving care to suspected or confirmed cases and engaging in laboratory testing, it is a priority in the national strategy in combatting COVID-19 to make sure that healthcare professionals are safe and secure while in duty. To increase work efficiency it is imperative to provide adequate protection for healthcare personal specifically in an emergency infectious disease outbreak (Isa et al 2019; Tan et al, 2020). Although healthcare training for the COVID-19 pandemic had been started in early stages of the pandemic in the country in 2020, except in major hospitals, access to PPE and N95 grade masks had been limited. Further, safety procedures and equipment in newly converted centers of COVID-19 had also been inadequate in the initial months of the pandemic (Ministry of Health, Sri Lanka, 2020). It is understood that the spread of COVID-19 in Sri Lanka as in other countries has created an extraordinary demand for PPE by hospitals, other healthcare institutions and other allied functionaries in the healthcare system in the country (Sharma et al, 2020). The rapid spread of the pandemic has created a temporary shortage of PPE in many countries. Nurses in many countries were subjected to severe psychological problems due to inadequate supply for PPE (Arnetz er al., 2020; Sharma et al, 2020).

However, provision of PPE seems to be not associated with the development of depressive symptoms in nurses. Sri Lanka has been ranked as one of the top countries in the world for voluntarism. This would have contributed significantly to lower the psychological burden of nurses. They probably have been motivated by the nature of Sri Lankan culture to make their own PPE, buying from stores, and to prepare their own sanitizers. Community support to recover from adversities such as inadequate supply of PPE during COVID-19 pandemic would probably be a strong psychological strength for Sri Lankan nurses to be spirited at hard times. Creating supportive environments and enhancing the notions of social responsibility of nurses would ultimately aid them to become productive and responsible healthcare workers (Naser et al, 2019; Wu et al, 2020).

Results of this study showed that a higher proportion of nurses in our sample has reported having depressive symptoms during the initial months of the COVID-19. This would probably indicate that they endured a great deal of psychological distress during care of patients with COVID-19. The sources of such distress may include patients' death, the disease's unknown dimensions, the atmosphere of the working environment, professional commitments, and individual characteristics in addition to the availability of PPE. Holding training workshops on how to cope with health crisis, encouraging nurses to listen to each other's concerns, preventing negative news from being spread among health care workers and make appreciations of the hard work that they do during outbreaks can improve nurses' mental health.

During outbreaks of diseases and/or natural disasters, in accordance with their professional duties and missions, nurses are trained to provide health services for the sick by sacrificing their personal safety if necessary. In order to boost nurses' mental well-being, there is a need for support from decision and policy makers and governments to provide necessary facilities and safety equipment to make their workplace safe and secure. If no support is provided, nurses' workforce would be degraded, which can deliver the health system vulnerable to the crisis. Paying attention to the psychological experiences of nurses during the pandemics and identifying risk factors is a prerequisite for improving quality of their services. Thus, for maximum-quality health care services during pandemics, governments and health systems should minimize nurses' mental burden by delivering adequate personal protection equipment, strengthening mutual support among health team members, providing psychological counseling, and delivering timely information and educational supports (Niuniu et al, 2020; Lai et al, 2020). However, our observation that there was no significant difference of the mean values of CES-D scores between nurses who had adequate PPE and those who did not have adequate PPE probably would show their dedication to serve the patients in crisis situation and social support that they would have received from the general public. Further, research is, however, needed in this area.

There were several limitations in this study. The availability of PPE was assessed using a single yes/no question. Cross-sectional nature of the study did not allow us to make cause-effect relationships. However, the large sample size of the study would make the results of the study valid and appropriate.

In conclusion, a considerable proportion of nurses who worked in public healthcare settings in Sri Lanka during the initial period of COVID -19 seemed to have experienced depressive symptoms. Availability of PPE for them during that time was grossly inadequate. However, unavailability of PPE might not have caused psychological distresses in them. Further qualitative research is warranted to understand psychological behavior and associated factors of nurses during sudden outbreaks of infectious diseases.

REFERENCES

Arnetz, J.E. (2020). Nurse Reports of Stressful Situations during the COVID-19 Pandemic: Qualitative Analysis of Survey Responses." International journal of environmental research and public health,17(21):8126-132. doi:10.3390/ijerph17218126

Chandradasa, M., Kuruppuarachchi, K.A.L.A. (2020). Mental Health Impact of the COVID-19 Pandemic. Sri Lanka Journal of Medicine, 29(2):1-4 DOI: http://doi.org/10.4038/sljm.v29i2.218

Down to Earth. (2020). COVID-19: Global tally, death toll peak in December. Available from https://www.downtoearth.org.in/news/health/covid-19-global-tally-death-toll-peak-in-december-74858.

Eaton, W.W., Smith, C., Ybarra, M., Muntaner, C., Tien, A. (2004). Center for Epidemiologic Studies Depression Scale: Review and Revision (CESD and CESD-R). In Maruish ME. The use of psychological testing for treatment planning and outcomes assessment: Instruments for adults. 1st edition. Lawrence Erlbaum Associates Publishers; 2004. pp. 363–377.

Galehdar, N., Kamran, A., Toulabi, T. (2020). Exploring nurses' experiences of psychological distress during care of patients with COVID-19: a qualitative study. BMC Psychiatry, 20(489):1-9. https://doi.org/10.1186/s12888-020-02898-1

International Council of Nurses. (2020). International council of nurses covid-19 update . Available from: https://www.icn.ch/sites/default/files/inline-files/ICN%20COVID19%20update%20report%20FINAL.pdf

Isa, K. Q., Ibrahim, M. A., Abdul-Manan, H. H., Mohd-Salleh, Z. H., Abdul-Mumin, K. H., & Rahman, H. A. (2019). Strategies used to cope with stress by emergency and critical care nurses. British Journal of Nursing, 28(1):38– 42. https://doi.org/10.12968/bjon.2019.28.1.38

Lai, J., Ma, S., Wang, Y., Cai, Z., Hu, J., Wei, N., & Hu, S. (2020). Factors Associated With Mental Health Outcomes Among Health Care Workers Exposed to Coronavirus Disease 2019. JAMA Network Open, 3(3):e203976.

Lambert H, Gupte J, Fletcher H, Hammond L, Lowe N, Pelling. (2020). COVID-19 as a global challenge: Towards an inclusive and sustainable future. The Lancet Planet Health, 4(8):e312-e314. https://doi.org/10.1016/S2542-5196(20)30168-6

Ministry of Health Sri Lanka. (2020). Coronavirus disease 2019 (COVID-19) - Situation report [internet]. Ministry of Health, Sri Lanka: 2020. Available from: http://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-04-06_10.pdf Accessed November 3, 2020

Naser A.Y., Dahmash E.Z., Al-Rousan R., Alwafi H., Alrawashdeh H.M., Ghoul I.(2019) Mental health status of the general population, healthcare professionals, and university students during 2019 coronavirus disease outbreak in Jordan: A cross-sectional study. Brain Behavior, 10(8):e1730. https://doi.org/10.1002/brb3.1730

Nie, A., Su, X., Zhang, S., Guan, W., & Li, J. (2020). Psychological impact of COVID-19 outbreak on frontline nurses: A cross-sectional survey study. Journal of clinical nursing, 29(21-22):4217–4226. https://doi.org/10.1111/jocn.15454

Niuniu, S., Luoqun, W., Suling, S., Dandan, J. (2020). A qualitative study on the psychological experience of caregivers of COVID-19 patients. American Journal of Infectious Control, 48(6):592-598. doi: 10.1016/j.ajic.2020.03.018

Perera B, Wickramarachchi B, Samanmalie C, Hettiarachchi M. (2021). Psychological experiences of healthcare professionals in Sri Lanka during COVID-19. BMC Psychology, 9(1):49-55. doi: 10.1186/s40359-021-00526-5. PMID: 33761994; PMCID: PMC7988642.

Sharma, N., Hasan, Z., Velayudhan, A. (2020). Personal Protective Equipment: Challenges and Strategies to Combat COVID-19 in India: A Narrative Review, Journal of Health Management, 22(2):157–168. Doi: https://doi.org/10.1177/0972063420935540

The Lancet Editorial. (2020). COVID-19: protecting health-care workers. The Lancet, 395(10228):922. https://doi.org/10.1016/S0140-6736(20)30644-9

Tan B.Y.Q., Chew N.W.S., Lee G.K.H., Jing M., Goh Y, Yeo L.L.L., et al. (2020). Psychological impact of the COVID-19 pandemic on health care workers in Singapore. Annual International Medicine,173(4):317-320. https://doi.org/10.7326/M20-1083

World Health Organization. (2020). Coronavirus disease COVID-2019. Available from https://doi.org/10.30895/2312-7821-2020-8-1-3-8

Worldometers. (2021). CoVid -19 Coronavirus pandemic. Available from: https://www.worldometers.info/coronavirus/

Wu, P.E., Styra, R., Gold, W.L. (2020). Mitigating the psychological effects of COVID-19 on health care workers. Canadian Medical Association Journal, 192(17):459-60. https://doi.org/10.1503/cmaj.200519

Impact of COVID-19 pandemic on education and mental health of physical science undergraduates in the Faculty of Science, University of Kelaniya

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ABSTRACT

The novel coronavirus disease (COVID-19) was a pandemic identified in Wuhan, China in late 2019, which was a huge outbreak around the world including Sri Lanka. This work focuses on identifying the effect on education and mental health from the COVID-19 pandemic on physical science undergraduates of the Faculty of Science, University of Kelaniya, Sri Lanka. Chi-Square and post hoc tests with Bonferroni adjustment were employed to identify associations among considered factors while k-means clustering was applied in the detection of distinct groups among undergraduates. Undergraduates' preference was in-house lectures and practical sessions before the pandemic while Zoom lectures and screen-recordings were during the pandemic. The loss of jobs of family members was the major cause for the lower lecture attendance. Concerning mental healthiness, suicidal thoughts and home violence were prominent. Cluster analysis resulted in three and four clusters respectively when considering the impacts on education and mental health separately. It is noteworthy that undergraduates in Cluster 2 experienced major negative impacts on education while Cluster 1 experienced minor impacts. Identified Cluster 2 by considering the mental perception exhibits that most of the undergraduates' pessimistic thoughts whereas the majority of the students were first-year and female. In conclusion, this study evidence that there is a huge impact on education and the mental perception of undergraduates due to the COVID-19 outbreak. The findings of this study can be utilized by higher authorities of education to lend a helping hand for undergraduates to minimize the effect of COVID-19 on education and mental health.

Key words: Bonferroni adjustment, Chi–square test, K-means clustering, Covid – 19, Post hoc test

1. INTRODUCTION

The novel corona virus disease (COVID-19) was a pandemic identified in Wuhan, China in late 2019, which was a huge outbreak around the world. It has rapidly spread across the world including Sri Lanka causing a vast change in our everyday lifestyles. There were major impacts for Sri Lanka regarding the economy, physical and mental health, education and many other areas. When considering the education sector, the pandemic has a higher potential to affect university students physically, academically, mentally and financially. As a remedy for the prevention of the spread of the COVID-19 among university students, many countries have switched from in-house lectures to the online platforms. In a short period of time, the university student's lives changed as they were asked to leave the

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university and adapt to the online platform. Many studies have been conducted to find out the influence of the COVID-19 pandemic on the education sector including university education.

Different previous studies focus on this disease as it was the most recent issue raised globally. Among them, noteworthy attention is paid to university students all around the world. The study of Cao et al., 2020, focused on the mental status of the undergraduates of Changzui in China. The selected students using the clustering sampling technique were asked to fill a questionnaire created according to the generalized anxiety disorder scale. The results indicated 24.9% were involved in anxiety during this period and they claimed it is required to observe the mental well-being of the students during this hard period. Further, Grubic et al., 2020 and Kecojevic et al., 2020 have conducted similar studies.

Chaturvedi et al., 2021 have conducted a cross-sectional survey with a sample size of 1182 students in various educational institutes in New Delhi. They have identified the following as the impact of COVID-19 on the students of different age groups; the time spent on online classes and self-study, the medium used for learning, sleeping habits, daily fitness routine, and subsequent effects on social life, and mental health. Some other challenges are included as concerns about their health, the health of family members, and worry about finances. Significantly, the university students' mental health has been affected vastly by this pandemic.

Aucejo et al., 2020 addressed the experiences and the expectations of the students on higher education in the United States and the results conclude many pessimistic outcomes as loss of jobs, internships and delayed graduation. Moreover, one of their major findings was that, lower-income students, 55% more likely to delay graduation compared to high income counterparts. Likewise, Choi et al., 2020 explored the disruptions from the prevailed COVID-19 situation on examinations and placements on medical students in the United Kingdom.

Sahu in 2020, discussed the challenges faced by the universities during this epidemic. They were online education, exams and evaluations, travelling limitation, mental well-being, international students and support services. He indicated the priority of the universities should be to inform the students and staff about the situation with proper learning sources and counseling services. Similar studies were conducted by Savage et al.,2020 on Vietnam and van et al., 2020 on UK university students.

The study of Neuburger and Egger investigated the relationships between traveling habits, travel risk perception and COVID-19 perception in the DACH region for two selected time periods during the pandemic. There was a significant growth of the considered features over time. To identify distinct groups among travelers based on their perception of COVID-19 for the two periods, they applied the cluster analysis. Numerous studies were based on cluster analysis to explore the insights of the data in the pandemic. Some of them are Mulenga et al., 2020, Rahman et al., 2020, Bodrud-Doza et al, 2020 and etc.

No past studies were found which were aimed at identifying the impact of COVID-19 on the Undergraduates of Sri Lanka. This work focuses on identifying the effect on education and mental health from the COVID-19 pandemic on physical science undergraduates of the Faculty of Science, University of Kelaniya, Sri Lanka and identifying different clusters based on the impact of COVID-19. The findings of this study will lead to detect the potential impact of the terrible COVID-19 on university education and to recommend solutions for the identified problems.

Outline of this article is as follows: Section 2 consists with the methodology while Section 3 illustrates results and discussion. Finally, the conclusion section concludes the article.

2. METHODOLOGY

Two main approaches to the research problem with their methodologies are discussed here: Cross-sectional analysis by using the Chi-square association test was used to identify the relationships between the considered factors and further associations were examined using the post hoc test. K-means clustering was employed to detect groups with distinctive characteristics among the respondents.

2.1. Data collection

Data collection was done through an online survey questionnaire and it was carried out for the students in the Physical Science stream in the Faculty of Science, University of Kelaniya. The questionnaire was designed to meet the research objectives and it addresses the different dimensions related to the university students' experience during the COVID-19 pandemic: impact on education, health, economy, and mental perception (refer to the Annex 1).

Based on the data from the pilot survey, stratified sampling was used in calculating the sample size using Equation (1).

$$n = \frac{n_0}{1+\frac{(n_0-1)}{N}} \; where \; n_0 = \frac{z^2 p(1-p)}{e^2} \quad (1)$$

Where n is sample size, N *is* Population size, z is confidence level, p is population proportion and e is marginal error.

Figure 1 represents the details of the stratified sampling technique employed in the study. (For the stratum i; N_i - Population size, n_i -Sample size, M_i -Male Population size, m_i -Male sample size, F_i -Female population size, f_i -Female sample size where i =1,2,3,4)

2.2. Chi-Square Test of Independence and the Post Hoc Tests

The Chi-Square Test of Independence determines whether there is an association between categorical variables. For a chi-square independence test, the null hypothesis is that the two variables are not associated; the alternative hypothesis is that the two variables are associated.

The test statistic for the Chi-Square test of Independence is given by the Equation (2).

$$X_c^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad (2)$$

where c is degree of freedom, O is Observed value, E is Expected value. The number of degrees of freedom is $(r-1)(c-1)$,

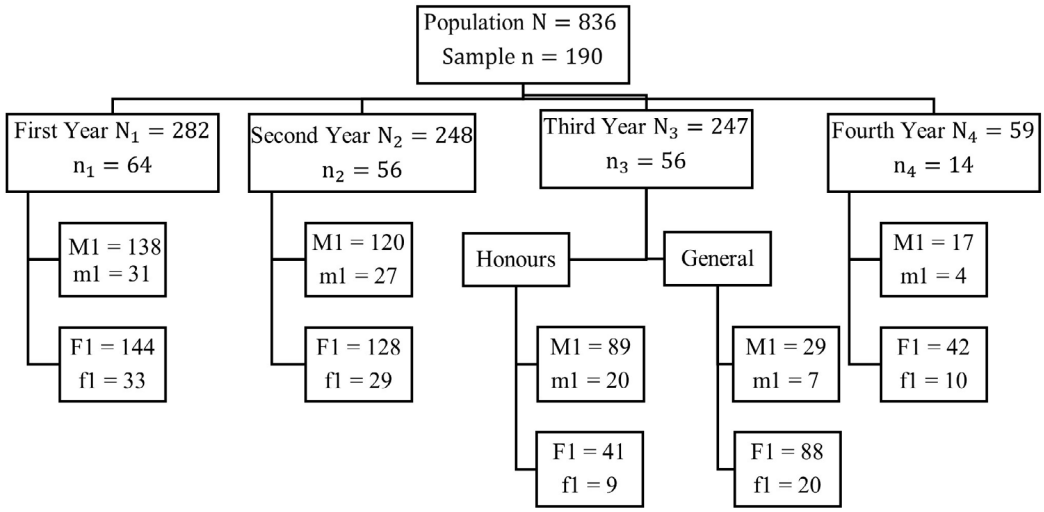

Figure 1. Sample calculation using the stratified sampling technique

where r and c are the number of possible values for the two variables under consideration.

After finding that there is an association between the two variables by a Chi-Square test, post hoc tests can be conducted to identify the differences between factor levels of the two variables. This post hoc approach used in this study is also known as the Bonferroni Adjustment. The goal of using the Bonferroni Adjustment is to consider the maximum overall type 1 error rate.

2.3. K-means Algorithm

Moreover, to classify the students into groups with similar characteristics a clustering technique was addressed in the study. K-means clustering which is a technique of iterative refinement was employed as the algorithm is computationally fast, producing tighter and high intra-clusters than other algorithms (Narang et al., 2016).

For a set of k means, the algorithm is implemented alternating two steps until convergence is achieved as below (Narang et al., 2016).

Step 01: Each observation is assigned to a cluster with the least sum of squares for the nearest mean.

Step 02: Calculate the new centroids of each observation in the updated clusters.

Moreover, to identify the optimal number of clusters used the trial and error method (Pham et al., 2005) and minimum convergence iterations (Hung et al., 2005).

3. RESULTS & DISCUSSION

This study was conducted with a sample of 190 respondents, including 53.2% of females and 46.8% of males representing all four years of the physical science stream.

3.1. Cross-Sectional Analysis

Usually, the type of residence of 17.4% of students, were boarding places and it was reduced to 1.6% during the pandemic. Most of the students were at home during the COVID-19 period.

Concerning the impact of education and mental health of undergraduates during the COVID-19 pandemic, a cross-sectional analysis was carried out using the Chi-square test and Table 1 illustrates prominent results. Further explored the associations using post hoc tests and only significant associations with respective p-values are illustrated in Table 2.

According to Table 1 and Table 2, it is clear that the majority of the students preferred in-

Table 1. Results of the Chi-square Test

No.	Variable 01	Variable 02	p-value
1	Year of the study	Preferred methods for university education before the COVID-19 pandemic	0.023
2		Methods used to continue university education during the pandemic	0.000
3		Method of participation in the lectures during the pandemic	0.000
4		Average attendance for online courses	0.004
5	Gender	Most convenient way to engage in practical sessions	0.000
6		Most convenient way to engage in lectures	0.004
7		Difficulty in concentration on studies	0.049
8	Average attendance for the online courses	Type of effect on family economy from the pandemic	0.037
9	Having suicidal thoughts	Unfamiliar with the online platform	0.000
10	Home violence/ Roughness/ Cruelty	Parents are alive or not	0.023
11		Current employment sector of the mother	0.009
12		Type of effect on the family economy from the pandemic	0.001

Table 2. Results of the Post hoc Tests

No.	Significant factor levels		p-value
	Factor 1	Factor 2	
1	Fourth year students	CAL, In-house workshops, Email, Social media	0.00000
2	First year students	CAL	0.0004
	Fourth year students	CAL, Online lectures, Online workshops, Online courses (Coursera), Email, Social media	0.0000
3	Fourth year	through online Zoom lectures and By referencing the lecture notes	0.0000
	Second year students	referencing the screen recordings and By referencing the lecture notes	0.0000
4	First year students	80%-100% attendance	0.0012
	Second year students	80%-100% attendance	0.0012
5	Female/Male students	Lectures in the lecture hall with the Lecturer	0.0000
	Female/Male students	Through online lectures	0.0031
6	Female/Male students	Lectures in the lecture hall with the Lecturer	0.0006
7	Female/Male students	Low difficulty in concentration on studies	0.0024
8	Average attendance 0-20%	lost jobs of family members	0.0000
9	High suicidal thoughts	Very high unfamiliarity with online platform	0.0001
	Moderate suicidal thoughts	moderate unfamiliarity with online platform	0.0001
10	Very high home violence	Only father alive	0.0005
11	Very high home violence	Lost jobs of family members	0.0000

house lectures as the most convenient methods to engage in lectures and practical sessions. Nevertheless, online lectures via zoom and screen recordings were identified as the most preferred methods during the pandemic. Moreover, the time taken to adapt to online education was less than a week, but the majority of the first-year students have taken 2 weeks. According to the post hoc tests, the majority of both male and female students have low difficulty in concentration on studies during the pandemic. As well as the loss of jobs of the family members has significantly affected the lower attendance of the online lectures by the undergraduates.

Unfortunately, 14.2% of the undergraduates have undergone suicidal thoughts due to this hazard and according to Table 2, the unfamiliarity of the online platform has a significant effect on it and this should be addressed by providing proper training and online facilities. The pre – existing depression of the students was not considered when performing this analysis. However, with consideration of a factor like pre- existing depression will improve the analysis with more relative outcomes. The suicidal intensity was assessed with the five-point Likert scale which allowed the student to express the nature of their suicidal thoughts compared to normal lifestyle and no standard clinical assessment tools were used.

A foremost finding is, home violence has been identified among 40.5% of students of the sample during the pandemic and losing the jobs of the family members, only having a single parent, specifically only father in the family were identified as the underlying main reasons.

3.2. Cluster Analysis

The k-means clustering technique was applied to identify distinct groups among undergraduates based on the impact of the pandemic on the education and mental perception separately.

Three clusters were identified by considering the impact on education and Cluster 1 consists of 68 students, Cluster 2 of 70 and Cluster 3 of 52. In Cluster 1, the majority of students followed the online available courses with high average attendance from Gampaha and Kandy districts. However, in Cluster 2, several students did not participate in the online lectures because of poor connection, engage in essential activities like jobs and cultivation and

unavailability of internet facilities from few districts. From all the 3 clusters, the majority response was for the most convenient way to engage in lectures and practical sessions were in-house lectures. Most of the undergraduates from Cluster 1 adopted for the online lectures during less than a week while the majority from Cluster 2 adopted for the online lectures after a period of one month. A lot of students from Cluster 2 did not inform the difficulties in engaging in lectures and submitting tutorials online to the academic staff. Nevertheless, students from Cluster 1 inform the difficulties in engaging in lectures and it is noteworthy that they all received solutions from the academic staff of the Faculty.

Considering the impact on the mental perception of undergraduates, four clusters were recognized. Cluster 1 includes 13 students while Cluster 2, 3 and 4 consists of 71, 37 and 69 students. In Cluster 2 most of the undergraduates felt more nervous, anxious, suicidal thoughts, depressed, worried about the effect of COVID-19 in themselves and their family's health and education. Similarly, they lost interest in extra activities, increased in sleeping hours, high appetite, difficulty in concentrating in studies. In the same time, students in Cluster 2 faced home violence during this epidemic compared to other clusters. Most of the students in this cluster were female and first-year undergraduates. As they are freshmen it is hard to adjust quickly to a changing and new environment without support. Most of the students were from Gampaha and Kaluthara districts. A moderate amount of students felt isolation in Clusters 2, 3 and 4. However, some of the students in this cluster indicated that they received support from family and friends to overcome the loneliness feeling and to continue the education. Cluster 3 and 4 mainly consists of opposite features discussed related to Cluster 2. Moreover, overall IT knowledge has risen in all the students except for few students.

The government and the higher education authorities can take many actions based on the findings of this study in order to help the university students. Some suggestions include, helping students to overcome mental health problems by counselling, increasing knowledge of online platforms, providing loan facilities to buy laptops and online connecting devices and organizing awareness workshops.

The findings of this study are limited to the physical science undergraduates of the Faculty of Science, University of Kelaniya. As a further study, same techniques can be applied by considering a wider audience to cover all 16 Universities in Sri Lanka.

4. CONCLUSION

In conclusion, this study evidence that there is a huge impact on education and mental health of undergraduates due to the COVID-19 outbreak. Therefore, students have to adapt to a new environment with a lot of difficulties. Even though the students have adapted the online learning environment, majority prefer in-house lectures and practical sessions. Loss of jobs of family members during the pandemic can be highlighted as a major problem faced by students which affected both education and mental healthiness. The students are in their youth and it is fair to have depressed thoughts as indicated in the study. Outcomes of this study can be considered by higher authorities of education to lend a helping hand for undergraduates to minimize the effect of COVID-19 on education and mental health.

REFERENCES

Aucejo, E. M., French, J., Araya, M. P. U., & Zafar, B. (2020). The impact of COVID-19 on student experiences and expectations: Evidence from a survey. *Journal of public economics*, *191*, 104271.

Bodrud-Doza, M., Shammi, M., Bahlman, L., Islam, A. R. M., & Rahman, M. (2020). Psychosocial and socio-economic crisis in Bangladesh due to COVID-19 pandemic: a perception-based assessment. *Frontiers in public health*, *8*, 341.

Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., Dong, J., & Zheng, J. (2020). *The psychological impact of the COVID-19 epidemic on college students in China*. *Psychiatry research*, 112934.

Chaturvedi, K., Vishwakarma, D. K., & Singh, N. (2021). COVID-19 and its impact on education, social life and mental health of students: A

survey. *Children and youth services review*, *121*, 105866.

Choi, B., Jegatheeswaran, L., Minocha, A., Alhilani, M., Nakhoul, M., & Mutengesa, E. (2020). The impact of the COVID-19 pandemic on final year medical students in the United Kingdom: a national survey. *BMC medical education*, *20*(1), 1-11.

Grubic, N., Badovinac, S., & Johri, A. M. (2020). Student mental health in the midst of the COVID-19 pandemic: A call for further research and immediate solutions. *International Journal of Social Psychiatry*, *66*(5), 517-518.

Hung, M. C., Wu, J., Chang, J. H., & Yang, D. L. (2005). An efficient k-means clustering algorithm using simple partitioning. *Journal of Information Science and Engineering*, *21*(6), 1157-1177.

Kecojevic, A., Basch, C. H., Sullivan, M., & Davi, N. K. (2020). The impact of the COVID-19 epidemic on mental health of undergraduate students in New Jersey, cross-sectional study. *PloS one*, *15*(9), e0239696.

Mulenga, E. M., & Marbán, J. M. (2020). Prospective teachers' online learning Mathematics activities in the age of COVID-19: A cluster analysis approach. *EURASIA Journal of Mathematics, Science and Technology Education*, *16*(9), em1872.

Narang, B., Verma, P., & Kochar, P. (2016). Application based, advantageous k-meansclustering Algorithm in Data Mining-A Review. *International Journal of Latest Trends in Engineering and Technology (IJLTET), ISSN*.

Neuburger, L., & Egger, R. (2020). Travel risk perception and travel behaviour during the COVID-19 pandemic 2020: a case study of the DACH region. *Current Issues in Tourism*, 1-14.

Pham, D. T., Dimov, S. S., & Nguyen, C. D. (2005). Selection of K in K-means clustering. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *219*(1), 103-119.

Rahman, M. A., Zaman, N., Asyhari, A. T., Al-Turjman, F., Bhuiyan, M. Z. A., & Zolkipli, M. F. (2020). Data-driven dynamic clustering framework for mitigating the adverse economic impact of COVID-19 lockdown practices. *Sustainable Cities and Society*, *62*, 102372.

Sahu, P. (2020). Closure of universities due to coronavirus disease 2019 (COVID-19): impact on education and mental health of students and academic staff. *Cureus*, *12*(4).

Savage, M. J., James, R., Magistro, D., Donaldson, J., Healy, L. C., Nevill, M., & Hennis, P. J. (2020). Mental health and movement behaviour during the COVID-19 pandemic in UK university students: Prospective cohort study. *Mental Health and Physical Activity*, *19*, 100357.

Van Nguyen, D., Pham, G. H., & Nguyen, D. N. (2020). Impact of the COVID-19 pandemic on perceptions and behaviors of university students in Vietnam. *Data in Brief*, *31*, 105880.

Annex 1. Impact of COVID-19 Pandemic on Education and Mental Health of Physical Science Undergraduates in the Faculty of Science, University of Kelaniya

You are an important student in the University of Kelaniya, and we thank you for giving your valuable time to complete this survey. Your participation in the survey is completely voluntary and all of your responses will be kept confidential. Your responses to this survey will help us to evaluate the effectiveness of the Mental Health and Quality of life among University Students during the COVID-19 pandemic.

Basic data

1. Gender?
- Male
- Female

2. Year of the study?
- 1st year
- 2nd year
- 3rd year
- 4th year

3. Degree type
- General degree
- Honours degree

4. If general, major subjects (You can select more than 1 option)
- Statistics
- Computer Science
- Computer Studies
- Physics
- Chemistry
- Pure mathematics

- Applied mathematics

5. If Honours, major subject
- Statistics
- Computer Science
- Pure Mathematics and Statistics
- Computer Studies
- Physics
- Chemistry
- Pure and Applied Mathematics

Home situation

6. District, where you live permanently

7. Living district before the pandemic Type of residence – Home, apartment, Hotel, boarding, shared accommodation, Hostel, Other

8. Living district during the pandemic Type of residence – Home, apartment, Hotel, boarding, shared accommodation, Hostel, Other

9. Are your parents alive?
- Both
- Only mother
- Only father
- None

10. What is the current employment sector of your father? (You can select more than 1 option)
- Not employed
- Government
- Semi-government
- Private
- Self-employed
- Not applicable

11. What is the current employment sector of your mother? (You can select more than 1 option)
- Not employed
- Government
- Semi-government
- Private
- Self-employed
- Not applicable

Education impact

12. Your preferred methods to continue the university education before the COVID-19 pandemic? (You can select more than 1 option) Lecture sessions (In-house lectures)
- CAL
- Discussions
- Practical sessions
- In-house workshops
- Email
- Social media (Whatsapp, Viber, You tube)
- ----------

13. Methods that you have used to continue the university education during the pandemic? (You can select more than 1 option)
- CAL
- Online lectures (ZOOM, Google meet, Microsoft Team)
- Online workshops
- Online courses (Coursera)
- Email
- Social media (Whatsapp, Viber, You tube)
- …….

14. Percentage of the online availability of lectures for your registered courses during the pandemic?
- 0% - 20%
- 20% - 40%
- 40% - 60%
- 60% - 80%
- 80% - 100%

15. Did you follow all the courses via online for this semester?
- Yes
- No

16. Your average attendance for the courses via online for this semester? 0% - 20%
- 20% - 40%
- 40% - 60%
- 60% - 80%
- 80% - 100%

17. Your method of participation in the lectures during the pandemic? (You can select more than 1 option)
- Through online Zoom lectures
- By referencing the screen recordings
- By referencing the lecture notes
- Submitting the answers for Tutorials and assignments
- Forums
- Other methods ……..

18. Reasons for not participating in the lectures during the pandemic (You can select more than 1 option)
- Unavailability of internet facilities
- Poor connection
- Unavailability of resources (Laptops/tabs/ desktops/mobile phones)
- Having the resources but in not reachable (Ex: Laptops are forgotten in the boarding house)
- Unavailability of the lecture materials
- Engaged in essential activities like jobs and cultivation
- Other ……..

19. Most convenient way for you to engage in lectures
- Through online lectures
- By referencing the screen recordings
- By referencing the lecture notes
- Lectures in the lecture hall with the Lecturer
- Social media
- Email
- …….

20. Most convenient way for you to engage in lectures during the pandemic
- Through online lectures
- By referencing the screen recordings
- By referencing the lecture notes
- Social media
- Email
- Other ……..

21. Most convenient way for you to engage in practical sessions
- Through online lectures
- By referencing the screen recordings
- By referencing the lecture notes
- Lectures in the lecture hall with the Lecturer
- Social media
- Email
- ……..

22. Most convenient way for you to engage in practical sessions during the pandemic
- Through online lectures
- By referencing the screen recordings
- By referencing the lecture notes
- Social media
- Other ……..

23. Reason for choosing your answer in part 18 and 20? (You can select more than 1 option) (see table for q 23)

24. Did you experience any difficulty when engage in lectures via Zoom/ Google meet/ Microsoft Team?
- Yes
- No

25. If yes, what are the difficulties?
- The lecture is not clearly audible due to poor internet connection.
- Disconnection problems
- Poor video quality
- Sense of isolation (No external support)
- Other……

Table for q.23

Online Zoom/Google meet lectures / Team viewer	**Screen recordings**	**lecture notes**
Live interaction	Accessible at any time	Accessible at any time
Convenient in practical session	Easy to explain in detail	Wide range of content
Recording facility	Wide range of content	
Easily screen share facility	Proper organization	
Live chat facility		
Managing subject matters of the students		
Virtual lecture hall		
…….	……	…….

26. Did you experience any difficulty when submitting tutorial/assignment answers during the pandemic?
- Yes
- No

27. If yes, what are the difficulties?
- Can't understand the lecture properly
- Heavy workload
- Lack of knowledge for the online submission
- Unavailability of the electronic devices
- …….

28. Did you inform the difficulties faced in lectures and tutorials to the academic staff during the pandemic?
- Yes
- No

29. Did you get solutions after discussing the difficulties with the academic staff?
- Yes
- No
- Not applicable
- If yes, what are the solutions? Mind making
- Providing devices
- Deadline extension
- Further explanation of lectures and tutorials
- Not applicable
- ……

30. Time taken for you to adapt to the online education system during the pandemic
- Less than a week
- Less than 2 weeks
- Less than a month
- More than a month

Health impact

31. Did you/ anyone lived/stayed in your residence imposed to the medically approved quarantine?
- Yes
- No

32. If yes, what is the place of Quarantined?
- Home
- Quarantine centers

33. Please specify the center
- ……..

34. Did you had any other illness during the pandemic?
- Dengue
- Chickenpox
- Leptospirosis
- None
- …….

35. If you had an illness, did you recover?
- Yes
- No
- Not applicable

Mental perception

36. Rate the following thoughts during the pandemic compared to your normal life style (see table for q.36)

Economic impact

37. What kind of economic impact has the pandemic had on your family?
- No impact
- Lost savings
- Lost jobs
- Reduced the income
- Threat to the self-employments

38. Did you engaged in a job before the pandemic?
- Yes
- No

39. If yes, how did you work during the pandemic?
- In the office
- Work from home
- Lose the job
- ……..

40. Did you have a requirement to do a job during the pandemic?
- Yes
- No

41. If yes, how did you work?
- In the office
- Work from home

Table for q.36

Thoughts	Very high	High	Moderate	Low	Very low
Feeing more nervous, anxious					
Worrying too much about the effect of Covid 19 on your health and safety					
Worrying too much about the effect of Covid 19 on your family's health and safety					
Worrying too much about the effect of Covid 19 on your education					
Getting easily annoyed or irritable					
Losing interest or pleasure in doing extra activities					
Gaining interest or pleasure in doing extra activities					
Increase in sleeping hours					
Overeating (High appetite)					
Difficulty in concentration on studies					
Feeling down, depressed or hopeless					
Feeling helpless or frustrated					
Sharing feelings with the family members					
Support from friends					
Feeling isolated					
Not familiar with the online platform					
Frustration due to unavailability of resources to continue studies					
Reluctance to adapt to new environment					
Unnecessary fear (confusion)					
Home violence/ roughness/cruelty					
IT knowledge and skills					
English knowledge					
Support from family and friends to overcome the loneliness feeling					
Support from friends to continue the education					
Feeling of give up on university education					
Financially unstable					
Depress due to the economic problems					
Suicidal thoughts (negative thoughts)					

42. If yes, what are the reasons?

- Financial issues in the family
- Lose of the jobs of parents
- To earn more money
- To spend time more useful way
- Other……

43. Rate the following expenses during the pandemic compared to your normal life style

Expenses	Unchanged	Increased	Decreased	No cost
Boarding fees				
Travelling costs				
Cost for meals				
Cost for education				
Cost for clothing				
Other expenses……. (Please specify)				

Mitigating the 'Shadow Pandemic' of COVID-19: A project by undergraduates of a university in Sri Lanka

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ABSTRACT

Introduction: The coronavirus pandemic has resulted in the escalation of violence against women (VAW) in Sri Lanka. This is mainly because women were confined to households with their violent partner and with curfew in effect, women found it difficult to seek help. This, combined with stress and economic uncertainty caused by the pandemic, amplified the issue.

Objectives: Aims of the study were to increase understanding of the different forms of violence a woman can face, address masculine norms and toxic masculinity, encourage the public to actively participate against VAW and spread a clear message of zero tolerance to violence against women.

Methodology: Golden Z Club, Faculty of Medicine, Colombo carried out a project, titled "She deserves better" for one month and disseminated informational materials in Sinhala, Tamil and English, addressing statistics of VAW, toxic masculinity, and assistance available for victims. They were distributed via varied social media platforms of different organizations.

Results: The study received feedback from public and non-governmental organizations. It also created online conversations among youth, especially university students, on VAW. Majority shared the view that VAW is unacceptable.

Discussion: Study was able to improve sensitivity and awareness among youth, potential victims and perpetrators, and witnesses of VAW, due to multiple modes of dissemination through varied stakeholders. Despite reaching large audience, lack of face-to-face communication was a limitation noted.

Conclusion: The project was able to impart knowledge, address and condemn toxic masculine attitudes and behavior that contribute to VAW.

Key words: Domestic violence, Health promotion, Social media,Violence against women

1. INTRODUCTION

Beginning March 2020, to curb the spread of COVID-19, an island-wide curfew was imposed in Sri Lanka. Subsequently, reports of increased domestic violence against women (VAW) - the 'shadow pandemic' - were indicated from all-over the island. A main reason for this was women were being confined to their households with violent partners. Physical distancing and intermittent island-wide curfew made it harder for them to seek support. This, combined with the stress and economic

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uncertainty caused by the pandemic, resulted in a heightened risk of VAW, which has many physical and psychological repercussions. Even before the COVID-19 crisis, VAW was deeply rooted in society. To end such violence, raising public awareness is important because an increased knowledge would lead to a society that is more willing to change their attitudes and behavior. Hence, the objectives of the study were: (i) to increase the understanding of the different forms of violence a woman can face; (ii) address masculine norms and toxic masculinity; (iii) encourage public to actively participate in the resisting VAW and spread a clear message of zero tolerance to violence against women.

2. METHODOLOGY

Golden Z Club, Faculty of Medicine, University of Colombo carried out a project titled "She deserves better" for one month. A series of original posts and videos, created by the Golden Z Club members, in English, Sinhala and Tamil, were shared across social media with the purpose of educating the general public on violence against women, empowering women, and addressing toxic masculinity. The various platforms that were used to disseminate the posts are given below, along with the number of participants (where relevant):

- Public health nurses, matrons and sisters in the government sector – 150
- Group of garment workers in Katunayake Free Trade Zone
- Nurses in government hospitals – 150
- Medical officers of Mental Health unit of Ministry of Health – 125
- Physiotherapists in government hospitals – 250
- Sumithrayo and Shanthi Maargam (non-government organizations)
- Women's Education and Research Centre (WERC) Facebook page
- Women's organizations in Northern and Eastern parts of Sri Lanka through WERC
- Non-Communicable Diseases network of the Ministry of Health
- Hospitals, schools, government offices adjacent to MAS factories in the Biyagama Free Trade Zone
- Family Planning Association
- MFC Echo – YouTube (Media Club of Faculty of Medicine, University of Colombo)
- University of Colombo student and employs networks
- United Nations Populations Fund
- Golden Z Club, Faculty of Medicine – Facebook, Instagram pages

Different aspects of violence against women were addressed over the course of a month. Firstly, a brief introduction was given, along with important statistical data regarding the violence against women in Sri Lanka. Then, the public was educated about the physical and emotional consequences of violence with how the victim can deal with being in the house with her abuser. Posts about how the family and bystanders can approach and help the victim were also shared. At the latter part of the project, the masculine norms present in society and the harmful effects of toxic masculinity were discussed. A creative and thought-provoking video produced by the editorial team of Golden Z Club tackled the masculine norms present in the common Sri Lankan household. The public was further educated on how these harmful stereotypes could be broken for a violence-free future. In addition, a video featuring Nadeepa Ranasinghe (LLB), Attorney at Law and Personal Development coach addressed the legal outlook of violence against women in Sri Lanka.

3. RESULTS AND DISCUSSION

In its reach, only on the Golden Z Club Facebook page, all the videos posted had a total of over 14,000 views, and the e-posts had a combined total reach of over 73,000 (Figure 1).

The project received comments from the public as well as feedback from non-governmental organizations. One such stakeholder shared the importance of empowering women and shifting the burden

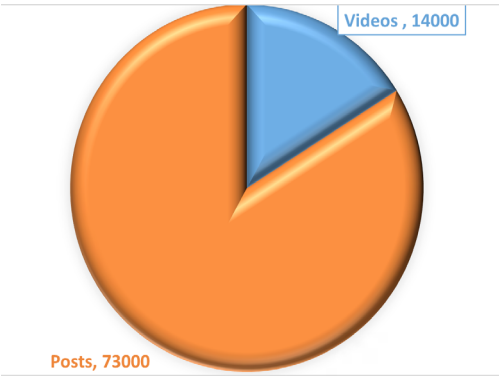

Figure 1. Frequency distribution of views of informational materials shared in the project

to the perpetrators and stated that there was a "need to get these messages out and empower the country as a whole to stand behind these vulnerable women". The project gained attention from youth too, including university students, which resulted in online conversations on the topic. Most of them shared the idea that VAW is unacceptable.

The results obtained indicate that there is an overall improvement of knowledge and awareness of violence against women. The baseline knowledge of the public was assumed to be inadequate due to a few negative comments regarding the content matter of one of the first posts. However, as the project progressed, increasing activity on the posts and videos via likes, comments, shares and views, suggested that the viewers were gaining knowledge and were encouraged to share this with others too. For instance, one of the final videos on masculine norms gained over 100 likes, 100 shares and seven comments, whereas the first video about the statistics of violence against women obtained only 42 likes and 28 shares.

Improved sensitivity and awareness can be ensured across young people, potential victims and perpetrators, groups at risk and witnesses of violence against women due to the wide-ranging modes of dissemination used throughout the project. Despite posting organic content and reaching large audiences, a few limitations like the lack of face-to-face communication and emotional connection were present due to the use of social media to circulate the posts.

4. CONCLUSION

Even before COVID-19 existed, violence against women was one of the greatest human rights violations. The emerging pandemic only exacerbated an underlying fundamental problem present in the society. "She Deserves Better" was able to not only empower women and encourage victims to speak out, but also to address and condemn the toxic masculine attitudes and behavior that contribute to violence against women.

BIBLIOGRAPHY

Demographic and Health Survey. (2016). Domestic violence from intimate partner

United Nations Population Fund Forum Against Gender Based Violence. (2015). Key information and guidance note for Service Providers supporting Women and Girls subject to violence during COVID-19

NATIONAL SCIENCE FOUNDATION

Section 4

Economy

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Economy: Introduction

Prema-chandra Athukorala

This section of the book comprises six chapters that aim to broadening our understanding of the challenge faced by Sri Lanka in achieving post-COVID-19 economic recovery and the related policy options.

The section begins with a wide-raging chapter by W. A Wijewardena that maps a strategy for economic recovery against the backdrop of an in-depth analysis of the pre-pandemic structural weaknesses of the economy and the depth to which the economy has fallen after the onset of the pandemic. The key premise of the chapter is that, since the entire globe has been a victim of the pandemic, the recovery requires countries to work together rather than in isolation, while framing the national development strategy to address country-specific structural impediments to global economic integration. Based on this premise, the chapter proposes a national road map for post-COVID recovery that encompass the following key components: joining the global production network; acquiring technology via promoting foreign direct investment (FDI); increasing the country's R&D capability; and overhauling the education system to create a human capital base that meet the prerequisites for meeting challenges in this era of global economic integration. How to systematically sequence and coordinate policy priorities relating to components of the proposed road map is an important issue for further research. The nature of R&D capabilities and human resources required for a country to successfully joining global production networks depends on comparative advantage in international production, which naturally varies from country to country depending on the stage of economic advancement and the resource endowment.

In Chapter 02, Dushni Weeracoon examines macroeconomic challenges of the Sri Lankan economy in facing the COVID-19 economic fall-out with emphasis on the constraining effect of massive public debt accumulated over the preceding decade with a heavy external (dollar-denominated) debt exposure. The core of the chapter is a penetrating analysis of the inherent risk and vulnerability of country's current macroeconomic policy posture that leans heavily on monetary policy interventions, including direct financing of government spending and yield curve control measures to keep borrowing costs down. This analysis yields the important policy inference that the resilience and sustainability of the recovery process will depend crucially on efforts to set a robust fiscal and debt sustainability path to help by-pass medium-term risks. A key general lesson from the Sri Lanka's pre-pandemic debt-dependent development strategy, which deserves further analysis, is that foreign-currency debt (normally US$ denominated) puts a sharper limit on how much debt a country can accumulate. When the US$ strengthen, countries that issue US$-denominated debts must spend more of their depreciated currency to make scheduled interest payments and debt repayments. This is an important lessons for those who have blindly embraced the advocacy of modern monetary theory (MMT) for deficit financing, which is relevant only for some rich countries whose debts are denominated in their own currencies.

Chapter 01 by Prema-chandra Athukorala contributes to the contemporary policy debate on industrialization strategy in Sri Lanka by analyzing policy regime shifts and their outcomes during the post-independence era. The findings, based on an analysis of the Sri Lankan experience under alternative policy regimes guided by the received body of knowledge built on the experiences of the high performing East Asian economies (HPEAEs), makes a strong case for reconsidering the merit of the emerging emphasis on combining import substitution with export orientation with a sector specific focus. The key message of the paper is that there are important lessons to learn from the outcome of Sri Lankan's liberalization reforms initiated in 1977, when systematically analyzed while allowed for the incomplete implementation of the proposed reform package and the adverse impact of the protracted civil war on the investment climate and macroeconomic stability. The

analysis makes a strong case for averting backsliding from liberalization reforms, continuing with the reforms agenda that was left incomplete in the late 1990s, and setting up institutional safeguards to avert further policy backsliding.

Can the Sri Lankan apparel industry benefit from the import tariffs imposed by the USA under the Trump administration on imports from China? This is an important issue for Sri Lanka because apparel is the country's single most important export product, the USA is by far the largest importuner of apparel from Sri Lanka, and there are indications that the new Biden administration is staying the course Trump set relating to trade with China. The purpose of Chapter 03 by Subhashini Abeysinghe and Mathisa Arangala is to address this issue by undertaking an analysis of finely disaggregated data on US apparel imports, disaggregated by source country, during the period 2011-2019. The authors first delineate apparel products with early signs of diverting imports away from China to other source countries. Then, they identify from this list the products exported from Sri Lanka that can potentially benefit from the import diversion, after allowing for the level of competition Sri Lanka faces in the US market from imports from third countries. The supply-side problems faced by the Sri Lankan appeal producers in penetrating the US market in these identified products is an important subject for further research to complement this interesting analysis.

Chapter 04 by Naduni Nayanathara, Jeevika Weerahewa and Devesh Roy examines the impact on household expenditures and nutrient intake of the restrictions on food imports recently introduced by the government in response to the balance of payment crisis. A simulation analysis has been undertaken to assess the effects by applying a dataset put together from scattered source on household expenditure, price changes, own and cross price elasticities of demand to a simple household food demand model. The analysis covers almost all import-competing food products using data for the period 18th March to 26th June 2020. The findings indicate that import restrictions have had a significant adverse impact on the welfare of the households in in terms of reduction of levels of consumption and the nutrient intakes, with possible adverse long-term impacts on human capital formation. The study has solely focussed on the immediate direct price effect of import restrictions on household expenditure. In the medium to long run, the response of domestic import-competing producers to the new prices could at least partly counterbalance the direct price effect, an interesting subject for future research.

The final chapter by S. Sahibzada and J. Weerahewa examines the effect of COVID-19 tariff changes in Asian countries on processed food exports from Induced Agro-food Trade Policy changes in selected Asian countries on processed Food Exports from Bangladesh, India, Pakistan, and Sri Lanka. The methodology involves simulating the impact of alternative scenarios of changes in both import and export tariffs on processed food exports from these four countries to the other countries in the region using the Global Trade Analysis Project (GTAP) with data for 2014. The results suggest that overall effect of the policy response of the COVID-19 by major Asian trading partners was largely beneficial for the four exporting countries. As the authors have justly concluded, the validity of the results are, of course, subject to a number of well-known caveats relating to GTAP policy simulations.

Covid-19 pandemic and suggested economic recovery plan‡

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ABSTRACT

This paper analyses how Sri Lanka should strategize its future economic plans to come out of the depth to which the country's economy has fallen after it had been hit by COVID-19 pandemic. While authorities are hopeful of attaining a quick recovery, the third wave of the pandemic which hit the country in April 2021 has derailed that hope prognosticating a prolonged recovery. However, Sri Lanka's economy had been ailing for some time mainly due to structural problems. The country had relied on a production model involving simple technology which has prevented it from beating the middle-income trap in which the country has been ensnared since 1997 due to lack of adherence to high-tech production systems. Hence, the solution lies in transforming the country's economy into a high-tech economy. It will enable Sri Lanka to leapfrog from 2IR to 4IR bypassing 3IR. The paper has suggested a five-pronged plan to attain this objective: introducing a road map, joining the global production network, acquiring technology and market access via FDIs, increasing Sri Lanka's R&D expenses, and overhauling education system to proliferate science, technology, engineering, creative art, and mathematics. The paper concludes that these five components should be essential parts of future economic strategies.

Key words: COVID-19, High-tech product, Simple technology, Structural change, Industrial revolutions

1. INTRODUCTION

COVID-19 pandemic which started in late 2019 in Wuhan in China has brought in a devastating effect on the global economy. One salient outcome has been the decline in the per capita income in rich countries faster than that in emerging market economies (Deaton, 2021). It has been hitting the world in waves one after the other. Sri Lanka had its first case in late March 2020 and since then till middle of 2021, has encountered three waves of the pandemic. Each subsequent wave inflicted a greater human cost than before and hence made a permanent dent on the country's economy.

The early projections made by authorities in April 2020 indicated that the country will have a quick V-shape recovery with the real growth rate falling only to 1.5% in 2020 and steadily rising to 6% in 2022 (CBSL, 2020). Though these projections were revised downward in response to subsequent developments, the authorities still maintain the notion of a quick recovery in the economy. Accordingly, the economy, which experienced a negative growth of 3.6% in 2020. is projected to recover quickly in 2021 with a real growth of 6%. Thereafter, the projected growth rate will rise to 6.5% in 2024 and further to 7% in 2025 (CBSL, 2021). These projections are at variance with those made by independent authorities. For instance, the World Bank in its Sri Lanka

‡ **Invited Paper**

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Development Update 2021 has projected a slow recovery for Sri Lanka's economy with a growth rate of 3.4% in 2021 and a declined rate of 2.1% in 2023 (World Bank, 2021). Both these projections had been made before the country was hit by the third wave of the pandemic in April 2021. Hence, at most, the expectation is that Sri Lanka will have a slow and prolonged economic recovery assuming that there will not be further waves of the pandemic hitting the country.

In this context, it is necessary for policymakers to take a stock of the Sri Lanka's economy and plan for a smooth recovery path. Since the entire globe has been a victim of the COVID-19 pandemic, recovery strategies require countries to work together rather than in isolation. A country has no choice in its quest for economic recovery. It must approach it by enriching others, while getting enriched in return. It is a 'win-win' option for both categories of countries. Hence, it behoves the world's nations to shed ideological, social, cultural, and economic differences and work together for the creation of a shared world. Perhaps, this is one of the unintended blessings which COVID-19 pandemic has delivered to world's nations. This cooperation should be in the fields of science, technology, investment, and market access. What this means is that countries should, instead of embracing isolationist national economy based economic growth models, adopt the global economic system based open economy models. This requires a complete change of the popular slogan of 1960s and 1970s that nations should think locally but act globally. Putting this slogan in a different tone, the prescription for Indians in 1990s was that they may chant in Sanskrit but necessarily rant in English (Das, 2002). Thus, the post COVID-19 pandemic growth model requires countries to both think and act globally.

This paper analyses how Sri Lanka should map out its strategy for economic recovery in the post COVID-19 pandemic era. The paper is organised as follows. Section I will analyse the present state of the Sri Lanka's economy and how recovery should begin by addressing the challenges posed to it. Section II will present the broad economic strategy to be adopted considering the need for cooperative arrangements with the rest of the world. Section III is dedicated for a summary and conclusions.

2. SECTION I: THE PRESENT STATE OF THE ECONOMY OF SRI LANKA AND ITS CHALLENGES

Even before Sri Lanka was hit by COVID-19 pandemic, its economy had been ailing for some time. Immediately after the end of the civil war in 2009, there was an economic boom raising the country's growth rate to above 8%, a historical high, during 2010-2. But this was short-lived and could not be maintained in the subsequent period. Accordingly, the growth rate fell to an average of 3.9% during 2013-9. This was below the historical average growth rate of 4.5% experienced by Sri Lanka in the whole of its post-independence period. The growth rate declined during 2013-9 and bottomed in 2019 at 2.3%, the lowest since the economic contraction of 1.5% in 2001. That was partly due to the Easter bomb attacks in April 2019 that crippled economic activities, specifically those in the hospitality sector, for two quarters and partly due to the adverse weather conditions decimating growth in the agriculture sector (CBSL, 2020). These two factors may have certainly contributed to stunt the economic growth in 2019. However, the examination of the medium to long-term data shows that this is a continuation of the growth slowing scenario since 2013 and, therefore, was not unexpected. It would have been better had attempts been made to identify the root causes for the declining trend and address them promptly.

Sri Lanka's present economic problems are more of a structural nature than periodic adverse weather or negative internal/external shocks. The colonial economy which Sri Lanka inherited at independence in 1948 was based on the export of three tree crops, namely, tea, rubber, and coconuts. That economic system helped Sri Lanka to improve the welfare level of its people significantly compared to its peers in the region. The World Bank Mission on

Economic Development that visited Sri Lanka in 1952 had observed that the country could no longer depend on this economic model (GOSL, 1952). Its population had trebled in the previous 75 years and there was doubt whether the old production pattern could keep up with the increasing population. Hence, there was the necessity, said the World Bank mission, for "expanding and diversifying the sources of production fast enough to maintain the tempo of progress". The expansion of the tea sector had been limited by the non-availability of suitable land, while rubber had faced uncertain markets and coconuts the low yields. The solution, according to the Mission, lay in the fast industrialisation of the economy (GOSL, 1952) and the modernisation of agriculture, both based on the adoption of new technologies The Mission has specifically recommended that "Efforts must be started immediately to widen the base for industrial growth, even if the major developments are expected to arise much later". While light industries can be started immediately, the Mission had opined that more industries should be selected based on "modern methods of applied technical research (GOSL, 1952).

A salient feature of the technological development in the present era has been its fast evolution from one state to another. Hence, if a country does not get itself integrated to the fast-changing technological world, it becomes a laggard. Even the Sri Lanka's apparel industry which supplies to a niche market is faced with the problem of the buying countries moving toward 'on-shoring and near-shoring' production models[1]. The countries which were successful in moving from the low-income state to the high-income state within a generation in the latter part of the 20th century were able to do so by transforming the respective production patterns to high-tech production models. East Asia, accordingly, shifted its production mix from 'textiles, shoes, and fireworks' to 'high-value electronics, biotechnologies, gene technologies, and information and communication products' (Pierer, 2002). The process has been facilitated by the readiness of people in East Asia to embrace new technologies, driven by high investments in human capital and talents. However, even these countries have now identified the need for moving forward along with the new developments in technology. Unless a country gets into this technological race, it is inevitable that it is left behind. Sri Lanka's track record shows that it falls into this category.

The economic reforms introduced by Sri Lanka in 1977 aimed at converting the import substitution relying domestic economy based economic system to an outward-looking export-oriented economy. The attainments in the subsequent period have been remarkable. Within a decade, the country was able to expand its industrial base in production from a share of 20% of GDP during 1950-1977 to an average share of 27% during 1978-1988. Meanwhile, the contribution of agriculture to total output was reduced from 37% to 28%. In the next two decades, while industry contribution remained on average at 27%, the share of agriculture fell to 20%. In 2020, the latest year for which data are available, industry had a share of 26%, while that of agriculture has further declined to 8%. This structural transformation in the economy is reflected in the structure of exports too. At independence in 1948, agricultural exports accounted for 90% of exports, while that of industry was insignificant. In 1977 when the new economic policy regime was introduced, agricultural exports had declined to 79%, while industrial exports had accounted for 14%. This ratio has drastically changed in the subsequent four decades. In 2020, the three tree crops had a share of 16% in total exports, while the share of industrial exports had amounted to 76%. Of the industrial exports, textiles and garments had the lion's share of 58%.

This structural transformation had entailed a salutary impact on Sri Lanka's economy. But it relied on a single industry, namely, garments and textiles, to generate

1 For details see: McKinsey and Company, 2018, Is Apparel Industry Coming Home? (Available at: https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/is%20apparel%20manufacturing%20coming%20home/is-apparel-manufacturing-coming-home_vf.pdf) (Accessed on 30.5.2021)

wealth and income for people. This reliance has generated a new risk to the economy. That risk arises from its use of simple technology for production enabling potential competitors to imitate it easily and out-beat Sri Lanka in global markets. When a similar threat had driven the General Electric (GE) Corporation to bankruptcy in early 1980s, the management was able to rescue the company by shedding simple technology-based products and going for complex technology-based products (Welch, 2003). Accordingly, it concentrated on manufacturing jet engines, power turbines, sophisticated medical equipment, and high-tech entertainment products. The rationale was that these products based on high technology cannot be easily imitated by others. Thus, the production of labour-intensive mass consumer items was left to companies blessed with low wage workers. With this strategy, GE was able to make a turnaround of the company by 1986.

What is relevant to GE is relevant to Sri Lanka at present on two counts. One is Sri Lanka's wages are rising and therefore, it can no longer compete with low wage countries like Myanmar, Bangladesh, and Cambodia which also have entered the apparel market today. This is evident from the increase of Sri Lanka's garment and textile exports by 33% from US$ 4.2 billion in 2011 to US$ 5.6 billion in 2019. During this period, Bangladesh which is a newcomer to the market had almost doubled its exports of garments and textiles from US 17.9 billion to US$ 34.1 billion. Because of this low wage advantage, even Sri Lanka's garment manufacturers have established factories in Bangladesh. Hence, while Sri Lanka's garment and textiles industry is limping forward, that of Bangladesh is progressing in leaps and bounds. In the case of Myanmar, garment exports increased by nearly 6 times from US$ 361 million to US$ 1988 million, while in Cambodia, they increased by nearly 3 times from US$ 2.5 billion to US$ 7 billion during this period. Sri Lanka should, therefore, like GE, shed low wage products and embrace high tech products.

The other reason which compels Sri Lanka to shed low tech products and embrace high tech products arises from its being ensnared in what is known as the 'Middle Income Trap (MIT)'. This is a notion that has been coined by Gill and Kharas, (2007) by reference to the growth pattern of some of the East Asian countries. Economic growth becomes a trap for many of these countries due to the following reasons. It is easy for a low-wage labour-abundant country to move from the low-income state to middle income state by producing mass products for the global markets. This is their first integration to the world economy. But when income increases, the wages also increase making their production lines uncompetitive compared to other low-wage low-income countries. Since these production lines use simple technology, it is easy for them to imitate that technology and produce for the global markets. As a result, the countries in the middle-income group are unable to compete with them. They cannot compete with the rich countries too because of the lack of technology. Hence, the second integration to the global economy does not take place as easily as the first integration. As a result, according to Gill and Kharas (2007, 22), middle income countries grow less rapidly than either the rich or poor countries. Gill and Kharas, therefore, conclude "this (factor) accounts for the lack of economic convergence in the twentieth century world. Middle-income countries, it is argued, are squeezed between the low-wage poor-country competitors that dominate in mature industries and the rich-country innovators that dominate in industries undergoing rapid technological change" (Gill and Kharas, 2007).

Sri Lanka elevated itself from a low-income country to a lower middle-income country in 1997 by engaging its low-wage labour to produce garments and textiles that used simple technology. However, even in 2020, it is still a lower middle-income country struggling hard to push itself to the status of a higher middle-income country. In 2019, it was elevated to the status of a higher middle-income country based on its per capita Gross National Income (GNI) in 2018. However, this was short-lived, and the country was downgraded to a lower middle-income country in 2020 since per capita GNI had fallen in 2019 below the threshold level

of US$ 4046 (Wijewardena, 2020). With a negative economic growth in 2020 and the projected low growth till 2024, it is unlikely that Sri Lanka will get elevated to the status of a higher middle-income country soon. However, this gap in time will enable Sri Lanka to map out suitable policies for converting it into a high-tech nation.

Sri Lanka's export structure is still dominated by low-tech or raw products. Despite the elapse of four decades since the opening of the economy in late 1977, the country has not been able to make a breakthrough in changing its product mix in favour of high-tech products. According to the World Bank data, high-tech products constituted just 1% of Sri Lanka's manufactured exports in 2009. In 2017, the ratio has been the same. In the case of Vietnam, it was a jump from 11% to 42% between these two-time intervals[2]. Malaysia during this period has maintained a ratio of about 50%, India 10% and Thailand 25%[3]. At present, Sri Lanka is a laggard in the race for high technology. Yet, with a set of consistent and persistent policy package, Sri Lanka too can join this club. That should be the highest priority in Sri Lanka's economic policy making.

3. SECTION II: THE BROAD ECONOMIC STRATEGY[4]

Sri Lanka has no choice but to go for high technology in its product mix. The development of technologies has disrupted the way we produce, distribute, and consume. Every time a disruption takes place in an economy, some emerge as gainers, while some others are condemned as losers. This was typical of the first, second, and the third industrial revolutions. But for societies to progress, this disruption should necessarily take place. The Austrian American economist Joseph Schumpeter called this a 'creative destruction' (Schumpeter, 1942). It refers to the continuous product and process innovation creating new production units that will replace the old ones. This is now happening throughout the globe in what is known as the Fourth Industrial Revolution or Industry 4.0 or 4IR (Schwab, 2017). The emerging economic disruption is distinguished from previous three disruptors, namely, the first, second, and the third industrial revolutions.

The First Industrial Revolution or 1IR or Industry 1.0 had happened some 300 years ago. In 1IR, industrial production was mechanised basically by using steam-power or waterpower. Then, some 100 years ago, the Second Industrial Revolution or 2IR or Industry 2.0 took place by introducing electric power for mass production. The third phase of industrial revolution, code-named 3IR or Industry 3.0, began to disrupt the world some 50 years ago by introducing advanced information and communication technology (ICT) and electronics for automation of industrial processes. The new products that consumers use on a day-to-day basis like internet, world wide web, mobile phone, Google search engine, and laptops and tablets were introduced to the world during this phase of industrial revolution. But the world did not want to stay there. By the second decade of the 21st century, a fourth revolution, code-named 4IR or Industry 4.0, was taking shape disrupting even the new products and production processes that had been offered to the world by Industry 3.0. In 4IR, the focus is on Cyber Physical System, AI, machine learning, Internet of Things, robotic surgeries etc.

Some countries have moved into 4IR, while many are at its doorstep. A rule of thumb to gauge whether a country has entered 4IR is to look at the high-tech component in its manufactured exports. If that component is 40% or above, that country is already in 4IR. Table 1 presents the component of high-tech products in manufactured exports of some selected countries. It is noted that countries like Malaysia, Vietnam, the Philippines, Singapore, and Hong Kong are already in 4IR.

2 Available at: https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?locations=IN-VN (Accessed on 20.5.2021).

3 Available at: https://data.worldbank.org/indicator/TX.VAL.TECH.MF.ZS?locations=IN-VN-MY-TH (Accessed on 20.5.2021).

4 This section draws on Wijewardena (2021).

Table 1. Share of high-tech products in manufactured exports in some selected countries

Country	High tech exports % of manufactured exports
Sri Lanka	1
India	9
China	31
Malaysia	53
South Korea	32
Thailand	23
Vietnam	40
Indonesia	8
Philippines	61
Singapore	52
Russian Federation	11
Hong Kong SAR	66

World Bank Data Base; for 2017 and 2018

Note: Definition: High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

The countries like China, South Korea, and Thailand are moving fast toward that goal.

Sri Lanka with its 1% of high-tech products in manufactured exports is still in 2IR. Anyone visiting a tea factory, or a garment factory will observe that the whole manufacturing process is operated manually by using electricity-powered machines. But they are the largest export earners for the country. But this should not be taken as a disappointment. That is because it gives a space of 99% for Sri Lanka to move up in the ladder to be a high-tech manufacturing nation. All it must do is to adopt a suitable policy package consistently to take the country through that rugged path. But there is a challenge to be met. That challenge is since Sri Lanka is presently in 2IR, how it should leapfrog straight to 4IR bypassing 3IR. This is difficult but not impossible. In today's advanced learning, adoption and adaptation techniques, a nation need not move ahead by following the steps one after the other. It can fast track by jumping several steps at a time. Therefore, for Sri Lanka to reach 4IR within the next decade or so is not an impossibility[5].

The government's commitment to convert Sri Lanka to a high-tech hub was pronounced in Budget 2021 (GOSL, 2021). Similar announcements were made by the previous government also in its economic policy statements (GOSL, 2016). However, without a concrete plan to attain that goal, they just remained a wish that had not gone beyond paper. The present government can avoid making the same mistake by going for a time-bound action plan and sticking to it consistently. This needs several steps to be followed.

Step 1 will be the preparation of a road map to convert Sri Lanka to a high-tech economy. The road map should clearly spell out the objectives, strategies, inputs to be used, key milestones and final deliverable products. Vietnam which has at present a high high-tech component in its manufactured exports had prepared such a road map in 2019 to complete the country's transmission to 4IR by 2030[6] Vietnam had embarked on its journey to be a 4IR country a few years back by introducing science, technology, and creative innovation

5 The strategies to be followed to attain this goal have been presented by IPS, 2019.

6 (Available at: https://english.mic.gov.vn/Pages/TinTuc/139776/Proactively-participating-in-Industry-4.0.html) (Accessed on 20.5.2021)

to its production structure. The new road map will have several milestones to pass in that journey. One such milestone is to improve its ranking in the Global Innovation Index or GII to be within top 40 countries by 2030. This is an eye-opener for Sri Lanka since it is ranked at 101 out of 131 countries in GII. Another milestone aspired by Vietnam is to increase the size of the digital economy to 30% of GDP, while increasing labour productivity by 7.5% per annum. It also plans to make broadband access inclusive by 2030. For that, it plans to complete the digitisation of the whole society, businesses, and the government.

Step 2 involves joining the global supply chain or global production sharing chain[7] by producing inputs for products that are assembled elsewhere. In today's context, a country cannot produce a whole product and claim that it is made in that country. That is because components come from manufacturing facilities in many countries. It has been found that Apple sources components for iPhone from 43 countries, while it is finally assembled in FoxConn Factory in China[8]. There are several manufacturing facilities in Sri Lanka that have already joined the global production sharing chain. Two noted firms are Harness Lanka at Biyagama that supplies sensors for airbags in vehicles[9] and MAS Fabric at Thulhiriya that produces canvass for Nike shoes[10]. But the country needs a critical pool of such firms-a sufficiently large number of firms that can change the shape of the country-to join 4IR. Vietnam in its road map for 4IR has specifically proclaimed its intention to seamlessly integrate to the global economy. If this is to be attained, Sri Lanka should switch from the present domestic economy based economic growth to international economy based economic growth strategies.

Step 3 involves strategies for acquiring technology immediately for use by the country's manufacturing outfits. One way to do so is to get technologies already developed elsewhere in the globe. They could be automatically acquired by attracting foreign direct investments or FDIs with a high-tech component that will enable market access too. This was the strategy adopted by South Korea and Singapore in their initial phase of economic development and the strategy presently being pursued by Vietnam. In early 1980s, Sri Lanka got such technology for its apparel industry through FDIs. Today, garments are no more fashionable and, hence, technology drive should shift from garments to high-tech products.

Step 4 requires Sri Lanka to develop its own technology in the medium to long-run. This requires Sri Lanka to invest a greater portion of its national income in research and development or R&D. According to World Bank data, Sri Lanka spends only 0,1% of GDP on R&D. This is much lower even by South Asian standards where on average, 0.65 of GDP is spent on R&D. This expenditure need not necessarily be incurred by the government. As it has happened in Japan, South Korea, Singapore and Hong Kong, private companies too should participate in R&D drive. Once new inventions are made through R&D, such inventions should be properly marketed to enable prospective entrepreneurs to produce them commercially. Austrian American economist Joseph Schumpeter named this process as innovation (Schumpeter, 1942).

Step 5 is about developing the country's thinking, inventing and innovative power through a proper system of education. Traditionally, it has been emphasised that education should cover science, technology, engineering, and mathematics, abbreviated as STEM. But to create a creative thing, it is essential that inventors should possess a creative mind too. This comes from creative Art. When creative Art is added to STEM, it will become STEAM. The policy of the government should be to change the education, learning, training, and systems to reflect STEAM.

7 Details of production sharing networks could be found in Athukorala, et al, 2016.

8 https://www.mhlnews.com/global-supply-chain/article/22050401/the-iphone-6-supply-chain-saga-infographic (Accessed on 21.5.2021).

9 For details, see Wijewardena (2018).

10 For details, see Wijewardena (2019).

These five steps are the minimum tasks which the government should accomplish to accelerate Sri Lanka's drive towards a high-tech nation. People today are impatient because the country remains an emerging nation forever. Hence, the government cannot pursue 'an announce and forget' policy. It should announce the policy but should not allow it to be only on paper. It should therefore be an 'announce and implement' policy for attaining the best results for the country.

4. SECTION III: A SUMMARY AND CONCLUSIONS

This paper has analysed the economic challenges faced by Sri Lanka after it had been hit by COVID-19 pandemic. There has been a wide-spread economic disruption crippling all the three major economic activities, agriculture, industry, and services. But this has been the common experience by all the countries in the world. Hence, economic recovery requires all the countries to cooperate and collaborate with each other rather than working in isolation. Though the Sri Lankan authorities expect a quick recovery, given the onset of the third wave of COVID-19 pandemic in April 2021, it seems that Sri Lanka is destined to have a prolonged recovery extending up to 2025. In this background, proper economic policies must be adopted to rescue the country's economy which has already fallen to a deep crevice.

Sri Lanka's economy had been ailing from around 2013 mainly due to the unaddressed structural issues. When Sri Lanka's peers have moved from simple technology to high technology, Sri Lanka has continued to produce adhering to the same old production techniques. As a result, Sri Lanka's high-tech products in its manufactured exports have remained at around 1% whereas its peers have increased this ratio significantly over the last decade. This factor along with the need for beating the middle-income trap has commanded Sri Lanka to change its product mix to include a higher proportion of high-tech products. This is a sine qua non for the country to embrace the fourth industrial revolution or Industry 4.0. Since Sri Lanka is still in the second industrial revolution or Industry 2.0, it is necessary for the country to leapfrog to Industry 4.0 bypassing Industry 3.0.

There are five steps which Sri Lanka should follow in its drive toward a high-tech nation. They are introducing a road map, joining the global production sharing network, acquiring technology via FDIs, increasing Sri Lanka's R&D expenses, and overhauling education system to proliferate science, technology, engineering, creative art, and mathematics. These five steps should receive top priority in the country's economic policy making.

REFERENCES

Athukorala, P., Talgaswatta, T. & Majeed, O. (2016). Global Production Sharing: Exploring Australia's Competitive Edge, Working Papers in Trade and Development, Australian National University.

Central Bank of Sri Lanka (CBSL). (2020). Annual Report for 2019, Colombo .

Central Bank of Sri Lanka (CBSL). (2021). Annual Report for 2020, Colombo.

Das, G. (2002) India Unbound, Penguin Books.

Deaton, A. (2021). COVID-19 and Global Income Inequality, NBER Working Paper, 28392

Gill, I. & Kharas, H. (2007). An East Asian Renaissance: Ideas for Economic Growth, The World Bank, Washington DC.

GOSL. (1952). Economic Development of Ceylon, World Bank Mission, Colombo.

GOSL. (2016). Vision 2025, Colombo.

GOSL. (2021). Budget Speech, (Available at: https://www.treasury.gov.lk/documents/budget/2021/budget_speech_en.pdf) (Accessed on 21.5.2021).

Institute of Policy Studies (IPS). (2019). Sri Lanka: State of the Economy: Transforming Sri Lanka's Economy in the Fourth Industrial Revolution(4IR), Colombo.

McKinsey and Company (2018). Is Apparel Industry Coming Home? (Available at: https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/is%20apparel%20manufacturing%20coming%20home/is-apparel-manufacturing-coming-home_vf.pdf) (Accessed on 30.5.2021).

Pierer, V.H. (2002). "Asia-A Region Oriented Toward 21st Century", in Richter, Frank-Jurgen and Mar, Pamilia CM, (eds), Recreating Asia:

A Vision for a New Century, John Wiley and Sons, Singapore.

Schumpeter, J. (1942). Capitalism, Socialism, and Democracy. New York: Harper & Bros.

Schwab, K. (2017). The Fourth Industrial Revolution, Penguin Books.

Welch, J. (2003). Straight From the Gut, Headline Publishers, London.

Wijewardena, W.A. (2018). "Rohan Pallewatta: Man Who Has Proved that Sri Lanka can also Do" at: https://www.colombotelegraph.com/index.php/rohan-pallewatta-man-who-has-proved-that-sri-lanka-can-also-do/ (Accessed on 21.5.2021).

Wijewardena, W.A. (2019). "Industry 4.0, Disruptive Technology and MAS Matrix: An Example for Way Forward for Sri Lanka", at https://www.colombotelegraph.com/index.php/industry-4-0-disruptive-technology-mas-matrix-an-example-for-way-forward-in-sri-lanka/ (Accessed on 21.5.2021).

Wijewardena, W.A. (2020) "Sri Lanka's Descent into Lower Middle-Income: Strategise to Move Up To High-Income Level, Daily FT (available at: http://www.ft.lk/columns/SL-s-descent-to-lower-middle-income-Strategise-to-move-up-to-high-income-level/4-702627) (Accessed on 20.5.2021).

Wijewardena, W.A. (2021) "Technology and Sri Lanka's Future", in Daily FT (Available at: http://www.ft.lk/columns/Technology-and-Sri-Lanka-s-future/4-710723) (Accessed on 21.05.2021).

World Bank. (2021) Sri Lanka Development Update 2021, Washington DC.

Adjusting to COVID-19: Sri Lanka's macroeconomic policy levers and impacts‡

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ABSTRACT

The global economic fallout of the coronavirus (COVID-19) pandemic is anticipated to be far worse than anything experienced in recent history. From a range of possible outcomes, developing economies will fare far worse, with greater exposure to contractions in world trade, declines in commodity prices, loss of foreign capital inflows, etc. In fashioning appropriate macroeconomic policy responses, they will also be more thinly stretched to provide adequate resources to safeguard public health, precarious jobs and limited social security cover. Amongst developing countries, those with higher initial public debt levels need to be particularly concerned. Despite a commendable health policy response, Sri Lanka is one such country, facing the COVID-19 economic fallout with a public debt ratio of near 90% of GDP and foreign debt settlements averaging USD 4 billion in the next few years.

However, given the necessity of doing everything possible to avert a sharp economic contraction, the tolerance levels for fiscal laxity and monetary easing are much higher. Sri Lanka has leaned heavily on monetary policy interventions, including direct financing of government spending and yield curve control measures to keep borrowing costs down. The paper argues that these measures, together with renewed post-election confidence, makes possible some attractive short-term numbers for the Sri Lankan economy in the form of a V-shaped recovery. The resilience and sustainability of that recovery process, however, will depend on efforts to set a robust fiscal and debt sustainability path to help by-pass medium-term risks. Otherwise, the recovery would l be fragile, leaving the economy vulnerable to similar shocks in the future.

Key words: COVID-19, Fiscal policy, Macroeconomics, Monetary policy, Sri Lanka

1. INTRODUCTION

The global economic fallout of the coronavirus (COVID-19) is anticipated to be far worse than anything experienced in recent history. From a range of possible outcomes, developing economies will fare far worse, with greater exposure to contractions in world trade, declines in commodity prices, loss of foreign capital inflows, and increased public debt burdens. In fashioning appropriate macroeconomic policy responses, they will also be more thinly stretched to provide adequate resources to safeguard public health, precarious jobs and limited social security cover.

Amongst developing countries, those with higher initial public debt levels, especially those carrying sizeable shares of public debt denominated in foreign currency, need to be

‡ **Invited Paper**

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particularly concerned about the economic fallout. Despite a commendable health policy response during the initial outbreak of COVID-19, Sri Lanka is one such country; from a ranking of emerging economies at most peril, Sri Lanka came in at a low 61 out of 66 on the basis of its public debt, foreign debt, cost of borrowing, and reserve cover. At end 2019, a growth slowdown to an 18 year low of 2.3%, a high fiscal deficit of 6.8% of GDP and a public debt ratio of 87% of GDP, and medium-term foreign debt settlements averaging USD 4 billion were notable weak initial conditions.

However, given the necessity of robust policy responses to avert a sharp economic contraction, the tolerance levels for fiscal laxity and monetary easing will have to be much higher (Baldwin and Weder di Mauro, 2020). This means a carefully coordinated use of policy levers and tools to stimulate demand and combat the immediate deflationary shock without inflationary expectations taking hold. This paper discusses these macroeconomic dimensions, examining the shifts in economic paradigms and related policy levers to deal with external shocks, Sri Lanka's fiscal and monetary policy responses to date, and the impacts of these on currency shocks and debt sustainability. The paper concludes with a policy options to set a robust fiscal and debt sustainability path to help by-pass risks, and mitigate the disruptive effects of the COVID-19 pandemic without major run long costs for the Sri Lankan economy.

2. ECONOMY-WIDE IMPACTS

COVID-19 has loopback effects on both aggregate supply and aggregate demand (Boissay and Rungcharoenkitkul, 2020). The early phase emerged in the form of a supply shock from disruptions to global supply chains and labour markets. Soon, demand-side impacts began to be felt as uncertainties related to income and job losses fed into increases in precautionary savings by households, and dampened spending. These demand-side impacts in turn feed into depleting firms' cash flows and liquidity, reinforcing the supply-side shock. Bankruptcies and loss of employment drag down consumption further, and lead to a further lowering of aggregate demand in the economy.

In this feedback loop, the demand side impact is expected to be much larger than the supply side impact. In such circumstances, fiscal policy responses are optimal. Relative to fiscal policy, the pass-through of monetary policy measures occurs with a longer time lag. However, given the scale of the economic fallout, an array of fiscal and monetary policy tools is being deployed, blurring the lines between the two as macroeconomic policies undergo a discernible paradigm shift.

Even before COVID-19, a shift in macroeconomic policy orientation was apparent, especially in response to the 2008 global financial crisis (GFC). While substantive monetary stimulus related to unconventional monetary policy tools like quantitative easing saw GDP growth and employment pick up gradually over time in advanced economies, monetary policy began to be less effective in dealing with the problem of demand generation. Inflation and interest rates remained stubbornly low even as new money was pumped in. In effect, the typical relationship between unemployment and inflation depicted by the Phillips Curve is found not to hold true in many of these countries.[1]

Keynesian-style fiscal policy – resorting to government spending (and indeed a larger role for the state) to stimulate employment began to assert itself more and more to revive aggregate demand. Indeed, large fiscal stimulus efforts were seen as the more obvious solution, and even more so with the onset of the COVID-19 related demand shock. Given spending constraints owing to limited fiscal resources, variations on direct central bank financing of fiscal spending too began to gain renewed attention. Proponents of theories such as new

1 According to the Phillips Curve, if unemployment falls too low, inflation will rise and vice versa, leading to a U-shaped curve. However, that curve is now flattening as many advanced economies experience low unemployment and low inflation.

Modern Monetarist Theory (MMT) – direct financing of budgets without the need to be repaid through higher taxes or spending cuts in the future – see a relegated role for monetary policy. The latter include helping governments to manage their public debt by lowering interest rates, and include radical calls for negative interest rate regimes to stimulate spending and borrowing (Kelton, 2020).

The benefits of issuing international reserve currencies mean that most advanced economies (and China that has USD denominated foreign exchange reserves of over 3 trillion) can practice MMT policies with limited sovereign risk. As issuers of international reserve currencies, their 'monetary sovereignty' allows them the wherewithal to print money. Governments in such economies are able to borrow more cheaply in their own currencies and manage large public debt thresholds. By contrast, large scale money printing in developing economies – where many rely on foreign currency-denominated (predominantly USD denominated) borrowing in international capital markets – will generate substantive currency instability. Additionally, they are hamstrung by more fragile fiscal conditions, whereby the overall impact of financial repressive outcomes in pursuit of reduced domestic borrowing costs, can prove to be more harmful than beneficial in the longer run.

Notwithstanding the above, Sri Lanka has largely pursued a policy of direct financing of fiscal expenditures and 'yield control' measures to lower interest rates with the CBSL introducing a pre-set yield ceiling on government securities, in a lopsided combination that is heavily reliant on monetary policy interventions to mitigate the COVID-19 related economic fallout.

3. COVID-19 AND SRI LANKA'S ECONOMIC POLICY RESPONSES

Sri Lanka had to face the COVID-19 economic shock with very weak initial macroeconomic conditions. Concerns about a deteriorating fiscal outlook – at end 2019, a fiscal deficit already at 6.8% of GDP, public debt at a high 87% of GDP and hefty foreign debt settlements averaging USD 4 billion each year up to 2025 – became more pronounced in the wake of a substantive package of tax reductions following presidential elections in November 2019. The tax cuts were contrary to the country's on-going Extended Fund Facility (EFF) programme with the International Monetary Fund (IMF) in place since 2016. Higher taxes under a revenue enhancing fiscal consolidation process were deemed in part to be responsible for Sri Lanka's lacklustre growth. The tax cuts, meant to revive growth, were nonetheless estimated to trim about 20-25% off government revenues in a pre-COVID-19 scenario.

In these fiscally strained circumstances, the COVID-19 related direct fiscal measures by necessity were very limited. Indeed, fiscal estimates for 2020 and 2021 presented in the Budget Speech in November 2020, appears to suggest plans for only a small nominal increase in recurrent spending in 2020 (Figure 1a). By contrast, emerging markets on average had spent as much as 3-4% of GDP on COVID-19 related mitigation and stimulus efforts as of mid-2020 (IMF, 2020). Much Sri Lanka's focus on the fiscal side was to facilitate additional

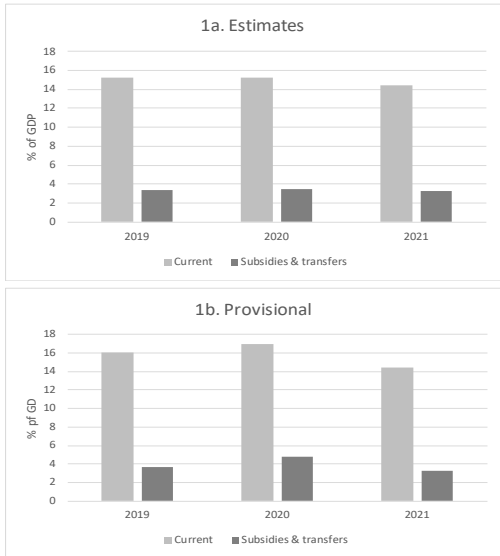

Figure 1. Recurrent Fiscal Spending

Source: Central Bank of Sri Lanka, Annual Report 2019 and 2020; and Ministry of Finance, Budget Speech 2021 (estimates).

health spending, offer tax deferments and exemptions, seek settlement of outstanding government payments to cash hit sectors, impose price ceilings on essential goods, and implement a cash transfer to deserving households.

Provisional estimates of the actual spending outcomes suggest that COVID-19 related expenses were much higher than anticipated (Figures 1b). Subsidies and transfers were higher by one percentage point of GDP in 2020 relative to 2019, based on which Budget 2021 estimates to deal with the protracted pandemic appear to be underestimates.

Without much room on the fiscal front to provide a substantial stimulus, Sri Lanka's macroeconomic measures have continued to rely heavily on monetary policy instruments. The initial conditions on the monetary front were supportive of the subsequent COVID-19 related policy measures. Persistent low growth in a single-digit stable inflationary environment and the need to assist businesses hit by the Easter Sunday terror attacks of April 2019 had already prompted an easing of monetary policy, including interest rate caps. In the wake of COVID-19, sharp cuts to policy interest rates and statutory reserve requirements (SRR) of commercial banks, debt moratoriums and refinance schemes, and monetary financing of fiscal expenditures were initiated as key measures.

As expected in view of the fiscal constraints, direct financing of fiscal spending by the CBSL increased sharply, as evidenced by the significant rise in its Treasury bill holdings (Figure 2a). The CBSL also introduced a pre-set yield ceiling on government securities to nudge interest rates down to lower government borrowing costs and help the government to better manage its interest payments on debt. Additionally, given that the pass-through of monetary policy measures typically occurs with a lag effect, the CBSL has also been at pains to exert moral suasion on financial institutions to pass on interest rate reductions and debt moratoriums to affected businesses and households. Overall, with these measures,

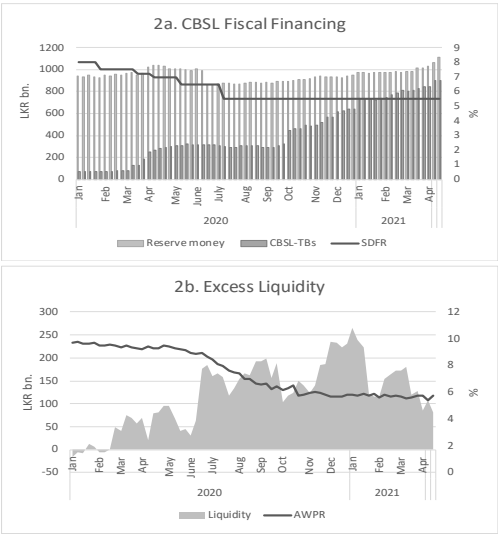

Figure 2. Monetary Policy Interventions

Notes: SLFR = Standing lending facility rate; AWPR = Average weighted prime lending rate.
Source: Compiled from data available from the Central Bank of Sri Lanka.

the Sri Lankan economy has been flush with excess liquidity for much of 2020, with a notable decline in bank lending rates (Figure 2b).

Given the nature of the COVID-19 deflationary shock, dampening consumption and investment demand as households and businesses face unprecedented levels of uncertainty, private sector credit growth has been slow to materialize (Figure 3). The key beneficiary of the low interest rate environment has been the government, with fiscal spending related borrowing rising sharply over the months. By end 2020, while credit growth to the private sector stood at a low 6.5%, it was a very high 55% to the government (Figure 3a).

With such large magnitudes of central bank financed spending – manifesting in excess liquidity and plummeting interest rates – there are concerns related to possible medium-term inflationary consequences. However, there can be sizeable demand destruction related to the COVID-19 economic insecurity. A typical household will practice consumption-smoothening behaviour of saving more and spending less. Thus, despite abundant liquidity and low interest rates, the COVID-19 fallout will

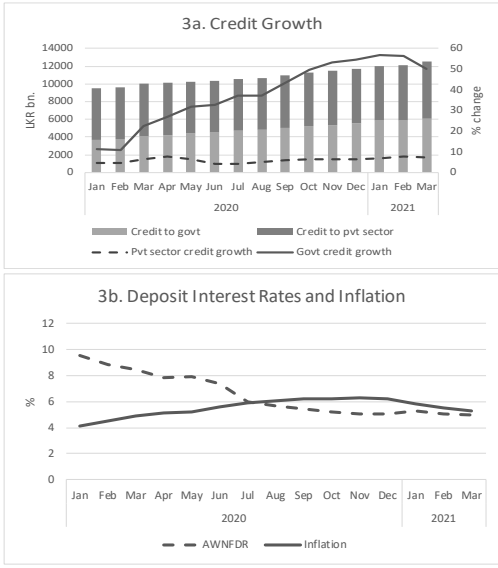

Figure 3. Monetary Policy Outcomes

Notes: AWNFDR = Average weighted new fixed deposit rates.
Source: Compiled from data available from the Central Bank of Sri Lanka and Department of Census and Statistics.

lead to an initial deflationary process. Beyond the short term though, there is a very real possibility that aggregate demand growth in the Sri Lankan economy will outpace the increases in aggregate supply, in an environment of more money chasing fewer goods and services. As of December 2020, money supply growth was at a relatively high 23.47%, up sharply from the 8.3% at the beginning of the year. Therefore, though the impact of stimulus measures in the early phases may help to combat deflationary conditions, the possibility of a build-up of inflationary pressures in the medium term is very real.

If inflation pressures pick up to erode the real value of their incomes, it will also hurt a large majority of Sri Lankan households that depend on fixed incomes. Already low deposit interest rates coupled with a higher rate of inflation indicate negative real returns on deposits for savers (Figure 3b). An environment of negative real interest rates and high liquidity can also drive investors and savers to search out higher returns in often riskier assets, as evidenced by the sudden spike in the Colombo Stock Exchange (CSE) driven by bullish sentiments (Bloomberg, 2021). The resultant asset bubbles generate bouts of market instability and boom-bust cycles that undermine sustained medium term economic expansion. Ultimately too, if inflationary pressures are allowed to build, the ultimate loser will be the government through costlier borrowing when interest rates have to be forced up.

4. SOCIO-ECONOMIC IMPACTS OF COVID-19

As expected, despite the fiscal and monetary stimulus, the fallout of the COVID-19 impacts on trade and investment more generally, and tourism in particular has been substantial. (Table 1). Worker remittances is an important outlier. After an initial contraction in inflows as migrants in host countries struggled to access their normal remittance channels, inflows picked up gradually. The latter is likely owing to more remittances being sent to families back home as a typical coping mechanism and termination of overseas employment that compelled migrant workers to remit their accumulated savings.

Amidst the economic fallout, the Sri Lankan economy shrank by 16.3% in the second quarter of 2020 before rebounding with positive growth in the third and fourth quarters to report a better-than-expected annual growth contraction of -3.6% (Figure 4a). The emergence of a much larger spread of infections from the fourth quarter of 2020 has seen a downward revision to Sri Lanka's growth forecast for 2021 to 4% by the IMF as of April 2021, as compared to a forecast of 5.3% in October 2020 (IMF, 2021).

Table 1. Foreign Exchange Earnings

	USD mn.			% Change		
	2018	**2019**	**2020**	**2018**	**2019**	**2020**
Exports	11,890	11,940	10,077	4.7	0.4	-15.6
Garments	4,960	5,205	3,939	4.7	4.9	-24.3
Tea	1,428	1,346	1,240	-6.6	5.7	-7.8
Remittances	7,015	6,717	7,104	-2.1	-4.3	5.8
Tourism	4,381	3,607	957	11.6	-18.0	-73.5

Sources: Central Bank of Sri Lanka, External Sector Performance, various issues.

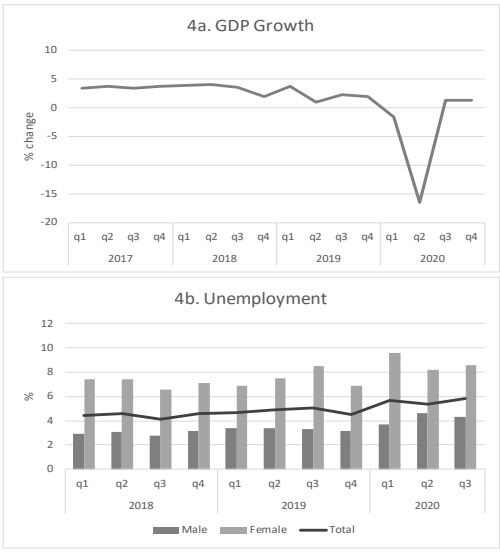

Figure 4. Impacts on GDP and Employment

Source: Department of Census and Statistics, Colombo.

The economic disruptions are felt most acutely in the labour market: the unemployment rate has remained above 5.5% for much of 2020, well above the range of 4.0-4.5% maintained in the two pre-crisis years (Figure 4b). Sri Lanka's high levels of labour market informality heightens the associated vulnerabilities. Total informal employment in Sri Lanka is estimated at around 68% (5.5 million workers), which includes 2.4 million self-employed people, 1.5 million temporary/ casual employees and 0.7 million employees who do not have a permanent employer (Jayawardena, 2020). These workers have little or no job security, and access to social safety nets. There is evidence that 88% of the country's temporary workers are not covered by either a pension scheme or the Employees' Provident Fund (EPF) with only 29% of Sri Lanka's workforce covered by social protection (Jayawardena, 2020).

These large numbers of vulnerable workers tend to depend overwhelmingly on government assistance as coping mechanisms during shocks such as COVID-19. According to the Household Income and Expenditure Surveys (HIESs) conducted by the Department of Census and Statistics (DCS), income poverty in Sri Lanka is estimated to have reduced to 4.1% (840,000 poor people) in 2016, from 6.7% in 2012/13. However, a mere 20% increase in the poverty line is estimated to increase the number of poor to over 1.8 million, indicative of a considerable number of vulnerable people just above the poverty line (Tilakaratna, 2020).

Thus, despite policy measures such as the provision of a monthly allowance of LKR 5,000 for two months to vulnerable households, the disruptions to livelihoods and lost income are likely to sharpen existing poverty and inequity outcomes in Sri Lanka. Indeed, a real concern is that in the recovery phase, such inequities may in fact widen further. As technology-enabled solutions gain momentum, the fact that only a fifth of households (23%) own either a desktop or a laptop computer and only 30.3% of the population use internet are some pointers. In such an environment, not only is access to education via e-learning platforms inequitable, but the same too applies for such practices as work-from-home opportunities (Arunatilake, 2020).

Redressing these gaps, whilst aiming for sustained long term growth, requires financial resources for targeted spending on social sectors such as health, education and social protection. The mounting demands on public spending, however, come up in the context of growing macroeconomic imbalances that threaten to destabilise Sri Lanka's nascent COVID-19 related economic recovery.

5. MACROECONOMIC IMBALANCES AND RISKS TO A ROBUST RECOVERY

As previously mentioned, with an elevated level of public debt, Sri Lanka did poorly in financial stress rankings as the scale of the COVID-19 crisis began to be felt. The most pressing concern was the risk profile of its public foreign debt (at 43% of GDP), with a heavy exposure to costly forms of foreign currency debt. Commercial and non-concessional borrowings accounted for 57% of Sri Lanka's public foreign debt, with international sovereign bonds (ISBs) alone accounting for 43% (or 18% of GDP) (CBSL, 2020).

This high cost, high risk foreign debt profile entails a foreign debt service burden averaging USD 4 billion per annum in the medium term. With the onset of COVID-19, not only did the key foreign currency earning sectors like exports, tourism and remittances see shortfalls, but critically, the Sri Lankan economy was left heavily exposed to global capital market shocks. Most forms of foreign capital sourced dried up, including foreign direct investment (FDI) and long-term loans to the government (Table 2). With a historical external current account deficit, and inadequate foreign currency reserves, Sri Lanka is largely reliant on access to international capital markets at any given time, to rollover maturing debt. However, as COVID-19 struck, access to international capital markets became hugely costly with a series of sovereign credit rating downgrades as macroeconomic imbalances widened,[2] resulting in Sri Lanka's ISB yields in the secondary market rising markedly (Figure 5a). Additionally, as evident from Table 2, Sri Lanka also experienced a net outflow of foreign investors from government securities totaling USD 553 million and from the Colombo Stock Exchange (CSE) to the tune of USD 225 million in 2020 as foreign investors pulled out of riskier emerging market economies.

Table 2. Capital Flows and Reserve Adequacy, USD mn

	2018	2019	2020
Gross capital flows			
FDI	1,614	743	434
Govt securities	706	596	120
Long-term loans	2,328	1,573	1,882
International sovereign bonds (ISBs)	2,500	4,400	-
Net capital flows			
Govt securities	-990	-334	-553
Colombo Stock Exchange	-55	-35	-225
Reserve adequacy			
Debt service payments	5,866	5,757	4,382
Gross official reserves	6,919	7,642	5,664

Sources: Central Bank of Sri Lanka, Annual Report 2020 and External Sector Performance, various issues.

2 In April 2020, Fitch downgraded the credit rating from B to B- and followed with a further downgrade to CCC in November. Standard & Poor's (S&P) downgrading long-term sovereign credit rating to B- from B in May 2020, with a further downgrade to CCC+ in December. Moody's downgraded Sri Lanka's B2 rating to Caa1 in September 2020.

Such foreign exchange constraints in the normal course can be expected to exert depreciating pressure on the Sri Lankan rupee. The situation, however, is exacerbated by the expanding monetary base on the back of a strong monetary stimulus. For Sri Lanka, the most common transmission channel is a spillover of excess liquidity into higher demand for consumer goods imports that in turn impacts the exchange rate of the rupee swiftly, owing to a thin forex market. To overcome this, 'temporary' restrictions have been imposed on 'non-essential' imports and curbs on capital outflows, signaling a broader shift in economic policy direction towards the adoption of a more inward policy stance, supportive of domestic production. Notwithstanding these restrictions and CBSL intervention in the foreign exchange market to maintain the exchange rate at a predetermined rate, the rupee has depreciated against the USD by nearly 10% from January 2020 to March 2021 (Figure 5b). With a large stock of foreign currency denominated debt in hand, a depreciating currency has an immediate impact on debt servicing costs. Foreign currency market intervention to stabilize the rupee with limited official reserves in hand, however, elevates the risks of macroeconomic instability.

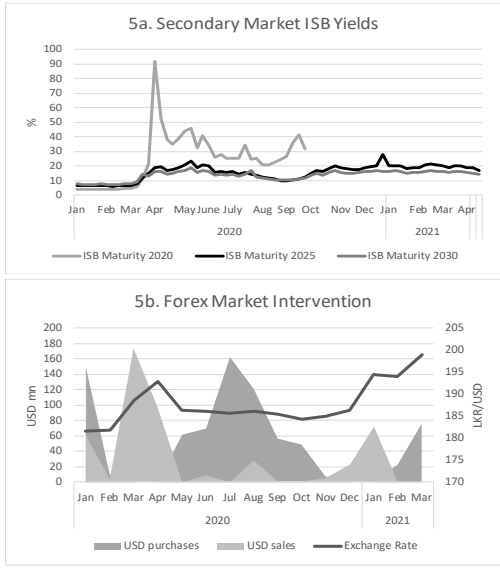

Figure 5. Foreign Exchange Market Trends

Source: Data available from the Central Bank of Sri Lanka.

By March 2021, Sri Lanka had official foreign currency reserves of only USD 4 billion, sufficient for about 3.1 months of import cover (Figure 6a). A general rule of thumb threshold sets the floor ceiling at three months of import cover, below which an economy is considered to be facing an imminent balance of payments (BOP) crisis. With sizeable foreign debt service payments due from 2019 onwards, with no letup in the medium term, debt sustainability remains a critical area of macroeconomic concern (Figure 6b).

Bilateral swap arrangements have allowed some leeway in managing repayments. A USD 500 million loan top us from the China Development Bank in March 2020 followed by a USD 400 million swap arrangement with the Reserve Bank of India (RBI) entered into in July 2020, and an overnight Repurchase (Repo) facility with the US Federal Reserve entered into in July 2020 to ease dollar liquidity by pledging USD 1 billion of reserves were some of the key initiatives. Additionally, a yuan currency swap of USD 1.5 billion was entered into with China in March 2021. Amidst these, Sri Lanka's request in April 2020 to the International Monetary Fund (IMF) under its Rapid Financing Instrument (RFI) window was pushed down the order of priority owing to the government's reluctance to enter into any conditionalities related to medium term fiscal consolidation strategies (Table 3).

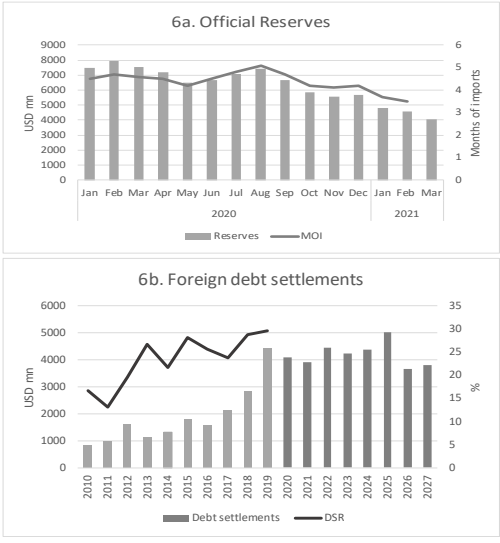

Figure 6. Reserves Cover and Debt Settlements

Notes: MOI = Months of imports; DSR = Debt service ratio (debt service as share of exports of goods and services).
Source: Data available from the Central Bank of Sri Lanka and Department of External Resources, Performance Report (various years).

Budgetary estimates presented in October 2020 for 2021 indicated continuing stresses on the government's fiscal position, with revenues estimated to decline to a low of 11.4% of GDP, with an overall deficit close to 9% of GDP. In reality, fiscal estimates for 2020 have proven to be significantly off the mark. Provisional data indicate that Sri Lanka's fiscal deficit has shot up to -11.1% of GDP with public debt standing at 101% of GDP (CBSL, 2021).[3]

Despite growing concerns on the country's weakening fiscal context without a clear exit strategy from direct financing of fiscal expenditures by the monetary authorities, and its related debt sustainability path, Sri Lanka is nonetheless expected to meet all its ISBs settlements in 2021. However, continuing pressure on the external front from future debt settlements will continue and will require urgent policy attention if the country is to regain better sovereign credit ratings and renew investor confidence on its economic outlook.

Table 3. Fiscal Estimates and Outcomes (as % of GDP)

	2020[a]	2020[b]	2021[a]
Total revenue	9.9	9.1	11.4
Tax revenue	8.5	8.1	9.8
Recurrent expenditures	15.3	17.0	14.4
Public investment	2.6	5.4	6.1
Overall fiscal deficit	-7.9	-11.1	-8.9
Foreign financing	-1.4	-0.6	0.6
Domestic financing	9.3	11.7	8.3

Notes: a: Estimates; b: Provisional outcome.
Source: Ministry of Finance, Budget Speech 2021. Colombo: Ministry of Finance.

3 The fiscal sector statistics of 2019 were restated to recognise expense arrears incurred in 2020 to 2019. If not for the restatement, the fiscal deficit for 2020 would have been 13.9% of GDP (see CBSL, 2021).

6. CONCLUSION AND POLICY RECOMMENDATIONS

For Sri Lanka, a COVID-19 economic recovery strategy is based on tax cuts meant to encourage spending and investment, to boost growth. Low interest rate policies are helping to maintain demand and keep government borrowing costs down. The government hopes that these, together with renewed post-election confidence, may make possible some attractive short-term numbers for the Sri Lankan economy in the form of a V-shaped recovery in 2021. Indeed, as of April 2021, the CBSL forecasts a growth rate of 6% for the year (CBSL, 2021).

Beyond the immediate recovery though, continued reliance on the current expansionary strategies will mean larger fiscal deficits, adding to already high public debt levels. Monetary expansion will inevitably exert pressure on the currency as already seen, requiring ever more stringent restrictions on imports and/or capital flows. Mandated requirements for banks to surrender 10% of all remittances inflows and exporters to convert 25% of earnings were introduced as interim measures, along with a string of swap agreements to meet foreign currency pressures. But, these offer only short term solutions to Sri Lanka's fiscal weaknesses and debt sustainability concerns.

For now, the government appears to be relying on attracting larger inflows of FDI to help stem external sector pressures and kick-off large infrastructure projects that will deliver growth. Indeed, one of its central initiatives, the Colombo Port City, is due to be granted significant tax concessions to attract projects. A key concern, however, is that despite a recovery in FDI inflows, such investments are likely to be channeled into less desirable non-tradable sectors such as real estate, mixed development projects and infrastructure, without laying the foundation for a strong export based economic recovery. As happened during the immediate post-war years, an infrastructure splurge can deliver growth, but the boom can also be short lived. More importantly, such non-tradable sector driven growth could worsen the anti-export bias in the overall incentive structure of the economy. For a debt sustainable, resilient recovery, Sri Lanka has to incentivize productive sectors that will earn foreign exchange for the country.

But, this requires that some hard policy choices be made. The policy dilemma for Sri Lanka at present, is acute. Any immediate upward tax adjustments in pursuit of bolstering government revenues or cuts to government expenditures to place macroeconomic fundamentals on a more robust path can squeeze growth. However, in the medium term, there is little option but to work towards a framework for public finances that is more resilient to future shocks.

This is because, historically, the Sri Lankan economy has fundamental imbalances that produce persistent fiscal and current account deficits (Weerakoon et al, 2019). It means very simply that a) national expenditure exceeds national income; and b) production of tradeable goods and services is inadequate. So long as foreigners are willing to finance the deficit, the imbalances are manageable. However, if there is a change of sentiment and a discontinuation of such flows, as happened amidst the COVID-19 shock, the economy is highly vulnerable.

A current account deficit can be addressed by either cutting national expenditure or raising income. The latter cannot be increased sufficiently in the short term as GDP growth typically increases expenditures, and productivity improvements take time. Alternatively, governments can attempt to switch resources to produce more tradeable goods and services. This calls for a currency depreciation.

However, a nominal depreciation alone is insufficient; expenditures (consumption or investment) must also be reduced to keep domestic cost increases at bay and ensure that a real depreciation of the currency takes place. Therefore, the government and/or private sector (firms and households) will have to curtail spending. Here, the response of

monetary authorities will also be critical to the question of who bears the cost of adjustment. If the rupee is not allowed to float freely, then interest rates may become the instrument to get the required cuts. Higher interest rates can attract foreign inflows (or discourage outflows); but it also increases the cost of credit to firms and households, and thereby reduces domestic expenditures. Indeed, Sri Lanka is seeing its interest rates beginning to nudge upwards, despite the best efforts of the monetary authorities to keep rates low.

Given Sri Lanka's high exposure to international investor sentiments, unwieldy fiscal and monetary policies will not help restore investor confidence on the resilience of Sri Lanka's medium-term economic outlook. Sri Lanka's prospects to mitigate the disruptive effects of the COVID-19 pandemic without major run long costs for the economy depends crucially on policy responses to synchronise monetary and exchange rate regimes, and mapping a robust fiscal and debt sustainability path.

REFERENCES

Arunatilake, N. (2020). COVID-19 and Beyond: Minimising the Costs of Pandemics. In Sri Lanka: State of the Economy 2020. Colombo: Institute of Policy Studies of Sri Lanka.

Baldwin, R. & Weder di Mauro B. (2020). Mitigating the COVID Economic Crisis: Act Fast and Do Whatever It Takes. London: CEPR Press.

Bloomberg (2021). 'The World's Best Stock Rally is in Sri Lanka'. Accessed at https://www.bloomberg.com/news/articles/2021-01-27/retail-army-helps-sri-lanka-stocks-skyrocket-to-world-s-best

Boissay, F. & Rungcharoenkitkul P. (2020). Macroeconomic Effects of COVID-10: An Early Review. BIS Bulletin No. 7. Bank for International Settlements.

Central Bank of Sri Lanka (2021). Annual Report 2020. Colombo: Central Bank of Sri Lanka.

Central Bank of Sri Lanka (2020). Annual Report 2019. Colombo: Central Bank of Sri Lanka.

International Monetary Fund (2021). World Economic Outlook. Washington, D.C.: International Monetary Fund.

International Monetary Fund (2020). Courage under Fire: Policy Responses in Emerging Market and Developing Economies to the COVID-19 Pandemic. Washington D.C.: International Monetary Fund.

Jayawardena, P. (2020). COVID-19 and the World of Work. In Sri Lanka: State of the Economy 2020. Colombo: Institute of Policy Studies of Sri Lanka.

Kelton, S. (2020). The Deficit Myth. New York: John Murray.

Tilakaratna, G. (2020). Harnessing Social Protection to Address Poverty and Vulnerability during Pandemics. In Sri Lanka: State of the Economy 2020. Colombo: Institute of Policy Studies of Sri Lanka.

Weerakoon, D., Kumar, U. and Dime, R. (2019). Sri Lanka's Macroeconomic Challenges: A Tale of Two Deficits. South Asia Working Paper Series No. 63. Manila: Asian Development Bank.

Rethinking Sri Lanka's industrialisation strategy: Achievements, lost opportunities and prospects

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ABSTRACT

The purpose of this paper is to contribute to the contemporary policy debate in Sri Lanka on industrialization strategy by analysing policy regime shifts and their outcome in terms of export performance, growth and employment during the post-independence era. The analysis is guided by the received body of knowledge relating to the challenges faced by a small economy that takes world prices as given and is unable to affect world demand and supply in designing national industrialisation strategy in this era of economic globalization. The findings demonstrates that the backlash against liberalization reforms in the contemporary Sri Lankan policy debate is largely based on ideological predilections rather factual analysis. Sri Lanka's dismal experience under import substitution strategy in the 1960s and 1970s makes a strong case for seriously rethinking the recent policy emphasis on combining selective import substitution with export orientation. The achievements of liberalization reforms are all the more remarkable when we allow for the fact the proposed reform package was not fully implemented and that the country failed to capture the full benefits of reforms undertaken because of the protracted civil war that damaged the investment climate and undermined macroeconomic stability. The comparative analysis of Sri Lanka's industrialization experience during the state-led import-substitution era and that of the post-reform era (in particular during the first two decades) makes a strong case for reconsidering the merit of the emerging emphasis on combining import substitution with export orientation with a sector specific focus. Selective policies to promote import substitution essentially impose a 'tax' on export producers.

Key words: Industrialization, Trade policy, Foreign direct investment, Economic globalisation

1. INTRODUCTION

The history of industrialization strategy in Sri Lanka is characterized by abrupt episodes of substantial changes associated with political regime shifts without settling to a stable path required for self-sustained growth. During the first decade after independence in 1948, development of industry was not a policy priority in Sri Lanka, unlike in many other newly independent nations. From about the late 1950s, a combination of the influence of the development thinking at the time and growing balance-of-payments problems induced a policy shift towards state-led import-substitution industrialization. In 1977 Sri Lanka embarked on an extensive economic liberalization reforms process that marked a

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I have drawn on my joint research-in-progress with Aneetha Warusavitarana (Advocata Institute, Colombo) in writing the case study of the 'mini electronics boom' in Section 3 of the paper. I am grateful to Aneetha for excellent research collaboration.

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decisive break with a two decades of state-led import-substitution industrialization strategy.

By the mid-1990s, Sri Lanka ranked amongst the few developing countries that had made a significant policy transition from inward orientation to global economic integration. However, over the past two decades, the merits of industrialization under liberalization reforms have become a hotly debated issue in the Sri Lankan policy circles. The anti-liberalization lobby has begun to portray the failure of reforms to elevate the country to the league of dynamic East Asian economies as an intrinsic flaw of liberalisation reforms, while downplaying (or overlooking) the constraining effects on the reform outcome of the incomplete and staggered nature of the reform process and prolonged civil war. The policy pendulum has therefore begun to shift in favour of combining import substitution with export orientation while 'guiding the markets' by the state. The massive disruption in world trade caused by the Covid-19 pandemic has further strengthened the case for emphasis on economic self-reliance in determining national development priorities.

The paper aims to contribute to the contemporary policy debate in the country on the need for and modalities of redesigning the country's industrialization strategy by analyzing changes and continuities in Sri Lanka's industrialization strategy during the post-independence era. The analysis is guided by the received body of knowledge relating to the challenges faced by a small economy that takes world prices as given and is unable to affect world demand and supply. The paper specifically focusses on factors behind shifts in industrialization strategy away from and towards global economic integration and the outcomes with respect to export performance, growth and employment generation, while paying attention to rapidly changing global context in this era of economic globalization.

The paper begins with an overview of changes and continuities in Sri Lanka's industrialization strategy during the post-independence era. This is followed by a comparative analysis of Sri Lanka's experience under import substation and export-oriented industrialization strategies, with emphasis on fundamental sources of discontent in the Sri Lankan policy circles with export-oriented industrialization strategy. The final sections summarizes the key findings and their implications for the contemporary policy debate in Sri Lanka.

2. A BRIEF POLICY HISTORY

During the first decade after independence in 1948, Sri Lanka maintained an open-market economy, with a liberal trade and foreign direct investment (FDI) policy regime. Unlike in many other newly independent countries, the development of manufacturing was not a policy priority. The main emphasis of the government's development agenda was reviving domestic food crop agriculture, predominantly rice, mainly based on colonization in the sparsely populated dry zone of the country (Snodgrass, 1966).

A major shift in development strategy towards import substitutional industrialization, with increased government intervention and state monopoly over strategic industries, took place following political regime shift in 1956. At the beginning, the policy shift was consistent with the conventional wisdom of the day in favour of import-substitution industrialization, but from the late 1950s import-restrictions became an integral part of the government response to the worsening external payments situation. The import-substitution rhetoric merely provided an ideological facade that was politically useful as the government was not willing to run the political risk of undertaking structural reforms in response to the balance of payment crisis. Import restrictions, initially imposed to address balance of payment difficulties, became increasingly tight with pervasive state interventions in the economy. The Business Acquisition Bill passed in 1971 allowed the government the takeover of any business enterprise, without providing safeguard against arbitrary takeover. By the mid-1970s, the Sri Lankan economy had become one of the most inward-oriented and

regulated economies in the world outside the Communist Bloc. The activities of the private sector remained caught up in a complicated cobweb of state controls (Cuthbertson & Athukorala, 1990).

Export promotion became a key policy focus as an appendage to the control regime in the late 1960s. In 1966, a bonus voucher scheme for non-traditional exports (broadly defined to encompass all exports other than tea, rubber and coconut products) was introduced. During 1968-70, a foreign exchange entitlement certificate scheme (FEECS), a dual exchange rate system with an exchange rate premium of 40% for non-traditional exporters, was part of a mini-trade liberalization episode. The FEECS premium was raised to 65% and a new convertible rupee account (CRA) scheme was introduced in 1972. A white paper of foreign direct investment issued in 1972 assured export-oriented foreign investors complete security of investment, complete compensation in the event of nationalization, and remittance of profit and repatriation of assets on business closure. However, these policies had little impact on averting the worsening external payments conditions of the country because the overall policy and political context was highly unfavourable to private sector activities in general and to export production in particular. Reflecting the cumulative impact of stringent import controls, high export taxes and the overvalued exchange rate, the overall incentive structure of the economy was characterised by a significant 'anti-export' bias throughout this period. In the early 1970s, there was a proposal in the government circles to set up a free-trade port at Trincomalee, but it was not acceptable to the left wing parties in the coalition government (Fitter, 1974).

By the mid-1970s, the state-led import substitution strategy had made the Sri Lankan economy extremely vulnerable to external shocks. Consumer goods imports had gradually converted into essential imports needed to maintain domestic output. There were no longer any compressible import fat left to cushion the economy against unexpected shortages of foreign exchange (Athukorala, 1981). As noted, the expansion of non-traditional exports had only a marginal cushioning effect against the unsatisfactory performance of traditional exports. There was clear evidence exposing the myth that Sri Lanka could develop in isolation from the forces molding the world economy. The groundswell of dissatisfaction of the populace with the government paved the way for a regime change in 1977.

The new government embarked on an extensive economic liberalization process that marked a decisive break with the two decades of protectionist policies. The first round of reforms carried out during 1977-79 included (a) replacing quantitative import restriction with tariffs that provided lower levels of nominal protection for domestic import-substitution industries; (b) opening the economy to foreign direct investment (FDI), with new incentives for export-oriented FDI under an attractive Free Trade Zone (FTZ) scheme and constitutional guarantee against nationalization of foreign assets; (d) abolition of the multiple exchange rate system followed by a sharp devaluation of the unified exchange rate; (e) the introduction of limits on direct public sector participation in the economy, and (e) a wide ranging export promotion schemes, including a revamped duty rebate scheme for export producers, under a newly established export development board (EDB) (Rajapatirana, 1988, Cuthbertson & Athukorala, 2000).

A 'second wave' liberalization package was implemented during 1990-93. This included abolishing export duties on all plantation products; extension of FTZ privileges to export-oriented firms located outside the EPZs, abolishing import duties on textile in order to help the expansion of the export-oriented garment industry, and significant fiscal consolidation (Dunham and Kelegama 1997). In 1994, Sri Lanka achieved Article VII status of the International Monetary Fund (IMF) after abolishing foreign exchange restrictions on current account transactions, including the foreign exchange surrender requirement on export proceeds.

The liberalisation reforms made a clear departure from the state-led import substitution policy posture. However, the reform process was incomplete in terms of the standard prerequisites for a market-oriented economy (Krueger, 1997). First, while some loss-making public enterprises were either shifted to the private sector or closed down, a number of them continued to operate with heavy dependence on budgetary transfers. Second, a gazetted bill to reform the labour legislation to achieve greater labour market flexibility was abandoned in face of widespread opposition by the trade unions.

Third, the complementarity between macroeconomic management and trade liberalization required for maintaining competitiveness of tradable production in the liberalized economy was missing. The original reform package of 1977 was formulated with emphasis on the complementarity between macroeconomic management and trade liberalization. The dual exchange rate system, which had been in operation since 1968, was abolished and the new unified exchange rate was allowed to adjust in response to foreign exchange market conditions. However, from about 1979 the Central Bank began to deviate gradually from the original plan and to intervene in the foreign exchange market to use the nominal exchange rate as an 'anchor' to contain domestic inflation. The policy emphasis on fiscal prudence, too, was short-lived. The main source of macroeconomic instability was a massive public-sector investment program that included the Mahaweli river basin development scheme, a large public housing program, and an urban development program (Jayasuriya, 2004). The real exchange rate (RER) (the standard measure of international competitiveness of an economy), which significantly depreciated showing improved international competiveness during the first few years following the economic opening, tended to appreciate during the ensuing years. Mild depreciation of the nominal exchange rate under the managed floating system was more than counterbalanced by the rate of increase in domestic prices that was far greater than that of Sri Lanka's trading partners. There was a notable reversal in RER appreciation during the second wave liberalization, but it quickly dissipated (Figure 1).

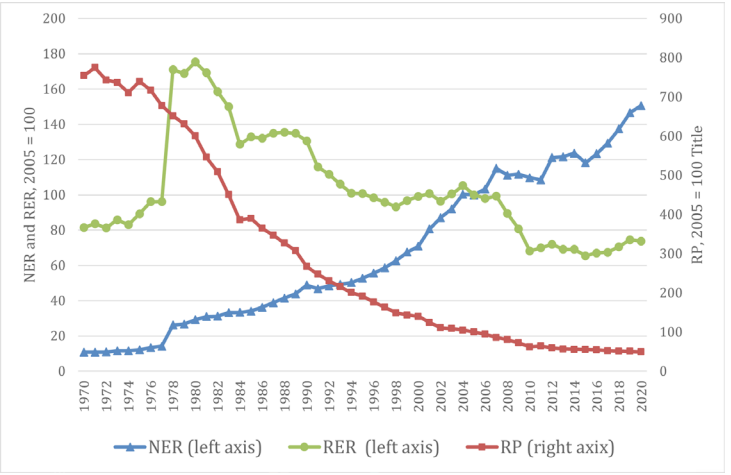

Figure 1. Real Exchange Rate and Its Component[1] (2005 =100), 1970-2020

Note: 1. NER is export-weighted nominal exchange rate (measured as rupees per foreign currency unit) relating to Sri Lanka's top six manufacturing export destination countries (which together account for over 90% of the country's total manufacturing exports). RER is NER adjusted for relative price level of Sri Lanka (measured by the GDP deflator) and the six destination countries (measured by the producer price index). An increase (decrease) in RER shows an improvement (a deterioration) in international competitiveness.

Source: Compiled from data extracted from World Bank, World Development Indicator database and Central bank of Sri Lanka, Annual Report (various years).

Reaping gains from liberalization reforms was also seriously hampered by the escalation of the ethnic conflict from the early 1980s. The conflict virtually cut off the Northern Province and large parts of the Eastern Province (which together account for one-third of Sri Lanka's total land area and almost 12% of the population) from the national economy. Even in the rest of the country, the prospects for attracting foreign investment, particularly in long-term ventures, were seriously hampered by the lingering fear of sporadic attacks by the rebels. The government's preoccupation with the civil war also hampered capturing the full benefits of economic opening through delays and inconsistencies in the implementation of the reform processes.

Despite the incomplete implementation and the debilitating effect of the civil war, the reforms significantly transformed the economic landscape of Sri Lanka (next section). The economic gains from reforms was substantial to make economic liberalization by-patrician policy in the 1990s (Kumaratunga, 1994). However, as early as the late 1990s, the trade liberalization process suffered a setback because of the pressure for raising additional revenue from import tariffs to finance the ballooning war budget. The planned reduction of tariffs into a single band was abandoned and from then on tariffs were adjusted frequently in an ad hoc manner. The protectionist tendencies soon received added impetus from the growing discontent amongst the electorate propelled by the crisis economic conditions as the civil war accelerated.

The backlash against liberalization reforms gained added impetus as the country returned to a state of normalcy at the end of the three-decade old civil war in May 2009 (Athukorala & Jayasuriya, 2015; Pursell & Ahsan, 2011; Kaminski & Ng, 2013). The government begun to emphasize the role of the state in 'guiding the markets' with a view to redressing perceived untoward effects of economic globalization. Privatization of key state enterprises (banking, power, energy, transport, and ports) was explicitly ruled out, while conspicuously avoiding any reference to trade policy reforms (GSL, 2010).

By 2009 the Sri Lankan tariff schedule included nine import taxes in addition to the standard customs duty. Of these nine taxes, five were 'para-tariffs': taxes which are only applied to imports and hence compounded protection provided to domestic production by customs duties. The total nominal protection rate (customs duty + para-tariff) more than doubled (13.4% to 27.9%) between 2004 and 2009 (Pursell & Ahsan, 2011). During the ensuing years, there were also many *ad hoc* duty exceptions and case-by-case adjustment of duties on many manufacturing imports which directly compete with domestic production. By 2015 the average effective rate of protection for manufacturing production had increased from 47% in 2000 to 63%, and production for the domestic market was over 70% more profitable compared to production for exporting (World Bank, 2005; DCS, 2018).

In 2008 the parliament passed a *Strategic Development Projects (SDP) Act*, empowering the minister in charge of the BOI to grant exemptions to 'strategic development projects' from all taxes for a period of up to 25 years. In the Act, a strategic development project meant 'a project which is in the national interest and likely to bring economic and social benefits to the country and which is also likely to change the landscape of the country, primarily through provision of goods and services which will be of benefit to the public, substantial inflow of foreign exchange, substantial employment, and technology transfer' (GSL, 2008). This definition left a great deal of room for the minister's discretion in the investment approval process, thus undermining the role of the BOI. A *Revival of Underperforming Enterprises and Underutilized Assets Act* was passed in November 2011 empowering the government to acquire and manage 37 'underperforming' or 'underutilized' private enterprises. The list included seven enterprises with foreign capital participation. Two major credit rating agencies (the Fitch Group and Moody Corporation) warned that the bill

would erode investor confidence and affect Sri Lanka's investment rating (Goodhand 2012).

The period from 2015 to 2019 was an era of policy inaction. In spite of the promised commitment to outward-oriented development strategy, no attempt was made to redress policy reversals. The government was active in preferential trade liberalization by entering into free trade agreements (FTAs), overlooking the fact that Sri Lanka's lackluster export performance was primarily rooted in unilateral policy reversals and other supply-side impediments. There was also an undue emphasis on achieving 'sophistication of the export composition' within the 'global product space' while ignoring the country's unexploited opportunities for export expansion by specializing in task within global production networks that fit with the country's own comparative advantage advantage (Thompson and Athukorala 2020).

The present government has not so far come up with a definitive industrial development policy. However, according the manifesto issued at the presidential election (*Vistas of Prosperity and Spender*), the envisaged policy choice is a 'mixed-economy' model that combines selective import substitution with export-orientation. In April 2019, the government appointed a Presidential Task Force on Economic Reveal and Poverty Eradication (PTFERPE) to recommend establishing 'a people-centric economy that encourages local industrialists and entrepreneurs, blending new technologies with expansion of import substitution products, local farmer products, agricultural products and other small and medium scale industries to encourage exports and reduce the trade gap by devising measures to diversify the production economy' (GSL, 2020, p. 5A).

The Task Force has come up with a list of potential winning industries, 'pharmaceuticals, rubber products, coconut related products, spices, electronics and electrical components, ship and boat building, food and beverages, cosmetics, toys, machinery and machinery appliances, and ceramic products among others' for selective policy intervention (CBSL, 2021, p 20). The Central Bank endorsed that '*the novel economic policy framework* of the government is expected to address impediments to growth and promote domestic production especially though the agricultural sector and earmarked manufacturing and export industries, while enhancing non debt creating foreign exchange inflows' (CBSL 2021, p 3). The Bank further stated that ' ... in the short term, prioritizing winning industries of the country, will drive the overall export performance, while enhancing domestic production ... [and] resolve the numerous *legacy issues* that straddle the performance of the export sector' (emphasis added) (CBSL 2021, p. 20), without spelling out what the so-called 'legacy issues' are.

3. MANUFACTURING PERFORMANCE

Growth of manufacturing in the Sri Lankan economy, as reflected in the national accounts, was lackluster during the stet-led import substitution era. In the 1960s, at the early stage of import-substitution industrialization (ISI), the average annual manufacturing growth rate was around 8.5%, but it propped to a mere 3% in 1970-76 (Table 1). By that time, unanticipated curtailment of imported intermediate inputs in response to foreign exchange scarcity had become a binding constraint on industrial expansion (Athukorala, 1981).

The manufacturing sector entered a distinct growth phase following the liberalization reforms. Contrary to the gloomy predictions by the critics of reforms, the lifting of import controls did not result is a sudden massive contraction. Free availability of imported inputs and capital goods in the liberalized economy, the cushioning effect against import competition provided by moderate tariffs, and the exchange rate depreciation help domestic manufacturing to face import completions, although there was some business failures (in particular virtual disappearance of the handloom industry). Following initial adjustments to the new competitive market setting, manufacturing growth surpassed that

Table 1. Manufacturing Sector in the Sri Lankan Economy, 1960-19 (%)

Period	GDP growth[1]	Manufacturing output (value added)[2]	Manufacturing share in GDP (%)
1960-69	4.7	8.3	9.7
1970-77	3.0	1.1	12.7
1978-84	7.0	4.6	13.1
1985-89	3.3	5.9	15.3
1990-94	6.2	8.9	15.1
1995-99	4.4	7.1	16.3
2000-04	5.0	0.8	16.9
2005-09	6.0	5.1	18.9
2010-14	6.8	5.8	17.0
2015-19	3.7	3.4	16.5
2020	-3.6	-5.0	15.5

Notes
(1) Computed using GDP at constant (2010) prices.
(2) Computed from real valued added using the 'implicit manufacturing deflator' (2010 = 100) derived from national accounts.

Source: Data compiled from The Central Bank, Annual Report (various issues)

of other sectors during most years during the next two decades.

From the late 1970s to about the late 1990s, manufacturing grew at an average annual rate of about 6.5%, compared to an overall GDP growth rate of 5.3%. The manufacturing share of GDP therefore recorded an almost two fold increased, from 10% to nearly 20% by the early 2000s. Since then the trend has reversed, reflecting the faster growth the non-tradable sectors propelled by the post-civil war construction boon and the slowing of manufacturing growth. The share of manufacturing in GDP declined from 19% in the early 2000s to 15% in 2019 (Figure 2).

The expansion of manufacturing sector has also been underpinned by a dramatic shift in its ownership structure. The share of SOEs in manufacturing output dropped from about 70% in the mid-1970s to less than 3% by the turn of the century.

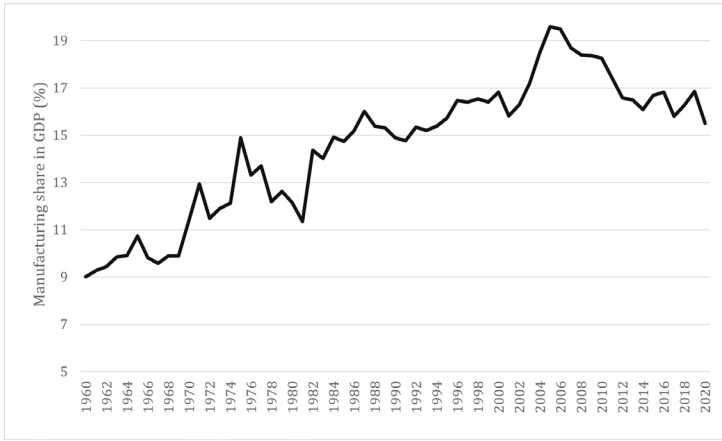

Figure 2. Manufacturing share in GDP, 1960-2000 (%)

Source: Date complied from Central Bank of Sri Lanka, Annual Report (various issues)

The immediate drivers of manufacturing output growth in the liberalized economy were the unrestraint availability of important inputs, increase in foreign direct investment, and access to a vast pool of cheap but trainable labour force that had been bottled up in the economy during the dirigisme era. However, there is evidence that total factor productivity (TFP) growth (increase in output over and above the use of inputs) played a significant role in the output growth. Almost 24% of total output growth between 1981 and 1993 came from TFP growth (Athukorala and Rajapatirana, 2000, Chapter 8). According to a recent study, TFP grew at an annual rate of 3.8 percent during 1990-02 (Bandara & Liyanaarachchi, 2020). However, there has been a notable decline in productivity improvement during the ensuing years: TFP growth declining to 1.7 percent during 2003-09 and further plummeted to a mere 0.5 percent during 2010-2016. Disaggregated industry level analysis in both studies have identified a statistically significant association between TFP growth and trade policy reforms, export-orientation and FDI. The shrinking of the role of SOE also had a salutary effect on productivity improvement in the manufacturing sector: during the ISI era SOEs dominated most domestic intermediate goods producing industries, with virtually exclusive access to imported inputs. Inefficiency of SOEs therefore spilled over to private sector manufacturing through both high prices charged by SOEs and poor quality of inputs (Wanigatunga, 1987; Sirisena, 1975).

There has been a notable increase in manufacturing employment. At the time when the reforms started, the manufacturing sector accounted for about 10% total employment in the country (Table 2, Figure 3). This increased continuously to over 18 percent by the mid-2010s, but has virtually stagnated around that figure from about the mid-2010s. The increase in manufacturing employment came from private sector with the share of employment in manufacturing SOEs declining sharply. Disaggregated data show that the export-

Table 2. Employment in the Manufacturing Sector,1960-2020

Selected years	Number employed ('000)			Manufacturing share of total employment (%)
	SOE[1]	BOI[2]	Manufacturing[3]	
1960	---	---	56	1.8
1965		---	134	4.2
1970	27	---	270	8.2
1975	48	---	417	10.5
1980	---	11	537	12.1
1985	---	36	648	12.6
1990	45	71	669	13.4
1995	40	233	789	15.3
2000	34	368	1045	16.6
2005	24	411	1385	18.4
2010	11	426	1348	17.5
2015	12	491	1408	18.0
2019	11	---	1504	18.4
2020	11	---	1398	17.5

Notes: *(1) State-owned manufacturing enterprises*
(2) Board of Investment approved firms
(3) Including SOE and BOI employment
--- Data not available.

Source: Data for 1960 and 1965 are from Hallett (1983); for other years: compiled from Central Bank of Sri Lanka, Annual Report and the Monthly Bulletin of Statistics (various issues).

oriented garment industry contributed to over 35% of total employment in organised manufacturing by the mid-1990s (DCS, 1978 – various years). This share declined slowly in subsequent years reflecting the expansion of other export oriented industries such as rubber products, ceramics, and travel goods. Total employment in the enterprises approved by the BOI, which are fully export oriented, increased from 11 thousands in 1980 to nearly a half a million by 2015.[1] The employment impact of new export-oriented industries would look even more impressive if employment in small-scale manufacturing were appropriately accounted for. Many export-oriented firms have production subcontracting arrangements with small-scale producers in the unorganised sector.

With the expansion of export-oriented labour-intensive manufacturing, there was a significant shift in the occupational composition in manufacturing, in favour of unskilled and semi-skilled workers and the share of female worker. The share of semi-skilled and unskilled workers in organised manufacturing increased from about 40 percent to over 70 percent, and the share of female workers from 32% to over 60% between the early 1980s the early 2000s (DCS, various issues). Most, if not all, of these workers come from low-income households. Growth of manufacturing employment growth, coupled with these compositional changes in employment, would have contributed to decline in absolute poverty (World Bank, 2005).

3.1. Export Performance

Following the 1977 policy reforms, the export structure of the economy has undergone a remarkable shift from the traditional 'primary trio' (tea, rubber and coconut products) to labour-intensive manufacturing. Exports of manufactured goods grew (in current United States dollar terms) at an annual compound rate of over 30% during 1978–2000, lifting their share in total merchandise exports to over 70%. However, since then the rate of expansion of manufacturing exports has lagged behind that of primary commodity exports, with the manufacturing share in total exports varying in the range of 70% to 68% (Figure 4).

The entry of foreign investors into export-oriented manufacturing played a pivotal role in the growth of manufacturing export. The share of foreign-invested enterprises (FIEs) in total manufacturing exports increased from 24% in 1977 to over 80% in mid-1995 (Athukorala

Figure 3. Employment in the Manufacturing Sector, 1990-2020

Source: Data compiled from Central Bank of Sri Lanka, Annual Report and the Monthly Bulletin of Statistics (various issues).

1 The BOI has stopped reporting employment data to the Central Bank from 2016.

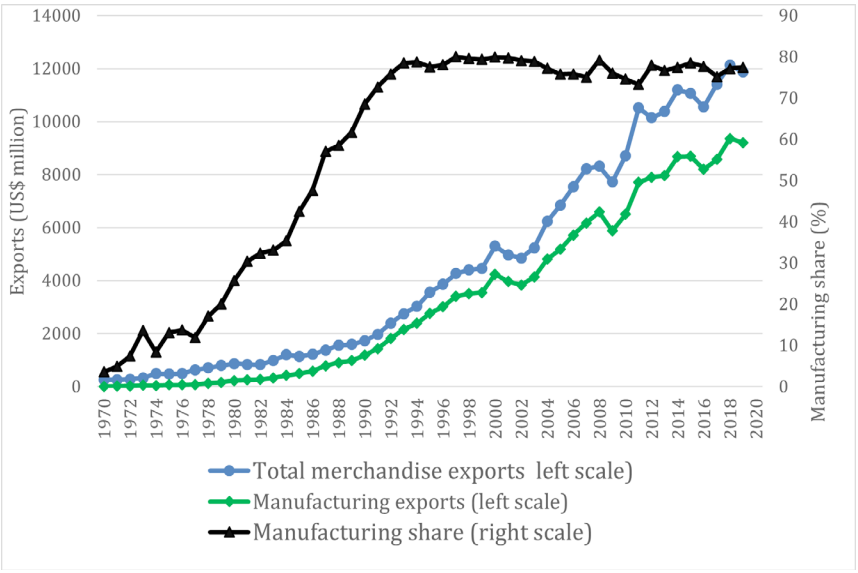

Figure 4. Sri Lanka's Merchandise Exports[1], 1970 - 2020

Note: Manufacturing products are defined as those belonging to product codes 5 through 8 of the Standard International Trade Classification excluding Code 68 (non-ferrous metals).

Source: Data compiled from UN Comtrade database.

& Rajapatirana, 2000, Table 5.8). Data for more recent year's show that the dominance of FIEs manufacturing exports has continued in the ensuing years: the share of BOI approved enterprises[2] varied in the rage of 82% to 90% during 2002-19 (Figure 5). Most of the foreign investors operate under joint venture arrangements with local entrepreneurs. FDI has, therefore, been an effective vehicle for transferring managerial practices and

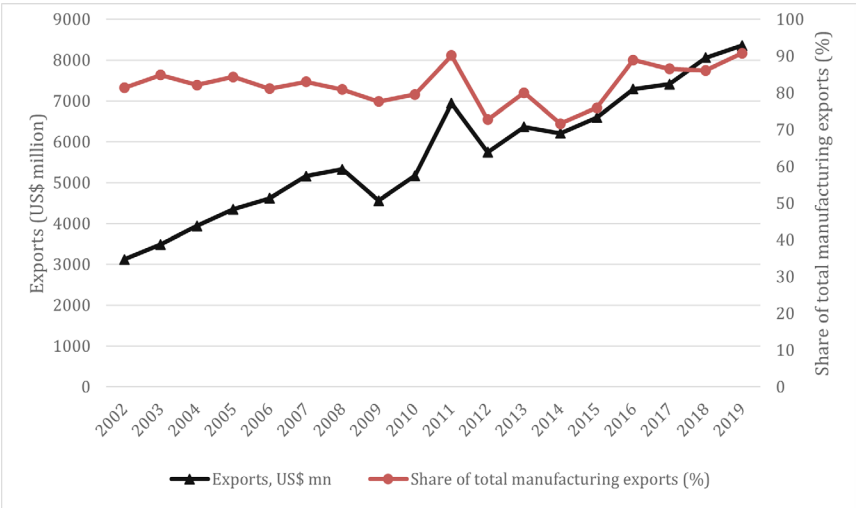

Figure 5. Exports from BOI approved firms, 2002-2019

Source: Data compiled from Central Bank Monthly Bulletin of Statistics and The Annual Report (various issues)

2 Over 90 percent of the BOI approved projects.

entrepreneurial skill to the local economy. A recent analysis of BOI records has found that the departure of some foreign investors contributed to slowing of manufacturing exports over the past ten years or so. The number of BOI approved firms in operation had dropped from 1150 in 2005 to 851 in 2015 (Athukorala, 2017).

Since about the later 1960s, there has been a dramatic shift in the origin of world manufacturing exports from the mature industrialized countries to developing countries: the share of developing countries share in world manufacturing exports surged from less tha10% in the 1970s to over 50% by the late 2010s (Figure 6). Sri Lanka's ability to reap gains from this structural shift in global manufacturing was virtually precluded by the dirigiste policy regime. Following the regime shift in 1977, there were some promising signs of regaining lost grounds. Sri Lanka's share in total manufacturing exports from developing countries increased from a mere 0.02 in 1976 to over 0.28% by the early 2000s, but the figure has plummeted since then, reverting to the level in the late 1980s of about 0.13%. This overall pattern suggests that slowing of Sri Lanka's export growth during the last two decades has been driven primarily by domestic supply-side factors which had constrained exploiting opportunities for world market penetration.

3.2. Product Composition of Exports

Date on the composition of Sri Lanka's manufacturing exports is summarized in Table 3. Garments (articles of apparel and clothing accessories) has been Sri Lanka's single largest export product. The share of garments in total merchandise exports increased from 1.3% in the early 1980s to over 60% (76% of total manufacturing exports) by the late 1990s. Since then the share has gradually declined to about 47% of total merchandise exports (70% of manufacturing exports) reflecting a modest diversification of the commodity composition to other labour-intensive products, such as leather goods, footwear, toys, plastic goods, and diamond cutting and jewelry, and domestic resource-based manufacturing, in particular ceramics and rubber.

Among the non-garments products, rubber-based products, in particular pneumatic (airless and solid) tires, have shown impressive growth. Sri Lanka's share in world exports of pneumatic tires (SITC 62594) increased from 6.0% in 1990-91 to 22.3% in 2018-19. Two Sri Lankan joint ventures, with Camso (a Canadian multinational enterprise) and Tellobrog (a

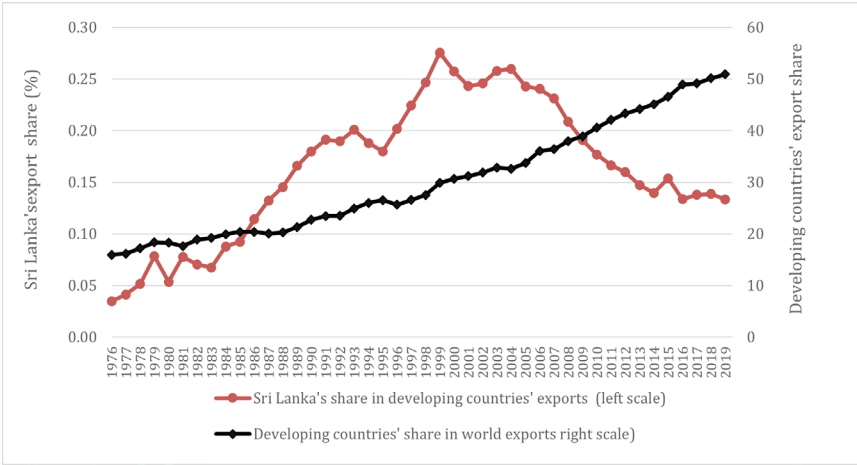

Figure 6. Sri Lanka's Export Performance in a Global Context, 1976-2019

Note: Classification of developing countries is based on the UN Standard International Country Classification: https://www.un.org/en/development/desa/policy/wesp/wesp_current/2014wesp_country_classification.pdf

Source: Data compiled from UN Comtrade database.

Table 3. Sri Lanka: Commodity Composition of Exports, 1965-2020[1] (%)

Product groups [2]	**1969-70**	**1974-75**	**1979-80**	**1980-85**	**1989-90**	**1994-95**	**1999-00**	**2004-05**	**2009-10**	**2014-15**	**2019**	**2020**
Primary products (0 + 1 + 2 + 3+ 4 + 68)	96.6	89.7	77.6	62.9	39.3	22.5	19.8	21.9	24.9	22.2	22.3	33.7
Primary products excluding petroleum (0 to 4 +68) – 33	95.9	86.0	75.0	59.6	38.2	22.0	19.3	21.8	24.7	21.8	22.0	33.4
Manufacturing (5 + 6 + 7 + 8) - 68	3.4	10.3	22.4	37.1	60.7	77.5	80.2	78.1	75.1	77.8	77.7	66.3
Chemicals and related products (SITC 5)	0.4	0.6	0.5	0.7	1.0	0.9	0.7	1.0	1.4	1.8	1.9	2.2
Manufactured goods classified by material (SITC 6 - 68)	2.3	6.9	8.8	6.2	16.8	15.0	14.4	16.0	13.0	14.8	11.7	13.1
Rubber manufactures (62)	0.1	0.1	0.3	0.5	1.6	2.3	3.2	4.9	4.9	6.4	2.7	5.3
Textile yarn and fabrics (65)	0.2	0.4	0.6	1.2	2.2	4.2	4.9	2.1	1.9	2.2	1.3	4.2
Non-metallic mineral products[2] (66)	1.8	5.9	7.3	4.3	12.2	7.8	5.7	5.7	5.5	4.8	3.6	2.2
Machinery and transport equipment[3] (SITC 7)	0.3	1.7	0.6	2.5	1.2	3.3	4.7	5.2	6.9	7.5	10.0	3.9
General industrial machinery and equipment[3] (74)	---	---	0.1	0.2	0.1	0.2	0.2	0.6	0.8	1.1	1.2	0.7
Office and data-processing machines[3] (75)	---	---	0.0	0.1	0.0	0.6	1.6	0.6	1.4	2.2	2.0	0.0
Telecomm and sound recording equipment[3] (76)	---	---	0.0	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.0
Electrical machinery and appliances[3] (77)	---	---	0.2	0.1	0.6	1.4	1.5	2.1	2.0	1.9	2.4	2.4
Road vehicles[3] (78)	---	---	0.0	0.0	0.1	0.1	0.3	0.5	1.3	0.5	0.6	0.6
Other transport equipment[3] (79)	---	---	0.0	1.3	0.1	0.0	0.3	0.2	0.8	0.9	2.7	0.0
Miscellaneous manufacturing (8)	0.4	1.1	12.6	27.6	41.8	58.2	60.4	55.9	53.8	53.7	54.1	47.0
Articles of apparel and clothing accessories (84)	0.2	0.7	11.9	26.2	38.5	50.6	52.8	51.9	50.6	50.3	50.4	43.2
Footwear (85)	0.0	0.1	0.1	0.4	0.6	1.2	1.0	0.3	0.3	0.5	0.2	0.2
Professional, scientific and controlling equipment[3] (87)	0.0	0.1	0.1	0.1	0.1	0.1	0.8	0.5	0.5	0.6	0.7	0.7
Total exports	100	100	100	100	100	100	100	100	100	100	100	100
US$ million	260	496	850	1210	1772	3326	4770	6569	8219	11126	11787	10047

Notes: (1) Two-year averages (except for 2019 and 2020), (2) Standard International Trade Classification (SITC) codes are in bracket, (3) Mostly ceramics and porcelain, (4) Parts and components
Source: Data compiled from UN Comtrade database.

Swedish multinational enterprise), account for the country's entire production of pneumatic tires. The share of natural rubber (Sri Lanka's second largest traditional export) in total exports has declined sharply as a result of the rapid growth of rubber-based manufacturing industries. Currently, more than 80% of the country's total natural rubber production is absorbed by the export-oriented rubber-based manufacturing, a notable achievement of domestic resource based industrialization under trade-cum-investment liberalization.

3.3. Garments[3]

In the Sri Lankan policy circles, garment is often treated as a 'traditional' products; its dominance is considered a structural weakness of the export structure of the country. However, in reality, the Sri Lankan garment industry has evolved to become a strong modern industry that has shown remarkable agility to thrive in a highly competitive global market setting, notwithstanding its conspicuous absence on priority lists prepared for the country's export development strategy.

Sri Lanka's 1977 liberalization reforms coincided with the tightening of import quotas allocated under the Multi-Fibre Arrangement (MFA) by the major importing countries to the three major garment producers in Asia, Hong Kong, Taiwan and South Korea. Given this happy coincidence, 'quota hopping' investors from these countries, and international buyers who followed them, played a pivotal role in the garment export boom in Sri Lanka.

The implications of the abolition of the MFA with effect from 31 December 2004 was, therefore, a key concern in the Sri Lankan policy circles. In the lead up to the MFA abolition, Sri Lanka was among the countries expected to experience significant contraction of garment exports during the post-MFA free era (Nordas, 2009). This gloomy prediction has not materialized, however. The average annual Sri Lankan garments exports during 2005–2019 was US$ 5.7 billion compared to $2.8 million during the preceding 5 years (2000–2004), a two-fold increase. Sri Lanka's share in total garments exports from developing countries increased from about 1.1% during 2000–2004 to 1.8% in 2018-19.

The MFA quota system certainly helped in bringing international investors and buyers to Sri Lanka's apparel industry. But, it was the trade-cum-investment liberalization that set the stage for Sri Lanka to exploit thither to unexploted comparative advantage in this global industry. The arrival of international investors and global byers opened the door for the local entrepreneurship that remained dormant during the dirigisme era to benefit from having access to trainable labour force at competitive wages. Through joint-venture arraignments with foreign investment partners and, more importantly, trade linked forged with international buyers, the Sri Lankan apparel industry has well settled into a smaller core of firms, which are well prepared to operate under competitive market conditions in the post-MFA era.[4]

The industry has developed a well-developed customer base including well-known brand names such as Abercrombie and Fitch, Gap, Hunkemoller, Liz Claiborne, Marks and Spencer, Nike, Pierre Cardin, Ralph Lauren, Sainsbury's, Tesco, Tommy Hilfiger, and Victoria's Secret. Large Sri Lankan apparel firms (at least the top 10 companies) have established their own design centers that work closely with design teams of brand owners. These firms have invested in computer-aided design and manufacturing, and in electronic fitting, which enables design decisions by visualizing the garment digitally, skipping fit-on sessions with models. Some of the large firms are now multinational enterprises in their own right with subsidiary companies

3 This section draws on Athukorala (2018) and Athukorala and Ekanayake (2018).

4 An analysis of firm-level Customs records indicates that there were 817 garment-exporting firms in Sri Lanka in 2004 (using an export value of $10,000 as the minimum cut-off point). The number declined to 450 in 2011, with the largest three firms accounted for over 35% of total exports in 2011 (13% in 2004) and the top 20 firms accounting for more than two-thirds of exports (39% in 2004) (Athukorala & Ekanayake, 2018).

in other apparel exporting countries, such as Bangladesh, India, Jordan, Kenya, Madagascar, Vietnam and Ethiopia. These firms have the ability to coordinate production within their global production networks to meet orders from their strategic buyers, reminiscent of the triangular manufacturing practices of the East Asian firms during the MFA era.

Given the country's long-standing commitment to providing universal free education, the workers seeking employment in the garment industry have a much higher level of formal education (on average 10 years of schooling) than in most other apparel exporting countries. Therefore, a worker who joined the labour force as a "helper" in an apparel factory takes only 2 to 3 months to become a machine operator, compared to 3 to 6 months taken by a Bangladeshi counterpart. In addition, the managerial and technical capability of Sri Lanka's apparel industry has improved notably during the past 4 decades, with public–private partnerships playing a pivotal role. Initially, the Sri Lankan apparel industry was heavily dependent on textile technicians from Hong Kong. The dependence on foreign textile technicians had virtually disappeared by the dawn of the new millennium. Sri Lanka has also become a supplier of textile technicians and managers to other apparel-producing countries in the region and beyond.

Until about the mid-1990s, the domestic content of apparel exports from Sri Lanka was basically equivalent to the labour content: about 20% (Kelegama & Foley 1999). At that time, the industry was treated as a glorified tailor-shop with little linkages with the rest of the economy: a symbol of dependent development (Lakshman, 1989). Since then, the three largest firms (MAS Holdings, Brandix and Hidramani, in that order) have set up plants to produce textiles (mostly knitted fabric and elastic) and ancillary inputs (hangers, brassier mounding, packaging material, labels, and buttons) to be used mostly in their own apparel plants, but also to meet the requirements of other apparel producers in the country. Currently, about 60% of fabric used in apparel production (about 80% of fabrics used in knitted apparel and about 20% of woven apparel) and the bulk of the ancillary inputs are produced domestically. Domestic availability of high quality inputs, which reduces the transport costs of inputs, delays, and the management time needed to coordinate a fragmented supply chain, is a key determinant of a firm's manufacturing flexibly is a highly competitive market.

With these preconditions, Sri Lanka's garment exports have undergone a remarkable compositional shift, away from 'basic apparel' and to 'fashion-basic apparel' [5]. The degree of concentration of Sri Lankan garment exports in the latter category had increased over time, reaching over 90 percent by mid-2010s. The share of women's apparel, which generally contain a higher fashion content, increased from 44% to nearly 60%. The two most rapidly expanding categories within this product group are brassieres and panties. In 2018-19, Sri Lanka accounted for 8.5% of total world exports of women's and girls' panties, up from 2.2% in 2003-04. Sri Lanka's world market share of brassieres increased from 3.2% to 7.8% in the same interval.

This compositional shift in the product mix has been the source of the industry's remarkable resilience to the MFA abolition. In basic apparel products, labour cost is the major determinant of international competitiveness; low-wage nations, especially those with access to inexpensive textiles, have the potential for major market share gains in the post-MFA era. By contrast, in fashion-basic products, exporting is more than a simple price-cost game; product designing, speed and flexibility are crucial capabilities for firms wrestling with product proliferation in competitive markets.

5 Basic apparel products are the standard apparel products that remain in a retailer's collection for many seasons, such as men's shirts, trousers, and underwear. Fashion-basic products are variants on basic products that contain some fashion elements (such as stone-washed jeans, pants with pleats or trim, and lingerie and intimate wear) Abernathy et al. (1999)

3.4. Missed Opportunities and Prospects

As noted, the heavy concentration of the export composition in garments has been a major concern in the Sri Lankan policy circles. However, the important issues of why the export success in garment industry did not take place in other industries as in the export-oriented economies in East Asia has not received due attention in this debate.

A comparison of Sri Lankan export composition with that of the high performing East Asian Economies (HPEAEs) vividly indicates that this lopsided nature of the export structure reflect Sri Lanka's missed opportunity to engage in 'production sharing' within vertically integrated global industries such as data-processing machines, telecommunication and sound recording equipment, electrical machinery and appliances, and professional and scientific equipment (broadly labelled as electronics and electrical industries). Global production sharing—cross-border dispersion of manufacturing processes that opens opportunities for countries to participate in different stages of the production process of a given product— has been the prime mover of shifting manufacturing production in these industries from mature industrial countries to developing countries. This phenomenon opens up opportunities for countries to engage in specific segment in the global manufacturing value chain (GMVC) depending on their relative cost advantage, intend of producing a good from the beginning to end within its national boundaries. The bulk of manufacturing exports from the HPEAEs, over two thirds of exports in some of these countries, take place within GMVCs (Athukorala 2014a).

In garments and other standard defused-technology industries, local entrepreneurs in a given country have the opportunity to penetrate global markets through links forged with international byers, with or without FDI involvement manufacturing, depending of course if the other preconditions are satisfied (as in the case of Sri Lankan garment industry). However, in GMVCs in electronics and electrical industries, production sharing takes place through intra-firm linkages, rather than in an arms-length manner. Intra-firm linkages are vital for preserving technological secrecy and/or to ensure quality/precision of parts and components produced in a given location, which is vital to maintain quality standards of the final product. Therefore, FDI plays a vital role in a country's participation in GMVCs in these industries.

The investment promotion campaign of the Greater Colombo Economic Commission (GCEC, later renamed BOI) placed emphasis during the early stage at attracting FDI into electronics and electrical assembly. In fact, the GCEC was successful in bringing two major electronics multinationals, Motorola and Harris Corporation, to the Katunayake Export Processing Zone (KEPZ). Motorola registered a fully-owned subsidiary in October 1980 to establish an assembly plant with an initial employment capacity of 2,624 workers. Motorola's decision to come to Sri Lanka was motivated by Sri Lanka's incentive package and perceived political stability of the country at the time, which handsomely compensated for the inherent locational disadvantage (long distance from the USA) (Weigand 1983). Harris Corporation registered a fully-owned subsidiary and even started building a plant in KEPZ with an initial employment capacity of 1,850 workers. Motorola left Sri Lanka in 1983 flowed by Harris Corporations in 1984 to locations in Malaysia as the political climate begun to deteriorate in Sri Lanka.[6] As of 2013, Motorola plant in Penang was employing 6500 workers; Motorola's operations in Penang has spawned a sizeable cluster of local subcontracting firms, some of which have become independent companies with even foreign operations on their own (Athukorala 2004b).

There is evidence of a "herd mentality" in site selection by multinational electronics firms: if the "first-comer" is a major player in

6 On signing the investment agreement with the Greater Colombo Economic Commission in 1980, W.D. Douglas, a vice-president of Motorola, said: 'Political stability is number one on our list wherever we go', quoted in Wijesinghe (1976)

the industry (Wheeler & Mody, 1992). If the Motorola and Harris Corporation projects had succeeded, other multinationals would have followed suit (Snodgrass 2008). Moreover, the entry of large players in vertically integrated global industries naturally sets the stage for the emergence of local small and medium scale firms supplying ancillary components and services, as in the case of Motorola's operation in Penang (Athukorala 2014b).

Perhaps the best way to understand how the missed opportunities in global production sharing dictated Sri Lanka's lopsided export performance is to compare the Sri Lankan export record with that of Vietnam, a latecomer to export-led industrialization that has already begun to show promising signs of growing by joining GMVCs. Vietnam embarked on market oriented reforms (transition from 'plan to market') much later than Sri Lanka (in the late 1980s). Since then until about the mid-1980s, Vietnam's export volume (in US$) was smaller than that of Sri Lanka (Figure 7). In 2005-06, when the export volumes of the two countries were more or less in size, garments accounted for the lion's share of exports (nearly two thirds) in both countries (Table 4). Since then, Vietnam has made a notable departure from Sri Lanka in export performance. By the end of 2010s, Vietnam accounted for over 5% of manufacturing exports from developing countries compared to a mere 0.13% share of Sri Lanka. Vietnam's meteoric rise as a dynamic export has been underpinned by a notable shift in the commodity composition towards dynamic products within GMVC, in particular electronics and electrical goods. In 1918-19 garments accounted for just 13% of total manufacturing exports from Vietnam. The process of dramatic structural transformation in Vietnam gathered momentum following the arrival of Intel Corporation in 2006 to set up an assembly and testing plant in Ho Chi Ming City (Athukorala & Kien, 2020).

3.5. Mini Electronics Boom

Even though large electronics MNEs shunned Sri Lanka because of the country risk, a sizeable number (over 30, according to BOI records) of fully export-oriented medium scale FIEs have been successfully operating in electronics, electrical goods, and auto part industries in the country for many years now. These firms currently employ over 20,000 workers (SLEDB, 2014).

These firms produce (mostly assemble) a wide range of parts and components ranging from sensors for the Airbus and weighing components for baby incubators. Total exports of these products increased from US$247 million (6.1% of total manufacturing exports) in 2007-08 to US$958 million (10.3% of total manufacturing exports) in 2018-19 (Figure 8). The annual growth rate of exports has been much rapid in more recent years: average annual growth rate of over 15% during 2015

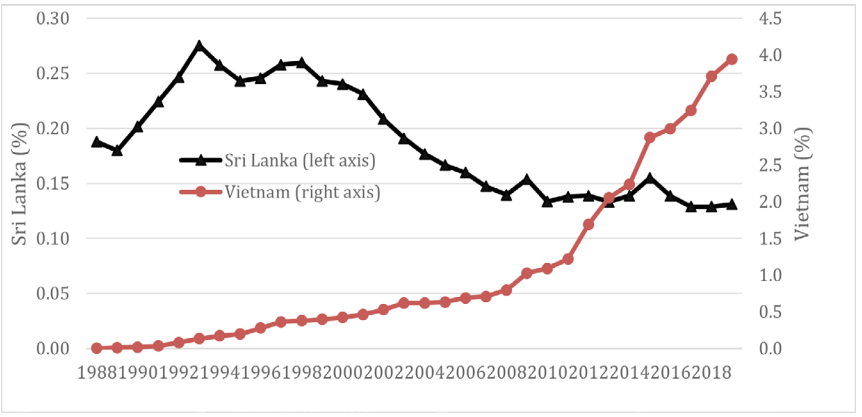

Figure 7. Vietnam and Sri Lanka: Share of manufacturing exports from Developing Countries, 1988-2019 (%)

Source: Data compiled from the UN Comtrade database.

Table 4. Sri Lanka and Vietnam: composition of manufacturing exports, 1995-96 and 2018-19[1] (%)

Product group[2]	Sri Lanka		Vietnam	
	1995-96	2018-19	1995-96	2018-19
Chemicals and related products (SITC 5)	2.63	2.42	2.52	2.12
Manufactured goods classified by material (SITC 6 - 68)	15.29	15.00	15.15	9.35
Machinery and transport equipment[3] (SITC 7)	10.43	7.39	8.92	46.87
General industrial machinery and equipment[3] (74)	0.22	0.16	0.19	31.65
Office and data-processing machines[3] (75)	3.30	2.87	3.09	5.26
Telecomm and sound recording equipment[3] (76)	0.11	0.16	0.13	8.36
Electrical machinery and appliances[3] (77)	0.75	0.75	0.75	1.17
Road vehicles[3] (78)	6.02	3.43	4.73	0.26
Other transport equipment[3] (79)	0.03	0.02	0.03	0.17
Travel goods (83)	0.06	0.05	0.06	1.73
Articles of apparel and clothing accessories (84)	60.37	64.55	62.44	13.69
Footwear (85)	0.31	0.31	0.31	9.93
Professional, scientific and controlling equipment[3] (87)	0.88	0.94	0.91	1.51
Toys and sport goods (894)	1.09	1.08	1.08	1.02
Unclassified	5.65	5.74	5.70	10.08
Total manufacturing	100	100	100	100
US$ billion	2.9	9.3	2.8	237.1

Note: *(1) Two-year average.*
(2) Standard International Trade Classification (SITC) codes are in brackets.
(3) Mostly parts and components.
Source: Compiled for UN Comtrade database.

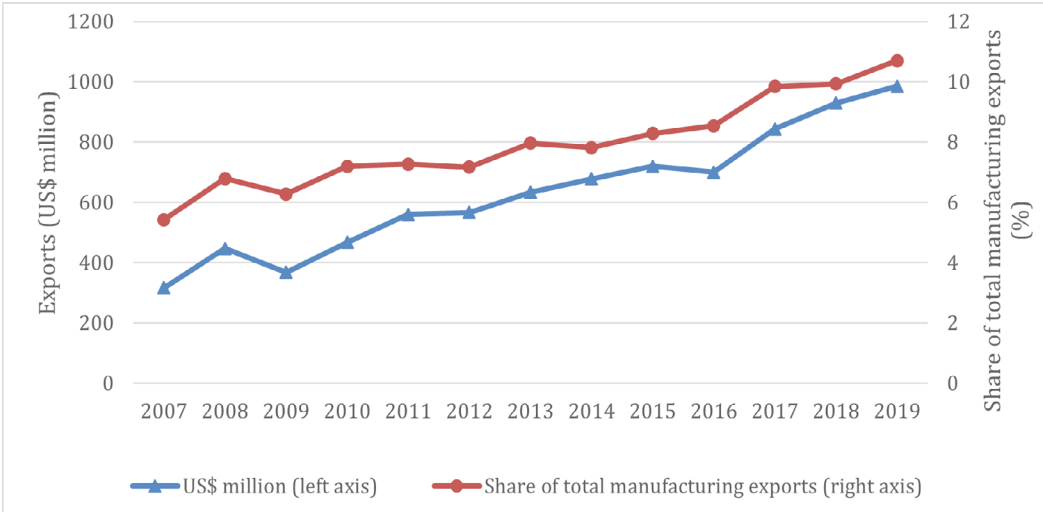

Figure 8. Sri Lanka's Exports of Electronic and electrical parts exported from Sri Lanka, 2007-2019

Source: Data compiled from UN Comtrade database.

-2019 compared 9% during 2007-2015. These are the fastest growing group of products in Sri Lanka's export composition during this period. Surprisingly this important development, which is relevant for any discussion of the country's export future, remain obscured in the Sri Lankan trade policy documents and policy debate.[7]

As part of our on-going research, we have put together basic information for 13 companies through internet search and interviews conducted with company executives (Table 5). All these firms are FIEs, with full or partial foreign ownership. The foreign parent companies of these FIEs are 'Nano' multinational enterprises (NMNEs) with operations in a few countries. They specialize in specific parts and component production and assembly within GMVCs through close, but alms' length, relations with original-manufacturing MNEs or large contract manufactures (CMs). Japan is by far the largest home country of these investors.

These investors have come to Sri Lanka based on personal contacts in the Sri Lankan business community, rather than in response to the investment promotion campaign of the BOI. All executives we interviewed stated that a trusted local relationship acts as a cushion against political risk and help attending with ease administrative commitments to various government bodies. The owner-manager of a highly successful auto part making company has written that,

'For decades, the Sri Lankan government through the BOI has embarked on many investment promotion missions to Japan and other countries. The writer participated in two such investment promotion missions to Japan in 2007 and 2013. These investment promotions impose a heavy financial burden on the national

Table 5. Sri Lankan Firms in electronics, electrical good s and auto part industries

Serial number	Year of establishment	Ownership	Product	Employment (number)
1	1982	Germany	Magnetic heads and electronic components	---
2	1986	Japan/SL	Electronics component, auto wire harnesses and LED/CFL lighting	250
3	1992	Japan/SL	Magnetic head, printed circuits, optical insulators	686
4	1997	Japan/SL	Printed circuit board/auto harnesses	250
5	1988	Japan/SL	Censor switches for seat belts and airbags	330
6	2008	Japan/SL	Electric components, crystal display modules, LED lighting devices	644
8	2010	USA/ Sweden/UK	Sensors for Airbus	2000 (planned)
9	2012	EU/India	Specialised, customised cables	---
10	2012	EU	Customised cable harnesses	---
11	2001	Switzerland/ USA	Printed circuit board/auto harnesses	600
12	2011	EU	Metal components	---
13	1991	Sweden	Weighing cells for medical devices (including baby incubators) and heavy machinery	650

Note: --- Data not available.

Source: Based on interviews and data compiled from Company websites.

7 In the Central Bank *Annual Report*, these dynamic products remain hidden in various sub categories under the broader category of machinery and transport equipment (Table 81 in the *2020 Annual Report*)

coffers. But the fact is that the BOI has failed to attract even a single substantial Japanese investor since the last Japanese investor came to Sri Lanka in 2002 that too on the initiative of the writer, not as a result of BOI promotion missions. Easjay Electromag, Tos Lanka, Laka Harness, Areosense, Cable Solutions, Metal Component Services, Lanka Precision Works, Nipon Maruchi were all established in Sri Lanka through a strong local relationship that was trusted by the foreign investor ...'. Pallewatta (2018, p 245)

Availability of trainable labour and complementary supervisory manpower is the major attraction of Sri Lanka as a production location for these investors. Contrary to the popular perception among policy makers in the country, none of the executives we interviewed complained about a human capital constraint. The majority of firms are in the hands of local managers and all workers and supervisors have been trained on the job within the firm. Some firms send their new recruits to their home countries for training.

We found no evidence to suggest that the advent of the so-called Fourth Industrial Revolution (IR4)[8] would put an end to the type of activities undertaken by these firms. In principle, almost all production processes can be robotised or automated, but, in reality, the actual replacement of labour with this IR4 technology depend on the relative cost of doing so, which depends on both complexity of the production process and the bulkiness of the given product. Automation or robotisation does not seem to be a cost effective alternative for the human touch involved in intricate assembly processes undertaken by these firms. According to our firm-level surveys, the Sri Lankan firms involved in assembling weighing cells, auto wire harnesses, sensors for aircrafts and optical insulators have long-term plans to expand production. Recently UK-based major player in the global aircraft component industry bought a Sri Lankan US-Sweden-UK joint venture firm producing sensors for Airbus as part of its production expansion program. The new owner has plans to expand the Sri Lankan operation to a projected employment capacity of 2000 workers, up from the current employment of 60 workers.

4. CONCLUDING REMARKS

The backlash against liberalization reforms in the contemporary Sri Lankan policy debate is largely based on defunct ideological predilection rather than factual analysis. The comparative analysis of Sri Lanka's industrialization experience during the state-led import-substitution era and that of the post-reform era (in particular during the first two decades) in this paper makes a strong case for reconsidering the merit of the emerging emphasis on combining import substitution and export orientation with a state-guided sector specific focus. Selective policies to promote import substitution essentially impose a 'tax' on export producers.

The economic liberalization reforms initiated in 1977 have brought about far-reaching changes in the structure and performance of the Sri Lankan manufacturing sector. The reforms helped transform the classical export economy of Sri Lanka inherited from the colonial era into a one in which manufacturing plays a significant role. The achievements of liberalization reforms are all the more remarkable when we allow for the fact that the proposed reform package was not fully implemented and that the country failed to capture the full benefits of reforms undertaken because of the protracted civil war that damaged the investment climate and undermined macroeconomic stability.

The experience under liberalization reforms demonstrated the complementarity of trade and investment liberalization in the process of export-oriented industrialisation: trade liberalization increased the potential returns to investment by capitalizing on the country's comparative advantage, while

8 Industrial advancement based on the convergence of digital technology with breakthroughs in material science and biotechnology: artificial intelligence (AI), robotics, internet of things (IoT) 3D printing (additive manufacturing), autonomous vehicles and nanotechnology (Schwab, 2016).

liberalization of foreign investments permitted international firms to take advantage of such profit opportunities. There is compelling evidence that the entry of foreign firms is vital for a "latecomer" to export successfully. In addition to foreign-invested enterprises' direct contribution to export expansion, their positive spillovers have contributed to the success of local exporting firms.

The Sri Lankan garment industry has successfully consolidated its position as a dynamic player in a highly competitive global market in the post-MFA era, contrary to the popular perception that treat it as a traditional sun-set industry. Sri Lanka missed the opportunity to gain export dynamism by entering into global manufacturing value chains in vertically integrated electronics and other related industries because of the debilitating country risk caused by the civil war and policy uncertainty. However, a small but dynamic parts and component assembly industry has emerged during that period through trustworthy personal links between international investors and the Sri Lankan business community. There are indications that this industry has the potential to become the harbinger of export dynamism in the post-civil war era, depending of course on the country's commitment to continue with reforms to facilitate global integration of domestic manufacturing.

Trade-cum-investment policy reforms has the potential to set the stage for new exporting industries and exporting firms to emerge in a global context in which factors of production-capital, technology, and marketing and managerial knowhow––are mobile across national boundaries. Developing human capital base and building the country's innovative capabilities should of course be among the government's long-term policy priorities, but there is no need to wait to achieve these objectives in order to link domestic manufacturing into global production networks. The human capital constraint on export success is vastly exaggerated in the Sri Lankan policy debate.

When talking about sector/industry specific approach to industrialization, we should not forget the fact that the Post-World War II economic history of developing countries, including that of Sri Lanka, is littered with cases of costly failure. Or course there were a few seemingly successful cases in some countries, but the available evidence clearly supports the view that these 'successes' were rooted in three fundamental traits of the industrialization policy regimes of these countries. First, the incentives given to the specific industries were strictly time bound; second, export performance requirement was strictly imposed on the beneficiary firms; and thirdly selective intervention was undertaken in the context of an overall economic setting that was conducive for private sector operations. It is pertinent to quote here the founding father of the Korean economic miracle:

'The economic planning or long-range development programme must not be allowed to stifle creativity or spontaneity of private enterprises. *We should utilize to the maximum extent the merit usually introduced by the price mechanism of free competition*, thus avoiding the possible damages accompanying a monopoly system. There can be and will be no economic planning for the sake of planning itself' (emphasis added) Park (1970, p. 214).

Selecting a large number of industries for preferential treatment and promising to add even more to the 'wish list' (CBSL 2021, p. 20) is a recipe for strengthening the hands of the domestic lobby that clamor for trade protection and government support. The few known successful cases of selective intervention world over were based on selecting a few cases based on systematic assessment of world market conditions and potential for gaining dynamic comparative advantage within an overall economic environment that is conducive for unhindered private sector operation. If there is uncertainty, the best practice is to rely on market forces. To quote Lee Kuan Yew:

'[W]e left most of the picking of winners to the MNEs that brought them to Singapore. A few such as ship repairing, oil refining and

petrochemicals banking and finances were picked by the EDB or Sui Sen, our minister of finance or myself personally… When we were unsure how new research and development would turn out, we spread our bet. Our job was to plan the broad economic objectives and target periods within which to achieve them (Lee, 2000, p.85).

In sum, the analysis of regime shifts and economic performance under state-led import substitution strategy and liberalisation reforms in this paper makes a strong case for averting backsliding in policy, continuing the market-oriented reforms agenda that was left incomplete in the late 1990s, and setting up institutional safeguards to avert further policy backsliding.

REFERENCES

Abernathy, F., Dunlop, J., Hammond, J., & Weil, D. (1999). *A Stich in Time: Lean Retailing and the Transformation of Manufacturing: Lessons from the Apparel and Textile Industries*. New York: Oxford University Press.

Athukorala, P. (1981). Import substitution, structural transformation and trade dependence: A case study of Sri Lanka. *The Developing Economies*, 24(2), 119-42.

Athukorala, P. (2014a). Global production sharing and trade patterns in East Asia', in I. Kaur and Singh, N. (eds.) *Oxford Handbook of Pacific Rim Economies*. New York: Oxford University Press, 334-360.

Athukorala, P. (2014b). Growing with global production sharing: The tale of Penang export hub, Malaysia.', *Competition & Change* 18 (, no. 3 (2014): 221-245.

Athukorala, P. (2018). Industrial upgrading in apparel value change: The Sri Lankan experience, in Natha, D., Tewari, M. and Sarkar, S. (eds.), *Challenges of Upgrading and Innovation: Asian Firms in GVCs*. Cambridge: Cambridge University Press, pp. 193-228.

Athukorala, P., & Ekanayake, R. (2018b). Repositioning in the Global Value Chain in the Post-MFA Era: Strategic Issues and Evidence from Sri Lanka. *Development Policy Review*, 36, O247-O26

Athukorala, P. & Jayasuriya, S. (2015). 'Victory in War and Defeat in Peace: Politics and economics of post-conflict Sri Lanka. *Asian Economic Paper*, 14(3), 22-54.

Athukorala, P. & S. Rajapatirana (2000) *Liberalization and Industrial Transformation: Sri Lanka in International Perspective*. Delhi and Oxford: Oxford University Press.

Athukorala, P. & Kien, N. T. (2020). Transition to a market economy, Foreign direct investment and export performance in Vietnam, in London. J. (ed.), *Routledge Handbook of the Vietnamese Economy*. London: Routledge (forthcoming).

Bandara, J.S. & Liyanaarachchi, T.S. (2019). Total factor productivity and its determinants in Sri Lanka. A study undertaken for World Bank Sri Lanka. Nathan: Griffith University, Business School (unpublished manuscript).

Central Bank of Sri Lanka (CBSL) (2021). *Annual Report 2020*. Colombo: CBSL.

Cuthbertson, A.G. & Athukorala, P. (1990). Sri Lanka, Part 3 in Papageorgiou, D. M Michaely, M. and Choksi, A.M. (eds) *Liberalising Foreign Trade: Indonesia, Pakistan and Sri Lanka*, Oxford: Basil Blackwell, pp 283-411.

Department of Census and Statistics (DCS) (2019). Effective rate of protection estimates. http://www.statistics.gov.lk/NationalAccounts/StaticalInformation/SNA_Accounts (accessed on 5 May 2021)

Department of Census and Statistics (DCS) (1978 – various years). *Annual Survey of Industry*, Colombo: DCS.

Dunham, D. & Kelegam, S. (1997). Does leadership matter in the economic reform process? Liberalization and governance in Sri Lanka, 1989–1993. *World Development* 25 (2), 179-190.

Fitter, J. (1970). Ceylon on the road to long-term decline?. *Intereconomics*, 1, 25-27.

Goodhand, J. (2012). Sri Lanka in 2011: consolidation and militarization of the post-war regime. *Asian Survey*, 52(1), 130-137.

Government of Sri Lanka (GSL) (2008). Strategic Development Project Act, No. 14 of 2008. Colombo: The Department of Government Printing.

Government of Sri Lanka (GSL) (2010). *Sri Lanka: The Emerging Wonder of Asia: Mahinda Chintana vision for the future*. Colombo: Department of National Planning.

Government of Sri Lanka (GSL) (2020). Gazette Extraordinary No. 2171/9, 20th April, Colombo: The Department of Government Printing.

Hallett, A.J.H. (1983). Employment, investment and production in Sri Lanka 1959-80: Reflections on what he figures reveal. *Marga Quarterly Journal*, 7(1),78-100.

Jayasuriya, S. (2004). Exchange rate, in Kelegama, S. (ed), *Economic Policy in Sri Lanka: Issues*

and Debates (A festschrift in honor of Gamani Corea), New Delhi: Sage Publication, 177-194.

Kaminski, B. & Ng, F. (2013). Revival of inward-orientation and its impact on Sri Lanka's performance in global markets. *WSiZ Policy Research Working Papers 2*. Washington DC: World Bank.

Kelegama, S., & Foley, F. (1999). Impediments to promoting backward linkages from the garment industry in Sri Lanka. *World Development* 27(8), 1445–60.

Krueger, A. O. (1997). Trade policy and economic development: how we learn. American Economic Review, 87(1), 1-22.

Kumaratunga, C.B. (1994). *Economic Policy Statement of the Government of Sri Lanka*. Colombo: The Board of Investment of Sri Lanka.

Lakshman, W. D. (1989). Lineages of dependent development: From state control to open economy in Sri Lanka, in Wignaraja, P. and Hussain, A. (eds), *The Challenge in South Asia: Development, Democracy, and Regional Cooperation*, New Delhi: Sage, pp. 105- 138.

Lee, K.Y. (2000*). From Third World to the First: The Singapore Story: 1965-2000*, Singapore: Singapore Press Holding.

Nordas, H. (2009). *The Global Textile and Clothing Industry Post the Agreement on Textiles and Clothing*. Geneva: World Trade Organization.

Pallewatta, R. (2018). Global production system: Sharing Sri Lanka's experience', in Fonseka, T. (ed), *Essays in International Business*. Colombo: Postgraduate Institute of Management, pp. 249-258.

Park, C.H. (1970). *Our Nation's Path: Ideology for Social Reconstruction*, 2nd Edition, Seoul: Hollym Corp.

Pursell, G. & Ahsan, F.M.Z. (2011). Sri Lanka's trade policies: Back to protectionism. *Australia South Asia Research Centre Working Paper 2011/03*, Canberra: Australian National University. https://socialpolicy.crawford.anu.edu.au/acde/asarc/pdf/papers/2011/WP2011_03.pdf

Rajapatirana, S. (1988). Foreign trade and economic development: Sri Lanka's experience. *World Development* 16 (10), 1143-1157.

Sirisena, P.T. (1975). An Evaluation of the Efficiency, Foreign Exchange Saving ands and the Welfare Impact of the Steel Industry. *Staff Studies: Central Bank of Ceylon*, 5(2), 15-32.

Sri Lanka Export Development Board (SLEDB). 2015. *Electronics Sector Baseline Survey*. Colombo: SLEDB.

Snodgrass, D. R. (1967). *Ceylon: An Export Economy in Transition*, Homewood, Illinois: Richard D. Irvin.

Snodgrass, D. R. (2008). The economic development of Sri Lanka: A tale of missed opportunities, in Rotberg, R.I. (ed.), *Creating Peace in Sri Lanka: Civil War and Reconciliation*. Washington DC: Brookings Institution Press, 89-107.

Schwab, K. (2016). *The Fourth Industrial Revolution*. New York: Portfolio Penguin.

Thomson, R. & Athukorala, P. (2020). Global production networks and the evolution of industrial capabilities: does production sharing warp the product space? *Oxford Economic Papers* 72 (3), 731-747.

Weigand, R. (1983), 'International Investment: Weighing the Incentives', *Harvard Business Review*, 61, 146-152)

Wanigatunga, R.C. (1974). Tyre Industry. *Staff Studies: Central Bank of Ceylon*, 4(3), 33-52.

Wheeler, D. and Mody, A. (1992). International investment location decisions: The case of US firms. *Journal of international economics,* 33 (1-2), 57-76.

Wijesinghe, M. (1976). *The Economy of Sri Lanka, 1948-1975*. Colombo: Ranco Printers.

World Bank (2005). *Sri Lanka Development Policy Review 2004*. Washington DC: World Bank.

Post-Covid19: Can the Sri Lankan apparel sector benefit from US-China decoupling? *A statistical analysis*

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ABSTRACT

The "US-China decoupling" has received much attention with the deterioration of US-China diplomatic and economic ties under the Trump administration. US firms seeking to reduce their reliance on China offers an economic opportunity for rest of the world to become an alternative supplier to products previously supplied by China. This paper assesses the extent to which such an economic opportunity is present in the US apparel market and Sri Lanka's potential to benefit from this opportunity.

The value (in current USD terms) of imports of apparel from China to the US started declining since 2015. The paper classifies a product as showing early signs of being diverted away from China if imports from China increased during 2011-2014, but declined during 2015-2019, while imports from the rest of the world increased. Of these products, potential products for Sri Lanka are identified based on the country's capacity to supply the US market based on value of current imports into US from Sri Lanka and the rate of growth in imports.

The analysis identifies 37 apparel products showing early signs of diversion and Sri Lanka has capacity to supply 21 of these products. Among the 21 products, Sri Lanka's potential to benefit from US-China decoupling, is 'high' in nine products, 'medium' in seven and 'low' in the rest of the products. The research finds preferential access to the US market to be less important in becoming a preferred alternative sourcing destination. Countries such as Vietnam, Bangladesh, Cambodia, which do not have preferential access to the US market, stand out as the key competitors of Sri Lanka in the 21 potential products.

Key words: Apparel exports, COVID-19, US-China trade war, US-China decoupling

1. INTRODUCTION

The possibility of a "US-China decoupling" has received much attention in the recent years with the deterioration of US-China diplomatic and economic ties under the Trump administration. The rising economic tensions between the two countries became highly visible with the US – China trade war that led to imposition of higher barriers to trade between the two countries. From early 2018 the US increased the average US tariff on Chinese goods from 2.7% to 17.5% on over USD 300 billion worth of Chinese goods. (Amiti et al., 2020) The US-China relationship also hit a new low during the COVID-19 pandemic. (Christensen, 2020) The supply chain shocks resulting from the COVID lockdowns also exposed the vulnerability of manufacturing firms being heavily dependent on China. The relationship between the two countries has been damaged to an extent that it is unlikely to be fully restored even after the US

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Presidency transitioned from Trump to Biden. (Disis, 2020)

These developments seem to have encouraged US firms to explore ways of reducing their heavy reliance on China. There are already reports of US companies seeking to diversify their production and sourcing away from China. (Rapoza, 2020) The trade between the two countries is already showing impact of higher trade barriers. The US share of Chinese imports and exports in 2019 has fallen to its lowest in 27 years, to levels prevailing before China's entry to the WTO in 2001 (The Economist, 2020)

The diversification of the supply base of US firms away from China presents an economic opportunity for developing countries like Sri Lanka to become a potential supplier of products that were previously sourced from China. This paper investigates the extent to which such an economic opportunity is present in apparel, which is Sri Lanka's main export product accounting for over 40% of total merchandise exports. The sector provided employment to around 729,427 persons in 2018. It accounts for approximately 18% of total female employment in Sri Lanka and 9% of total employment. (Department of Census and Statistics, 2019a & 2019b) The US is the largest buyer of apparel in the world and China the largest supplier. While China continues to be the leading supplier of apparel to the US, the growth trajectory has changed since 2015. Value of apparel imports from China to the US that steadily increased from USD 6.5 billion in 2000 to reach USD 32.3 billion in 2015, and has started declining since then to reach USD 24.6 billion by 2019. (U.S. International Trade Commision, 2020) The trade war between the US and China, has increased the cost of importing apparel from China to the US. Up to 99% of apparel imports into the US from China in terms of value have faced additional tariffs since 2019. (U.S. International Trade Commission, 2020)

These developments in the apparel sector offer an economic opportunity for countries like Sri Lanka to become an alternative supplying destination of apparel products that was previously supplied by China, which can potentially assist the apparel sector recovery from the negative impact of the COVID-19 pandemic.

The objectives of this paper are to 1) identify apparel products that show early signs of sourcing being diverted away from China presenting an opportunity in apparel for the rest of the world and 2) identify products exported by Sri Lanka, that can potentially benefit from this economic opportunity and 3) assess the level of competition Sri Lanka face in the US market for the identified potential products.

2. METHODOLOGY

The paper analysed 217 apparel products at the 6-digit level belonging to HS Chapters[1] 61 and 62. These are products for which annual imports from China accounted for over 5% of total US imports of the product during 2015-2019. The analysis relied exclusively on trade and tariff data published by the US International Trade Commission and the World Bank. Using this data, the paper first identified products that show early signs of sourcing being diverted away from China. It then shortlisted the products for which Sri Lanka has potential to be an alternative supplier.

The period 2011 to 2019 was taken as the period of reference in this paper. The early signs of deviation are assessed by looking at trends of imports into the US from China four years before 2015 and four years after. The imports peaked at USD 32.3 billion in 2015 and declined in absolute value for the first time since 2000, to reach USD 26.4 billion by 2019.

A product was classified as showing early signs of sourcing being diverted away from

1 Harmonized System – HS was developed by the World Customs Organisation to assess product concentration and composition of exports. The level of detail in the classification of products depends on the HS level specified. For example, a product classified at an 8-digit level is more specific than one classified at a 6-digit level which in turn is more specific than a product classified at 4-digit level.

China to other countries, creating an economic opportunity for the rest of the world, if it met following criteria.

- First criteria –the imports from China to US experienced growth during 2011-2015 but declined during 2015 and 2019[2] and;
- Second criteria - For the same products, despite the decline in imports from China, the imports into US from the Rest of the World (RoW) have increased during 2015 and 2019

The extent to which Sri Lanka can benefit from such diversion was assessed based on the value and growth of imports from Sri Lanka to the US. A product was classified as having the capacity to benefit from US-China decoupling, if the imports of that product from Sri Lanka to the US have recorded a minimum value of USD 1 million a year. The level of potential of these products to benefit from the economic opportunity present was analysed using following two criteria: 1) overall growth in imports to the US from the world and 2) the growth in imports from Sri Lanka to the US as shown in Table 1.

Table 1. 1) Overall growth in imports to the US from the world and 2) the growth in imports from Sri Lanka to the US

	Sri Lanka gaining market (Imports to the US from SL increased between 2015-2019)	**Sri Lanka losing market (Imports to the US from SL declined between 2015-2019)**
Growing US market RoW growth > China Decline	High potential	Medium potential
Declining US market RoW growth < China Decline	Medium potential	Low potential

2 The growth rates used in this paper to measure growth in imports is the compound annual growth rate (CAGR) of imports between the 4-year period 2015-2019.

Products that experienced growth in imports during 2015-2019 in a market where overall demand for the product in the US is increasing were classified as having high potential to benefit. Products were classified as having medium potential if imports from Sri Lanka have experienced decline in a US market where overall demand is increasing or if imports from Sri Lanka have experienced growth in a US market where overall demand is decreasing. In the former, growth potential is undermined by Sri Lanka while prospects in the US market seem positive. In the latter growth potential is undermined by overall decline in the US market while prospects of Sri Lanka in the US market seem positive. Products for which imports from Sri Lanka experienced decline in a declining US market are classified as having low potential.

Lastly, the analysis of potential also factored in the level of competition Sri Lanka face from other suppliers of the products to the US market. The level of competition was analysed by taking into consideration the number of key competitors and the duty-free access the key competitors have to the US market. The latter is an important factor to consider because Sri Lanka does not enjoy duty free access to the US market for apparel products compared to some of its competitors.

The key competitors are defined as countries that has over USD 1 million imports of the product a year to US that has seen growth in the imports of the identified potential products during 2015-2019. The level of competition products face were categorised as high, medium, and low as shown by Table 2.

The analysis provides valuable insights both for policy makers and private sector, that is looking for strategies to support sector's recovery from the negative impact of COVID-19.

Limitations

The results need to be interpreted with caution, since it relies exclusively on trade and tariff statistics up to 2019. While the analysis

Table 2. Level of competition products face

	Over 50% of the key competitors have duty free access	**Less than 50% of the key competitors have duty free access**
Number of competitors > above average*	High competition	Medium competition
Number of competitors > below average	Medium competition	Low competition

**Average number of competitors are found by dividing the total number of key competitors by number of products.*

provides early insights into products that can potentially benefit from US-China decoupling, these findings need to be further validated by investigating other factors such as price, quality, reliability, time to destination etc. that are important determinants of sourcing decisions of US buyers. In addition to that it is also important to re-assess the potential against potential medium to long term shifts in demand for apparel products in the US market that has resulted from COVID 19 led shifts in income levels, lifestyles, and consumption patterns.

3. FINDINGS

3.1. Products that show signs of sourcing being diverted away from China

Of the 217 apparel products analysed, 37 products showed early signs of sourcing being diverted away from China. (Annex 1) For all these products, imports from China to the US increased during 2011 to 2015 but declined from 2015 to 2019. While imports from China declined, the imports of these products to the US from the rest of the world (RoW) increased, indicating a certain degree of diversion of trade away from China. The US imports of these 37 products was around USD 25.3 billion a year between 2015-2019. These products accounted for 29% of total US apparel imports from the world and for 30% of apparel imports from China. (U.S. International Trade Commision, 2020)

3.2. Products for Which Sri Lanka Has the Potential to Benefit from This Transition

Of the 37 products which show signs of US sourcing being diverted away from China, 21 products have recorded at least USD 1 million or more imports from Sri Lanka to the US a year on average between 2015 and 2019. (Annex 2) During this period, the value of imports of these 21 products from Sri Lanka to the US was USD 567 million a year, and these accounted for 28% of total apparel imports of the US from Sri Lanka. The remaining 16 products, with annual average imports from Sri Lanka lower than USD 1 million accounted for only 0.1% [USD 2.8 million] of total imports from Sri Lanka to the US during the same period. (U.S. International Trade Commision, 2020)

Of the 21 products with over USD 1 million imports from Sri Lanka to the US, the analysis revealed nine products have high potential to benefit from this transition. US imports of these products from Sri Lanka experienced growth and total imports into US from the world also increased during the period 2015-2019. Seven products were found to have medium potential. Three of these products recorded an increase in imports from the world into US although imports from Sri Lanka to the US declined. Four of the medium potential products experienced a decline in imports from the world to US while imports from Sri Lanka to US market increased. The remaining five products were found to have low potential because both total US imports and imports from Sri Lanka of these products have declined during the period under consideration. (Table 3)

3.3. Level of Competition Faced by Sri Lanka in the US Market

On average, the Sri Lankan products faced 13 competitors for each of the 21 products; i.e., countries that recorded a minimum of USD 1 million worth of imports of the product by the US and has recorded an increase in imports during 2015-2019.

Table 3. Sri Lanka's potential to benefit from the from US apparel import diversion from China

Colour codes	Sri Lanka's market Share In the US: over 1%		Sri Lanka's market Share In the US: less than 1%	

	Imports from Sri Lanka increased between 2015-2019		**Imports from Sri Lanka declined between 2015-2019**	
	1 – High potential		2 – Medium Potential	
US imports from the World increased between 2015-2019	Total Imports of the US **USD 12,187 Mn**	*Products* 610520, 611030 620530, 620892	Total Imports of the US – **USD 2,444 Mn**	*Products* 610990, 611231
RoW growth > China's Decline	Imports from Sri Lanka **USD 152 Mn**	610342, 610343 610469, 620343 621010	Imports from Sri Lanka - **USD 33 Mn**	610130
	3 – Medium potential		4 – Low potential	
US imports from the world declined between 2015-2019	Total Imports of the US **USD 3,349 Mn**	*Products* 610831, 611693, 620640, 621143	Total Imports of the US **USD 5,025 Mn**	*Products* 611130, 611241, 620443, 620822, 621210
RoW growth < China's Decline	Imports from Sri Lanka **USD 20 Mn**		Imports from Sri Lanka **USD 363 Mn**	

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web

Four of the nine high potential products of Sri Lanka faced high competition in the US market, two faced medium competition and three products faced low competition. In contrast majority (four) of the low potential products faced low competition and none of the low potential products faced high competition. Majority of the medium potential products also faced low and medium level of competition. (Table 4)

As shown in Figure 1, the top six competitors that has successfully become alternative suppliers to China for the selected products are from the Asian region like Sri Lanka. These Asian countries except for Jordan do not have duty free access to the US market as well. (World Bank, 2018) A country is classified as succeeding in becoming an alternative supplier if the country has experienced growth in its market share in the US by over 1 percentage point between 2015 and 2019. Sri Lanka has managed to experience a similar growth in its market share for only one product (HS 610831) which is classified as a medium potential product.

Countries such as Haiti, Honduras, Guatemala, Peru and Nicaragua have also made significant gains in the US market for some of the products. While they have not been as successful as some of the Asian countries, it is important to note that these countries have two advantages over Sri Lanka and other Asian countries: 1) duty free access to US market and 2) proximity to the US market. The possibility of US buyers shifting production and sourcing to locations closer to home to make the supply chains more resilient to shocks, makes these countries competitors to watch out for in the future.

It is also important to note that China continues to be a key competitor in the US market in these 21 products despite the decline in imports between 2015-2019. For example, for seven of the 21 products China still maintained a market share of over 50% in 2019. Two high potential, two medium potential and three low potential products of Sri Lanka are among these seven products. This suggests that China, despite the decline, will continue to be a major competitor for the rest of the world in these product categories. (refer Figure 2)

Table 4. Level of competition Sri Lanka faces in the US market

Colour codes	High potential products	Medium potential products	Low potential products

	Over 50% of the key competitors have duty free access**		**Less than 50% of the key competitors have duty free access****	
The number of key competitors is above 13*	High competition Total Imports of the US **USD 10,808 Mn** Imports from Sri Lanka **USD 162 Mn**	*Products* 611030, 610520, 620530, 610343 610990	Medium competition Total Imports of the US **USD 2,294 Mn** Value of Imports from Sri Lanka **USD 53 Mn**	*Products* 620343, 610342 620640, 621143 620443
The number of key competitors is below 13*	Medium competition Total Imports of the US **None** Imports from Sri Lanka **None**	*Products* None	Low competition Total Imports of the US **USD 5,988 Mn** Imports from Sri Lanka **USD 352 Mn**	*Products* 610469, 620892, 621010 610130, 611231, 610831, 611693 621210, 611241, 611130, 620822

** 13 is the average number of competitors, i.e., total number of competitors divided by the number of products*
*** Duty free access to the US has been assessed as per 2018.*

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web; Tariff Data: World Bank, WITS Database, TRAINS Tariff Measures

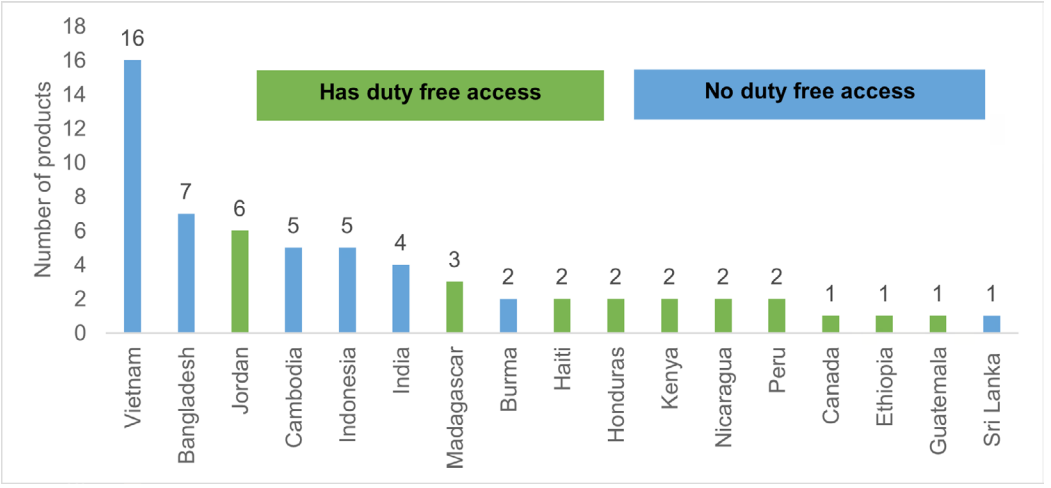

Figure 1. Competing countries that gained market share of more than 1% between 2015 and 2019 for the 21 products

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web; Tariff Data: World Bank, WITS Database, TRAINS Tariff Measures

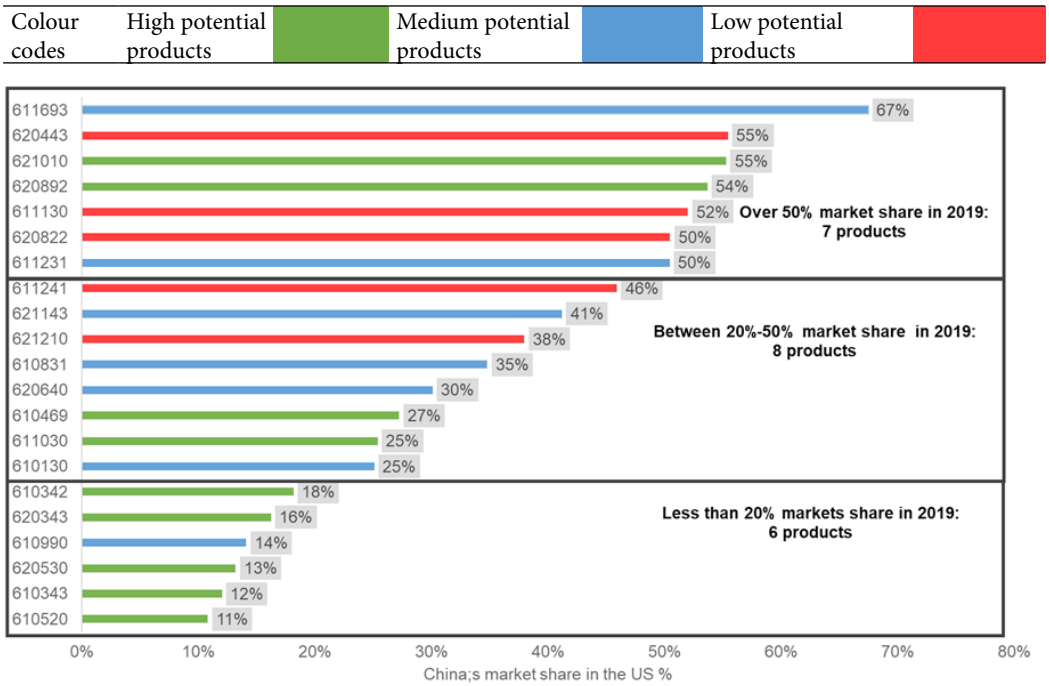

Figure 2. China's Market Share for the 21 products in 2019

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web

It is important to note however, that for most of the products identified as high potential products for Sri Lanka, the presence of China is relatively lower than for low potential products. As shown in Figure 2, for seven of the nine high potential products, China's share is below 30% in 2019. In contrast, for most of the low potential products, China remains the dominant supplier, with China accounting for over 45% of the imports into USA for four of the five low potential products.

4. DISCUSSION/CONCLUSION

4.1. Market for high potential products identified in this study has a large untapped and growing market in the US for Sri Lanka.

The current presence of Sri Lanka in the US market for the nine products classified as having high potential to benefit from this transition away from China is low. Sri Lanka's import share in the US market was 1.2%. These products accounted for 7.6% (USD 152 million) of total imports from Sri Lanka to the US a year on average during 2015-2019. Two products namely HS 611030 and 610520 accounts for 78% of the total value of imports from Sri Lanka of these nine products. However, it is important to note that the current size of the US market for these products is larger than the combined US market for products identified as having medium and low potential. Import of these nine high potential products accounted for 14.1% of total apparel imports of the US a year during 2015-2019 and the value of average annual value of imports into the US between 2015-2019 was USD 12 billion. In contrast the average US market between 2015-2019 for the seven medium potential products and the five low potential products were only valued at USD 6 billion and USD 5 billion, respectively.

Amongst these nine high potential products a single product, HS 611030 (Sweaters, pullovers, sweatshirts, vests and similar articles) accounted for 52% of the US market for the high potential products. The US market for this product was worth USD 6 billion in 2019. Total imports into the US have

increased on average by 2% despite a decline in imports from China of 3% during 2015-2019. Sri Lanka's market share of this product was 1.8% and the value of US imports of this product from Sri Lanka was USD 117 million in 2019. Imports from Sri Lanka has recorded a growth 3.7%, higher than the overall growth in imports of the product to the US market during 2015-2019. (refer Figure 3)

4.2. High potential products, however, face stiff competition from key suppliers other than China.

Four of the high potential products (611030, 610520, 620530, 610343) face high level of competition from suppliers other than China (refer Figure 4). Vietnam has emerged as the strongest competitor in all four products, with a market share of nearly 15% or higher and in general growing at a faster rate than

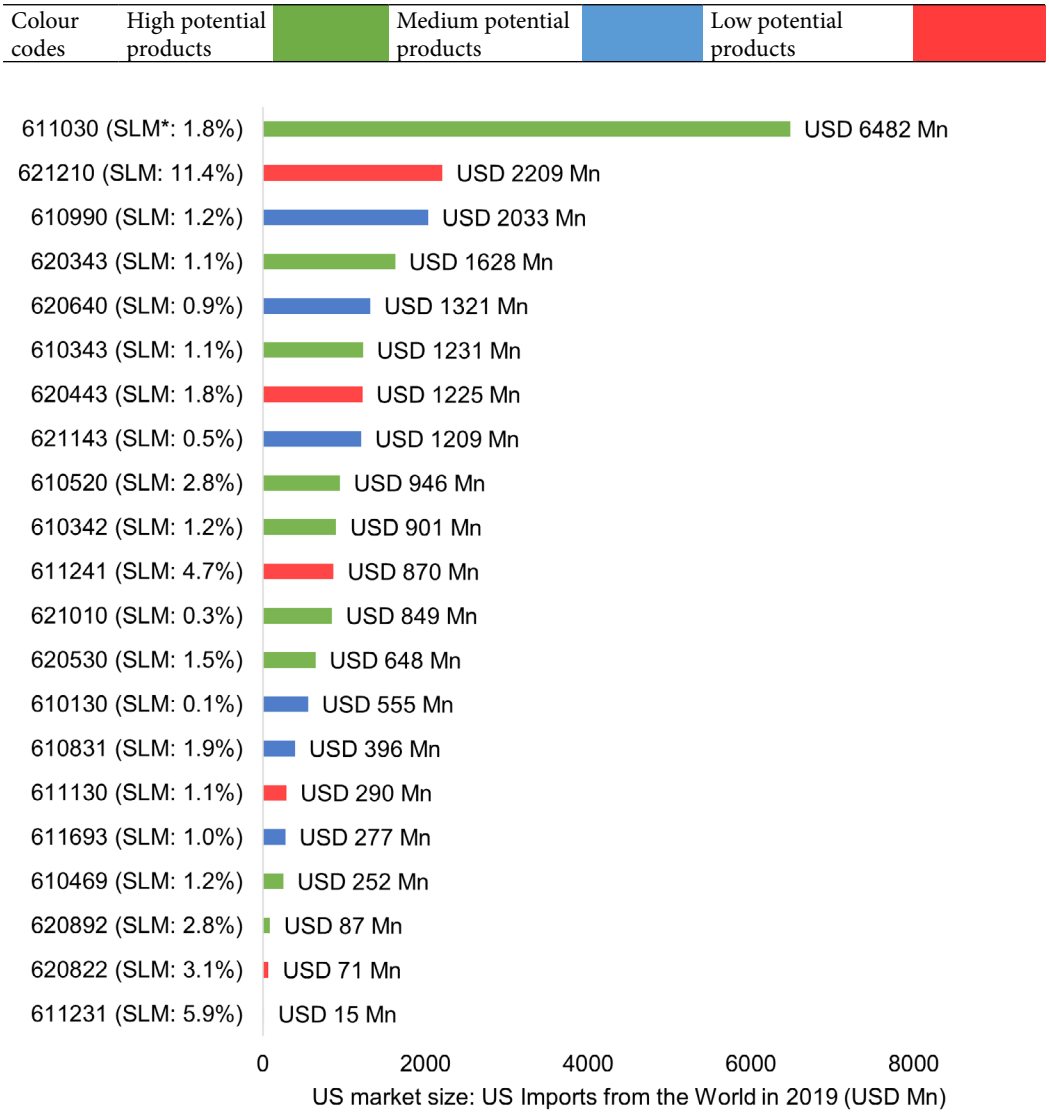

Figure 3. Value of the US market for the 21 products in 2019

** SLM: Sri Lanka's Market Share in the US*
Source: Import data of the US: United States International Trade Commission (USTIC) Data Web

Colour codes	High potential products		Medium potential products		Low potential products	
	High competition		Medium competition		Low competition	

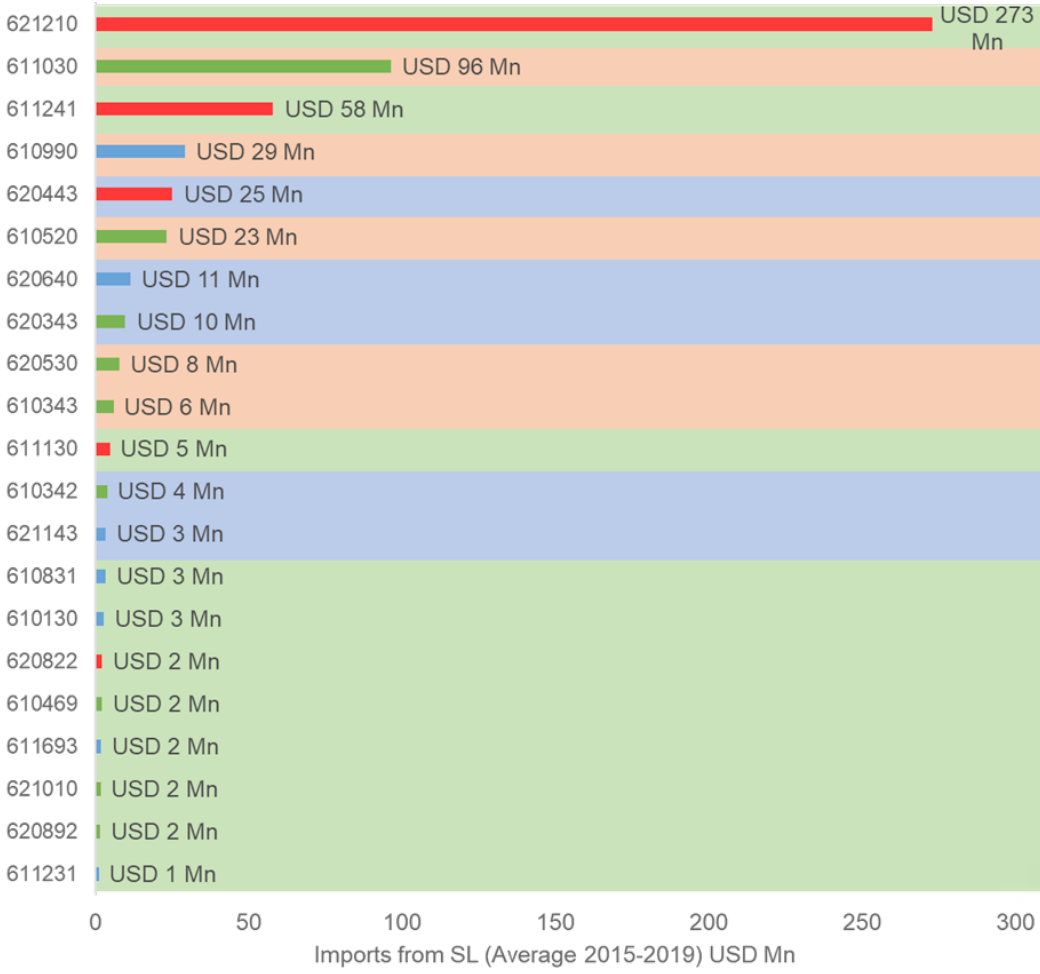

Figure 4. Summary of the 21 products by potential and level of competition

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web; Tariff Data: World Bank, WITS Database, TRAINS Tariff Measures

Sri Lanka. The other key competitors include countries such as Jordan, Egypt, Peru and Honduras, that has duty free access to the US market (refer Annex 2). While China remains one of the key suppliers of these four products, its presence is relatively low compared to other products (refer Figure 2). For three of the products, China's market share is less than 20% and for one product its 25%.

4.3. The analysis reveals that the relatively more important products for Sri Lanka in terms of export value have low potential to benefit from a possible US-China decoupling in apparel.

These products are in a market where overall import demand for the product in the US market has experienced a decline during 2015-2019 and imports from Sri Lanka also

have experienced a decline during the same period. The five products classified as low potential are worth 18% (USD 363 million) of total imports from Sri Lanka to the US a year on average during 2015-2019. As shown in Figure 4, the bulk of the value of imports from Sri Lanka for these low potential products are concentrated in three products (HS 621210, 611241, 620443). These three products can be considered important apparel products for Sri Lanka given the value of imports from Sri Lanka to the US accounting for 18% (USD 356 million) of total imports a year on average during 2015-2019.

The relatively high market share held by Sri Lanka for these products indicate that these are products where Sri Lanka has demonstrated competitiveness in the past compared to competitors. In fact, among these three low potential products is, Brassieres (HS 621210), the product which accounts for the largest share of apparel imported from Sri Lanka to US. This product alone accounted on average for 14% (USD 273 million) of total imports from Sri Lanka to the US a year during 2015-2019 and Sri Lanka maintained an average market share of 11.1% for this product in the US market. (refer Figure 4)

However, despite Sri Lanka having a high market share of this product in the US market, it has been classified as low potential as US imports from Sri Lanka has declined by 2.6% between 2015-2019 and it is operating in a declining US market with overall US imports for the product having declined by 3.6% during the same period. It is important to note however, that imports from China for the product has declined by a higher rate of 10.1% during the same period and in contrast to Sri Lanka, Vietnam seem to seem to have succeeded in becoming an alternative supplier to China in this product category. Although imports from Sri Lanka declined, imports from Vietnam have increased by 56.7% a year on average during 2015-2019. While in 2015 Sri Lanka was the leading supplier of this product to the US, over the last four years Vietnam has surpassed Sri Lanka having managed to increase its market share for the product from 2.1% in 2015 to 14.9% in 2019. During the same period, Sri Lanka's market share for the product has remained stagnant having increased by only 0.5 percentage points from 10.9% in 2015 to 11.4% in 2019.

4.4. Duty free access and proximity to the US market seem to be a less important factor that determines the sourcing decisions of US buyers.

The success of countries such as Vietnam, Bangladesh and Cambodia as alternative suppliers to China despite not having duty free access and not being in close proximity to the US market reveal that these factors are not the key determinants of sourcing decisions of US buyers. Overall Vietnam stands out as the most preferred alternative sourcing destination for US buyers seeking to diversify its supply base away from China, followed by Bangladesh, Jordan, Cambodia and Indonesia. It is notable that only Jordan out of these four have duty free access to the US market. (refer Figure 1)

4.5. Despite the visible decline of the value and share of imports during 2015-2019, China continues to be a strong competitor for seven of the 21 potential products.

China, despite the decline in import value, accounts for over 50% of the market for seven of the 21 products, indicating that it is by far the strongest competitor to any country supplying these products to the US. These include two of the products identified as high potential for Sri Lanka, two with medium potential and three identified as having low potential.

BIBLIOGRAPHY

Amiti, M., Kong, S. H., & Weinstein, D. E. (8 May 2020). *The Investment Cost of the U.S.-China Trade War*. Retrieved from Federal Reserve Bank of New York Liberty Street Economics: https://libertystreeteconomics.newyorkfed.org/2020/05/the-investment-cost-of-the-us-china-trade-war.html

Christensen, T. J. (2020, May). *A modern tragedy? COVID-19 and US-China relations.* Retrieved from The Brookings Institute Website: https://www.brookings.edu/wp-content/

uploads/2020/05/FP_20200511_covid_us_china_christensen_v3.pdf

Department of Census and Statistics (DCS). (2019a). *Annual Survey of Industries 2018,* Colombo: DCS.

Department of Census and Statistics (DCS). (2019b). *Labour Force Survey: Annual Report 2019,* Colombo: DCS.

Disis, J. (25 October 2020). *Trump promised to win the trade war with China. He failed*. Retrieved from CNN : https://edition.cnn.com/2020/10/24/economy/us-china-trade-war-intl-hnk/index.html

Rapoza, K. (7 April 2020). *New Data Shows U.S. Companies Are Definitely Leaving China*. Retrieved from Forbes: https://www.forbes.com/sites/kenrapoza/2020/04/07/new-data-shows-us-companies-are-definitely-leaving-china/?sh=7a536c8d40fe

The Economist. (8 October 2020). *The pandemic will not end globalisation, but it will reshape it*. Retrieved from The Economist: https://www.economist.com/special-report/2020/10/08/changing-places

U.S. International Trade Commision. (2020). *dataweb.usitc.gov: THE PREMIER SOURCE OF FREE U.S. TRADE & TARIFF DATA*. Retrieved from Dataweb: USITC: https://dataweb.usitc.gov/

U.S. International Trade Commission. (1January 2020). *Harmonized Tariff Schedule*. Retrieved from U.S. International Trade Commission: https://hts.usitc.gov/view/China%20Tariffs?release=2020HTSARev16

World Bank. (2018). *World Integrated Trade Solution (WITS) - Trains Tarrif Measures*. Retrieved from World Integrated Trade Solution (WITS): https://wits.worldbank.org/default.aspx

ANNEXES

Annex 1. 37 products that show early signs of sourcing being diverted away from China

HS Code	Growth in Imports (2015-2019)			Average Imports of the US (2015-2019)		
	World	China	Rest of World	World (USD Mn)	China (USD Mn)	Sri Lanka (USD Mn)
610130	1.7%	-4.0%	4.0%	506.6	156.2	2.7
610329	54.9%	-42.8%	228.8%	0.1	0.1	0.0
610332	-0.5%	-6.3%	11.7%	12.9	8.4	0.0
610342	8.3%	-6.5%	13.8%	716.9	182.1	3.7
610343	3.3%	-6.1%	5.0%	1129.4	170.3	5.8
610439	6.8%	-4.5%	15.4%	26.2	10.7	0.0
610444	-2.7%	-8.6%	1.6%	476.0	195.8	1.0
610469	2.2%	-7.0%	7.1%	250.3	83.3	2.1
610520	0.7%	-5.6%	1.6%	907.9	110.4	23.2
610690	-4.3%	-18.0%	7.7%	20.5	9.1	0.0
610829	14.2%	-1.0%	41.5%	1.7	1.0	0.1
610831	-2.4%	-10.1%	3.4%	402.7	172.3	3.3
610990	3.0%	-3.7%	4.3%	1922.5	302.7	29.0
611011	-4.8%	-9.9%	8.8%	397.6	284.1	0.3
611030	1.7%	-3.1%	3.6%	6279.2	1749.2	96.2
611130	-1.5%	-5.1%	3.2%	284.3	167.8	4.7
611231	1.4%	-1.1%	4.2%	14.7	8.0	1.0
611241	-1.0%	-2.4%	0.3%	895.6	440.6	57.8
611693	-1.1%	-3.2%	4.0%	251.9	174.1	1.8
620213	0.0%	-4.8%	8.3%	335.2	209.2	0.6
620332	-2.0%	-8.5%	2.8%	94.1	41.9	0.5
620343	3.4%	-4.7%	5.4%	1484.6	290.4	9.6
620443	-3.5%	-6.6%	1.1%	1312.6	779.8	25.1
620530	5.3%	-1.3%	6.6%	569.2	82.1	7.9
620620	0.3%	-6.7%	2.2%	6.5	1.1	0.0
620640	-1.7%	-7.5%	1.4%	1440.8	493.3	11.3
620729	-11.2%	-16.3%	5.4%	1.1	0.8	0.0
620822	-3.5%	-9.5%	5.6%	75.2	45.8	2.1
620892	5.5%	-1.8%	19.2%	79.6	51.9	1.5
621010	1.0%	-3.3%	8.0%	770.2	474.6	1.7
621040	0.9%	-3.1%	5.0%	671.2	332.7	0.0
621120	-3.8%	-22.2%	21.8%	5.9	3.2	0.0
621143	-1.1%	-3.7%	1.0%	1253.6	548.7	3.3
621210	-3.6%	-10.1%	1.8%	2456.9	1076.8	273.0
621320	-2.5%	-4.5%	8.5%	24.3	20.8	0.0
621520	-0.8%	-1.1%	5.1%	53.2	50.3	0.0
621710	1.6%	-0.8%	6.4%	168.3	108.7	0.2

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web

Annex 2. 21 selected products by potential

Source: Import data of the US: United States International Trade Commission (USTIC) Data Web; Tariff Data: World Bank, WITS Database, TRAINS Tariff Measures

Colour codes	High competition	Medium Competition	Low Competition
List of countries with duty-free access to the US		List of countries with no duty-free access to the US	
Canada; Colombia; Costa Rica; Dominican Rep; El Salvador; Ethiopia; Ghana; Guatemala; Haiti; Honduras; Israel; Jordan; Kenya; Lesotho Madagascar; Mexico; Morocco; Nicaragua; Peru Singapore; Tanzania		*Bangladesh; Bulgaria; Burma; Cambodia; Egypt; France; Hungary; India; Indonesia; Italy; Japan; Lebanon; Malaysia; Pakistan; Philippines; Poland; Portugal; Romania; South Korea; Spain; Sri Lanka; Taiwan; Thailand; Tunisia; Turkey; Ukraine; United Kingdom; Vietnam*	

HS Code	Product Description	Annual Average Value 2015-2019			Number of competitors	% of competitors with duty free access	Key Competitors (Countries with a minimum import value of USD 1 million or above a year between 2015-2019) sorted by market share
		Imports from Sri Lanka (USD Mn)	Growth of imports to the US from SL	Sri Lanka's Market Share			
High potential products							
611030	Sweaters, pullovers, sweatshirts, vests and similar articles	96.2	3.7%	1.5%	26	54%	Vietnam; Honduras; Jordan; Guatemala; El Salvador; Cambodia; Mexico; Nicaragua; Bangladesh; Haiti; Thailand; Sri Lanka; Kenya; Turkey; Dominican Rep; Peru; Italy; Portugal; Madagascar; Pakistan; Burma; Ghana; Ethiopia; Romania; Tanzania; France; United Kingdom
610520	Men's or boys' shirts of manmade fibres	23.2	3.5%	2.6%	15	73%	Vietnam; Jordan; Peru; Sri Lanka; Guatemala; Kenya; Madagascar; Tanzania; Ethiopia; South Korea; Nicaragua; Philippines; Ghana; Haiti; Turkey; Colombia
620343	Men's or boys' trousers, bib and brace overalls, breeches and shorts of synthetic fibres	9.6	37.0%	0.6%	22	41%	Vietnam; Bangladesh; Indonesia; Honduras; Nicaragua; Jordan; Haiti; Kenya; Cambodia; Philippines; India; Thailand; Sri Lanka; Turkey; Ethiopia; Madagascar; Taiwan; Italy; Burma; Portugal; Morocco; Costa Rica; Romania
620530	Men's or boys' shirts of manmade fibres	7.9	14.0%	1.4%	18	50%	Honduras; Vietnam; Bangladesh; Indonesia; Haiti; Nicaragua; Cambodia; India; Jordan; Sri Lanka; Madagascar; Kenya; Turkey; Italy; Colombia; Portugal; Thailand; Morocco; Ethiopia

HS Code	Product Description	Annual Average Value 2015-2019			Number of competitors	% of competitors with duty free access	Key Competitors (Countries with a minimum import value of USD 1 million or above a year between 2015-2019) sorted by market share
		Imports from Sri Lanka (USD Mn)	Growth of imports to the US from SL	Sri Lanka's Market Share			
610343	Men's or boys' trousers, bib and brace overalls, breeches and shorts of synthetic fibres	5.8	22.9%	0.5%	15	53%	Vietnam; Jordan; Egypt; Cambodia; Nicaragua; Haiti; Guatemala; Lesotho; Sri Lanka; Pakistan; Madagascar; Colombia; India; Italy; Turkey; Ethiopia
610342	Men's or boys' trousers, bib and brace overalls, breeches and shorts of cotton	3.7	58.9%	0.5%	18	33%	Vietnam; Honduras; Cambodia; Indonesia; Bangladesh; Malaysia; India; Jordan; Nicaragua; Guatemala; Thailand; Egypt; Sri Lanka; Turkey; Italy; Portugal; Canada; Burma; Singapore
610469	Women's or girls' trousers, bib and brace overalls, breeches and shorts of textile materials not elsewhere specified or included	2.1	14.4%	0.8%	11	36%	Vietnam; Indonesia; Jordan; Cambodia; Guatemala; Italy; Egypt; Turkey; Sri Lanka; Madagascar; El Salvador; India
621010	Garments, made-up of fabrics of felts and nonwovens	1.7	16.8%	0.2%	6	33%	Mexico; Vietnam; Cambodia; Burma; Dominican Rep; Sri Lanka; India
620892	Women's or girls' undershirts, briefs, panties, bathrobes, dressing gowns and similar articles of manmade fibres	1.5	10.1%	1.9%	4	0%	India; Vietnam; Cambodia; Indonesia; Sri Lanka
Medium potential products							
610990	T-shirts, singlets, tank tops and similar garments, of textile materials not elsewhere specified or included	29.0	-11.0%	1.5%	20	65%	Honduras; Nicaragua; El Salvador; Guatemala; Haiti; Jordan; Indonesia; Peru; Dominican Rep; Sri Lanka; India; Tanzania; Lesotho; Bangladesh; Thailand; Madagascar; Turkey; Pakistan; Ethiopia; South Korea; Morocco
620640	Women's or girls' blouses, shirts and shirt-blouses of manmade fibres	11.3	4.9%	0.8%	16	38%	Vietnam; Bangladesh; Turkey; Mexico; Sri Lanka; Italy; Cambodia; Morocco; Canada; Romania; Jordan; France; Colombia; Tunisia; Madagascar; Bulgaria; Japan
610831	Women's or girls' nightdresses and pyjamas of cotton	3.3	67.0%	0.8%	8	13%	Vietnam; India; Peru; Bangladesh; Indonesia; Pakistan; Sri Lanka; Philippines; Ukraine

HS Code	Product Description	Annual Average Value 2015-2019			Number of competitors	% of competitors with duty free access	Key Competitors (Countries with a minimum import value of USD 1 million or above a year between 2015-2019) sorted by market share
		Imports from Sri Lanka (USD Mn)	Growth of imports to the US from SL	Sri Lanka's Market Share			
621143	Women's or girls' garments not elsewhere specified or included, of manmade fibres	3.3	32.4%	0.3%	18	39%	Vietnam; India; Cambodia; Bangladesh; Haiti; Canada; Dominican Rep; Kenya; Italy; Morocco; Turkey; Egypt; Thailand; Sri Lanka; France; Madagascar; Jordan; United Kingdom; Portugal
610130	Men's or boys' overcoats, carcoats, capes, cloaks, anoraks, ski-jackets, and similar articles of manmade fibres,	2.7	-35.0%	0.5%	10	40%	Honduras; Jordan; Bangladesh; Cambodia; Egypt; India; Kenya; Sri Lanka; Pakistan; Dominican Rep; Italy
611693	Gloves not elsewhere specified or included, mittens and mitts, of synthetic fibres	1.8	11.6%	0.7%	6	17%	Vietnam; Indonesia; Cambodia; Canada; Bangladesh; India; Sri Lanka
611231	Men's or boys' swimwear of synthetic fibres,	1.0	-20.9%	6.9%	1	0%	Vietnam; Sri Lanka
Low potential products							
621210	Brassieres	273.0	-2.6%	11.1%	9	22%	Sri Lanka; Vietnam; Thailand; Bangladesh; Colombia; Italy; Burma; Lesotho; Turkey; Hungary
611241	Women's or girls' swimwear of synthetic fibres,	57.8	-15.2%	6.4%	7	43%	Vietnam; Sri Lanka; Colombia; Morocco; Italy; Canada; Portugal; Turkey
620443	Women's or girls' dresses of synthetic fibres,	25.1	-9.4%	1.9%	24	21%	Indonesia; India; Sri Lanka; Italy; Burma; France; Turkey; Canada; Cambodia; Romania; Israel; United Kingdom; Morocco; Portugal; Thailand; Spain; Bulgaria; Lebanon; Taiwan; Poland; Tunisia; Japan; Colombia; Hungary; Dominican Rep
611130	Babies' garments and clothing accessories of synthetic fibers,	4.7	-9.5%	1.6%	7	14%	Vietnam; Cambodia; Sri Lanka; Egypt; Philippines; Guatemala; India; Burma
620822	Women's or girls' nightdresses and pyjamas of manmade fibres,	2.1	-21.8%	2.8%	3	0%	Cambodia; Vietnam; Indonesia; Sri Lanka

Effects of food import restrictions on household expenditure and nutrition: Case of COVID-19 induced food import taxes in Sri Lanka

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ABSTRACT

Amidst the backdrop of the COVID-19 pandemic during March-August 2020, the Government of Sri Lanka reinforced already existing balance of payment induced checks on food imports comprising taxes, temporary suspensions, restrictions under open terms and even bans. Though recognised as a middle-income country, an average Sri Lankan household still spends 35% of its income on food, mostly comprising products with a high degree of import penetration. In terms of nutrients, 42%, 34% and 45% of energy, protein and fat, respectively is obtained from the consumption of imported food. Yet, the effects of changes in import policies on food prices and accessibility which affect cost of living as well as nutrition, remain instinctive without rigorous data analysis. To fill the research gap, this paper looks at the effects of potential accessibility to food at big and distinct policy changes on food imports as a COVID 19 pandemic policy response from Sri Lanka's perspective. Specific emphasis is given in analysing the effects of increase in Special Commodity Levy (SCL) on household food expenditure and nutrient intake. Results based on a simulation analysis with different assumptions on elasticity show, in the boundary case of perfect inelasticity, no change in level of consumption and the nutrient intake but over 25% increase in expenditure. In scenario 2 with only own price elasticities, 19.5% decrease in consumption and 2% decline in expenditure are observed. When adjustments to both own prices and prices of substitutes and complements are considered, the respective figures are 25.4% and 8%. In the last two scenarios, there likely is a clear drop in nutrient intake levels of energy, carbohydrate, protein, and crude fat.

Key words: Import taxes, Food imports, Household expenditure, COVID-19, Sri Lanka

1. INTRODUCTION

At the onset of the COVID19 pandemic, the government of Sri Lanka imposed several restrictions on imports. Initially, though the import of essential food commodities was facilitated (Extraordinary Gazette No 2167/10, 2020)[1], restrictions on imports of non-essential commodities were imposed almost immediately and some of these non-essential commodities comprised some food products as well. (Extraordinary Gazette No. 2170/5, No. 2171/5, No. 2171/2, No. 2173/12, 2020).

During March – August 2020, restricting imports spanned a gamut of policy instruments viz. import taxes (Special Commodity Levies), import bans, temporary suspensions and

1 All the Extraordinary Gazettes of Government of Sri Lanka are available at http://www.treasury.gov.lk

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restrictions on imports under open license. As it happens in almost all policy arguments, justification was that the objectives of these import restrictions were supposedly for larger set of objectives comprising boosting domestic agricultural production[2], saving foreign exchange to mitigate currency depreciation (Cabinet Decision, 28.05.2020; Central Bank of Sri Lanka, 2020; Extraordinary Gazette No 2171/5, 2020).[3] Subsequently, to offset the import restrictions, the government did provide tax concessions for some commodities (Extraordinary Gazette No 2176/20).[4] Yet, several import restrictions continued (Extraordinary Gazette No. 2202/7 and No. 2202/44).

There are different ways in which these import restrictions can affect the overall economy, and domestic production and household consumption and nutrition intake in particular. First, by reducing imports, they may contribute to foreign exchange savings, which in turn may lead to the appreciation of Sri Lankan rupee. Secondly, import controls reduce the total supply of commodities and increase the domestic prices of commodities at retail, wholesale, and farm-gate. The magnitude of the changes in retail, wholesale and farm-gate prices depend on the scale of change in the import duty rate, extent of substitutability between the imported item and domestic produce, degree of transmission of price shocks along the value chain and seasonality in agricultural production in the case of a tax hike. In the immediate to medium run, as retail and wholesale prices rise, the impact would be on the quantities bought and sold at retail and wholesale levels respectively. Thirdly, the changes in consumer expenditure will affect quantities of consumption and nutrition intake. Fourth, in the long run, there will be a producer response to the increased farm-gate prices and the profitability of domestic production of import substitutes. This results in an increase in local production and improve wellbeing of the farming community since they will be able to spend more on food consumption thus improving the intake of more nutrients. However, this profitability increase in farming and improved tax revenue is unlikely to compensate the losses to consumers at large and import restrictions entail a net loss to the overall economy of the country.

Several factors accentuate the impact of import price increase of food as an important concern. An average Sri Lankan household spends 35% of the income on food (Department of Census and Statistics, 2016). The food basket of Sri Lanka is highly import-dependent and the entire requirements of wheat and red lentils, along with 87% of sugar and 50% of milk and milk products imported. In terms of major nutrients, 42% of total energy, 34% of protein and 45% of fat are obtained from the consumption of imported food items as per the food balance sheets of Department of Census and Statistics, 2018). Hence, these changes in import policies could potentially have significant welfare effects in terms of cost of living as well as food security and nutrition.

In this paper, the likely effects of an increase in Special Commodity Levy (SCL) imposed during March – August 2020 are investigated in detail. SCL was first introduced in Sri Lanka in year 2007 under the Special Commodity Levy Act No. 48. When the SCL is imposed for a commodity and is in force, only that levy shall be levied in lieu of all other taxes. The all-encompassing feature of SCL, is considered to assess the potential effects of an increase on the food expenditure and possibly nutrition in Sri Lankan household. Furthermore, it should be noted that these import policy changes are also likely to have effects on the household income which would also have a bearing on purchase and consumption expenditure. Such income effects are not considered in this analysis.

This study also assumes that, imported items are perfect substitutes for domestic

2 https://economynext.com/sri-lanka-to-control-imports-except-oil-and-medicines-grow-vegetables-minister-63544/

3 https://www.businessnews.lk/2020/04/21/government-gazettes-extensive-list-of-import-restricted-items/

4 https://www.newsfirst.lk/2020/05/22/sri-lanka-lifts-import-bans-except-for-vehicles-in-covid-19-economic-recovery-plan/

produce and the total effect of the ad valorem tax is transferred to the consumer. The effects of the increase in retail price are evaluated under three scenarios; (a) perfectly inelastic demand (consumers do not make any adjustment to the level of consumption), (b) elastic demand (consumers do make adjustments to the level of consumption by looking only at the own price), and (c) elastic demand for own and cross prices (consumer adjust consumption levels by looking at prices of goods as well as prices of the substitutes and complements).

Global studies estimated effects of crises and policy responses on food consumption, household expenditure and nutrition. Weerahewa and Kodithuwakku (2011) analysed the effect of the global financial crisis in 2007-2009 on food prices, household food consumption patterns, expenditure on food and nutrient intake levels in Sri Lanka. An econometric model combined with a simulation analysis was used to show the possible effects on nutrient intake due to changes in world prices. Results specifically showed that mostly the urban households were adversely affected. Jensen and Miller (2008) examined the impact of increase of world food prices on consumption and nutrition of poor households in two Chinese provinces. The results showed that the overall nutritional impact of the global price increase was minimal on households as the domestic prices of staple foods remained low due to government intervention in grain markets. Moreover, there was a substitution where households were able to move towards buying cheaper foods. More recently, Martin et al. (2020) analysed the impact of COVID-19 on the consumption patterns of the households in United States and observed a significant drop in household savings and consumption and an increase in poverty levels from 17.1% to 25.9%.

COVID 19 crisis also led to several demand and supply shocks similar to traditional crises. Mottaleb et al. (2020) examined the food security and welfare impact of COVID-19 induced lockdown on daily wage workers both in the farm and nonfarm sectors in Bangladesh. The findings indicated that a one-day complete lockdown generates a US$ 64.2 million equivalent economic loss when the wage loss of the daily wage workers is considered.

Kansiime et al. (2020) assessed the implications of the COVID-19 pandemic on household income and food security in two East African countries i.e. Kenya and Uganda, using online survey data. It was found that more than two-thirds of the respondents experienced income shocks and food insecurity and the proportions increased by 38% and 44% in Kenya and Uganda respectively and in both countries the regular consumption of fruits decreased by about 30% during the COVID-19 pandemic. It is evident that studies have emerged in analyzing the impact of COVID 19 effects on food markets. However, an analysis or a research paper relevant to specific analysis of the effects of policy changes on food prices, food access and nutrition is presently not available. This is the first study to examine the impact of Sri Lanka's import restrictions on household expenditure and nutrition during a crisis.

2. METHODOLOGY

2.1. Assessing the effects of price changes on consumption expenditure

Assessing the effects of price changes on household welfare is a core area in economic analysis. Minot (2010) used an approximate measure of consumer surplus (size of price change and the consumption level) to quantify the welfare effects of food price changes in Sub-Saharan Africa. Following Singh et al. (1986) and Deaton (1989), Ivanic and Martin (2008) examined the welfare effects of higher food prices on households in nine developing countries by applying the commodity price and wage changes to individual households' net sales of staple foods to calculate the changes in revenue and expenditure.

Based on a review of literature, the authors developed a simple conceptual model to discuss the likely effects of import taxes on households. Increase in SCLs has an incremental effect on the cost of imports and in turn has an effect on domestic prices. Consumers respond to price changes by changing quantities of

consumption. Increase of price can lead to a change in expenditure if the reduction in quantity change does not compensate for the price rise.

The direction and the magnitude of the change in expenditure depends on the own-price[5] and cross-price elasticities[6] and the magnitude of the price hike. If the demand is perfectly inelastic, there would not be a change in consumption levels and the percentage change in food expenditure will be same as the percentage change in own price. When the demand is perfectly elastic, consumers stop consuming the commodity in response even to a small price change. Food demand elasticities can range from perfectly elastic to perfectly inelastic and usually demand is comparatively inelastic for staple and/or essential food and more elastic in the case of luxury food items.

Figures 1 and 2 illustrate the possible changes in expenditure caused by a rise in SCL of a commodity.

In Figure 1, P_2-P_1 depicts the rise in price due the increase in SCL for a particular commodity. The pre-COVID price, quantity and expenditure are given by P_1, Q_1 and area of P_1 A Q_1 O respectively. In scenario 1 where demand is perfectly inelastic in price, the quantity is not changed and the expenditure is increased (P_2 B Q_1 O>P_1 A Q_1 O). If the price is elastic but the cross-price effects are zero (scenario 2) the expenditure may increase (P_1 A Q_1 O <P_2 C Q_2 O) or decrease (P_1 A Q_1 O <P_2 C Q_2 O) depending on the price change resulting from the rise in SCL and the slope of the demand curve.

When price increases, the expenditure would decrease if the demand is elastic and the opposite will occur if the demand is

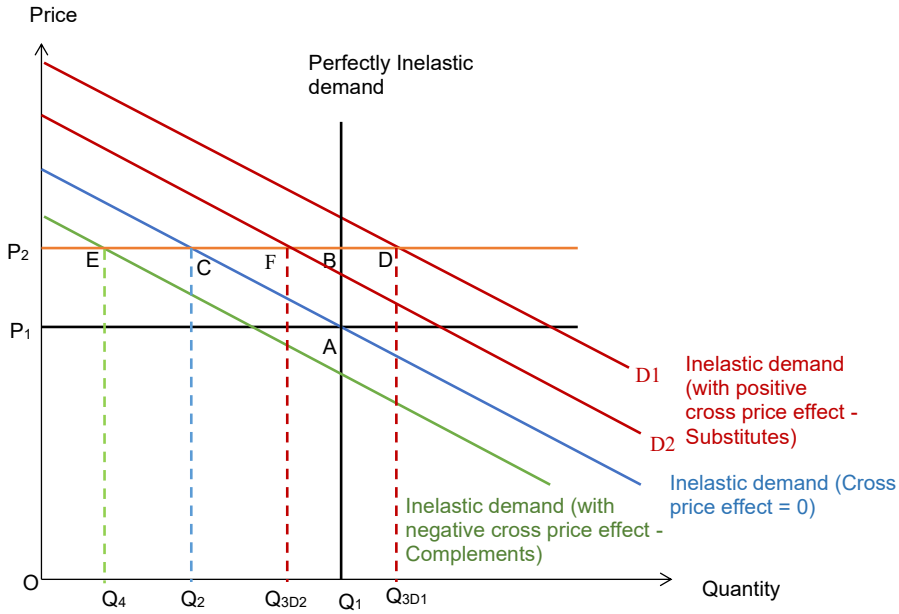

Figure 1. Change in expenditure due to the rise in price

5 The own price elasticity of demand is the percentage change in the quantity demanded of a good or service divided by the percentage change in the price. This shows the responsiveness of the quantity demanded to a change in price.

6 The cross elasticity of demand is the responsiveness in the quantity demanded of one good when the price for another good changes.

inelastic. Scenario (3) considers a situation cross price effects are non-zero (i.e., substitutes or complements exist). Suppose that price of a complementary good also rises. Then the demand of the commodity is further decreased due to cross price effect and this is in addition to the own price effect. This results in a decrease in the expenditure on the commodity (P_2 E Q_4 O < P_1 A Q_1 O). The demand curve D1 shows a case of an increase in a substitute. This results in an increase in demand despite the increase in own price and hence will lead to an increase in expenditure on a commodity (P_2 D Q_{3D1} O > P_1 A Q_1 O). The demand curve D2 shows a case of a smaller increase in price of a substitute which cause a decrease in quantity demanded. In this situation expenditure can be decreased (P_2 F Q_{3D2} O < P_1 A Q_1 O).

Figure 2 further illustrates the possible changes in the expenditure for a particular commodity (X) owing to a rise in price. The top panel of the figure shows the demand curve for commodity X and the lower panel shows the expenditure of the commodity corresponding to the demand curve. The pre-COVID or SCL status quo expenditure of the commodity can be placed either at A, B or C in Figure 2 depending on the price and quantity demanded at the prevalent time.

Assume the pre COVID expenditure was at level depicted by C. Due to the increase in price, expenditure of the commodity X moves from C to A causing an increase in the expenditure and a decrease in the consumption level. In contrast, if the pre-COVID expenditure was at A, an increase in price due to the SCL hike, causes a decrease in expenditure and the consumption level moving from A to point B. A similar movement takes place if the starting point was B, as well.

We use this framework, to perform the analysis of the effects of the increase in SCLs in response to COVID-19 on the average monthly household expenditure in Sri Lanka.

A simulation analysis was carried out to assess the effects considering the changes in retail prices of food items owing to changes in SCL rates i.e., the policy shock. For this analysis, increase of SCLs in food items during the period from 18th March to 26th June 2020 are considered. They include increase in SCL of vegetable oils on 09th April 2020 (Extraordinary Gazette No 2170/5), Fruits on 16th April 2020 ((Extraordinary Gazette No 2171/2), Big Onion on 30th April 2020 (Extraordinary Gazette No 2173/12), commodities under 69 HS code headings (6 and 8 digits) on 21st April 2020 (Extraordinary Gazette No 2176/18)

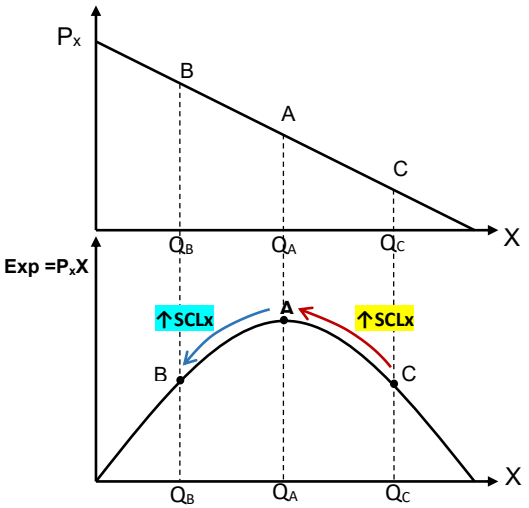

Figure 2. Change in expenditure in commodity X due to an increase in SCL considering own price elasticities

and vegetable fats and oils on 16th June 2020 (Extraordinary Gazette No 2180/11).

2.2. Data and Data sources

SCL levels and unit vales: SCL levels which were in place before COVID -19 outbreak and during the study period were obtained from the Extraordinary Gazettes and the unit values of the commodities at HS 8-digit level, for the most recent year available (2015) in the International Trade Centre's website of Trade statistics for international business development namely Trade Map.

Average household expenditure on food commodities: Average household expenditure of pre COVID-19 period were extracted from the Household Income and Expenditure Survey (HIES) report of 2016 by Department of Census and Statistics. As the HIES does not provide data at HS levels, matching the HIES commodity levels and HS levels were done through hand coding.

Elasticity estimates: The estimates of demand elasticities with respect to own price and cross prices were obtained from Lokuge et al. (2019). HIES commodity levels were aggregated to complement 10 product categories used by Lokuge et al. (2019), namely: fruits, dry fish, fresh fish, vegetables, edible oils, dairy products, sugar, pulses, maize, and potato. Annex 1 shows the approximations made in assigning elasticity values and Table 1 shows the average elasticity estimates for different food categories. In Table 1 the diagonal elements show the own price elasticities and other elements show the cross-price elasticities.

Nutrient intake levels: Food-nutrient conversion factors for calculating levels of energy and protein intake were obtained from standard food composition tables compiled by Biodiversity for Food and Nutrition Project Sri Lanka[7] and Standards Tables of Food Composition in Japan (2015). The nutrient composition of the item levels of HIES were extracted and averaged across the final product categories. Table 2 shows the average nutrient composition of the different food categories.

2.3. Calculating Price Changes

Using the unit values of the commodities prior to the crisis, the previous and new SCLs were obtained as ad valorem tax levels.

$$SCL\ as\ an\ ad\ valorem\ tax = \frac{SCL\ rate}{unit\ value} \times 100$$

Table 1. Elasticity estimates of demand with respect to price

	Fruits	Dry fish	Fresh fish	Vegetables	Edible oils	Dairy products	Sugar	Pulses	Maize	Potato
Fruits	-0.83	-0.04	0.03	-0.06	-0.01	0.03	0.00	0.00	-0.04	0.00
Dry fish	-0.02	-0.51	-0.01	-0.05	-0.03	0.02	0.00	-0.07	-0.09	0.04
Fresh fish	0.05	-0.02	-0.98	0.03	-0.07	0.14	0.00	0.06	-0.07	-0.07
Vegetables	-0.10	-0.02	0.00	-0.71	-0.06	-0.03	0.00	-0.09	-0.08	-0.02
Edible oils	-0.10	0.03	-0.10	-0.03	-0.66	-0.16	0.00	-0.04	0.02	-0.09
Dairy products	-0.03	0.05	0.07	0.05	0.00	-0.98	0.00	-0.07	-0.01	-0.06
Sugar	0.00	0.00	0.00	0.00	0.00	0.00	-0.86	0.00	0.00	0.00
Pulses	-0.06	-0.01	0.00	-0.01	-0.04	-0.11	0.00	-0.67	0.01	-0.01
Maize	-0.22	-0.14	-0.17	-0.15	0.02	-0.19	0.00	-0.09	-0.67	0.03
Potato	-0.02	0.02	-0.02	0.01	-0.02	-0.03	0.00	0.00	0.01	-0.88

Source: Lokuge et al. (2019)

7 http://bfnvw.bfnsrilanka.org/foodcomp/

Table 2. Average nutrient composition of the different food categories

	Energy (kcal/100g)	Carbohydrate (g/100g)	Protein (g/100g)	Crude Fat (g/100g)
Fruits	137.14	16.73	4.37	5.96
Dry fish	182.67	0.73	27.93	7.30
Fresh fish	156.00	0.10	20.70	7.20
Vegetables	70.75	14.13	3.05	0.23
Edible oils	832.25	22.37	1.35	70.09
Dairy products	52.50	9.05	2.20	0.95
Sugar	387.00	100.00	0.00	0.00
Pulses	342.00	58.87	20.83	2.55
Maize	363.00	71.00	10.00	4.50
Potato	97.00	22.60	1.60	0.10

Source: Biodiversity for Food and Nutrition Project Sri Lanka (undated) and Standards Tables of Food Composition in Japan (2015)

Next the pre- and post-COVID-19 retail prices were calculated assuming the total effect of the ad valorem tax is transferred to the consumer. In reality, due to market frictions or other policies the consumer prices may rise fully with SCL or may increase partially. Assuming full pass through, the increase in prices is as follows;

$$Retail\ price = unit\ value\left(1+\frac{ad\ valorem\ tax}{100}\right)$$

The change in retail prices owing to the new SCL rates were calculated as a percentage.

2.4. Simulation analysis

The effects on the average monthly household expenditure and nutrient intake are analysed considering three scenarios pertaining to elasticity measures. The demand for a product is assumed to be perfectly inelastic in the first scenario and less than zero in the second scenario. In both these cases the cross-price elasticities were considered as zero. In the third scenario, while own price elasticities being treated as less than zero, the cross-price elasticities were considered as non-zero.

The change in consumption is given by;

$$\%\Delta Q_i = \eta_i * \%\Delta P_i + \sum \eta_c * \%\Delta P_c$$

Where,

$\%\Delta Q_i$ = Percentage change in consumption of i^{th} food commodity

$\%\Delta P_i$ = Percentage change in price of i^{th} food commodity

η_i = Own price elasticity of demand

η_c = Cross price elasticity of demand

The levels of expenditure are given by;

$$\hat{E} = \left\{\bar{Q}_i * \left(1+\frac{\%\Delta Q_i}{100}\right)\right\} * \hat{P}_i$$

Where,

$\hat{E}$ = Expenditure for i^{th} food commodity post policy change

$\bar{Q}_i$ = Level of consumption of the i^{th} food commodity before the policy change

$\hat{P}_i$ = Price level of i^{th} food commodity during the crisis

In scenario 3 where, cross price elasticities are taken into account, the simulation model for demand of each food commodity was calibrated using the elasticity matrix, pre

COVID-19 prices and the consumption levels with coefficients and intercept obtained.

The level of consumption during the COVID-19 period is predicted by.

$$\hat{Q}_i = \beta_0 + \beta_i \hat{P}_i + \sum \beta_{ij} \hat{P}_j$$

Where,

$\hat{Q}_i$ = Level of consumption of the ith food commodity during the crisis
β_0 = Intercept
β_i = Coefficient of the own price of ith food commodity
β_{ij} = Coefficient of the price of jth food commodity with respect to ith food commodity
$\hat{P}_j$ = Price of level of jth food commodity which is a substitute/complement of the ith commodity

Change in nutrient intake is given by;

$$\%\Delta N_k = \frac{\sum(\alpha_i \hat{Q}_i - \alpha_i \bar{Q}_i)}{\sum \alpha_i \bar{Q}_i} * 100$$

Where,

$\%\Delta N_k$= Percentage change in nutrient intake of kth nutrient
α_i = Composition of the kth nutrient in 100g of the ith food commodity

3. RESULTS AND DISCUSSION

3.1. Changes in level of prices and consumption

Compared to the pre COVID-19 price averages after the policy change, the highest price change due to the SCL hike was recorded for edible oils (73.52%) followed by potatoes (42.37%), maize (33.07%), vegetables (25.56%), fruits (22.93%), dairy products (15.74%), sugar (15.40%) and dry fish (12.51%). The lowest changes were recorded for fresh fish (6.51%) and pulses (4.57%). In computing the above changes, it was implicitly assumed that SCL effect is fully passed on to the consumer.

The pre-COVID 19 consumption levels and percentage change in consumption levels after increasing the SCLs are given in Table 3. In scenario 1 where the price responses are treated as perfectly inelastic, the consumption levels remained unchanged whereas in the 2nd and 3rd scenarios where price elasticities are considered as less than zero, a clear drop in the quantity demanded in every food category could be observed. Edible oils and potatoes recorded the largest decrease of consumption in both scenarios 2 and 3 which was 48.52% and 37.29% decrease in scenario 2 and 51.49% and 44.37% in scenario 3. The lowest drop in consumption levels was observed in dry fish (6.38%), fresh fish (6.38%) and pulses (3.06%) in scenario 2, and in pulses (12.87%), dairy products (10.63%) and dry fish (7.93%) in scenario 3. The total consumption of all food

Table 3. Changes in level of consumption of each food category due to the increase in the SCL

	Level of consumption after imposing SCL (kg)		
	Scenario 1 (perfectly inelastic demand)	**Scenario 2 (inelastic demand-own price effect)**	**Scenario 3 (inelastic demand- with cross price effect)**
Fruits	0.08 (0.00)	0.07(-19.05)	0.05 (-37.76)
Dry fish	0.27 (0.00)	0.26 (-6.38)	0.25 (-7.93)
Fresh fish	0.26 (0.00)	0.25 (-6.38)	0.22 (-18.54)
Vegetables	0.99 (0.00)	0.81 (-18.15)	0.74 (-25.96)
Edible oils	0.60 (0.00)	0.31 (-48.52)	0.29 (-51.49)
Dairy products	0.07 (0.00)	0.06 (-15.42)	0.06 (-10.63)
Sugar	3.14 (0.00)	2.73 (-13.24)	2.73 (-13.24)
Pulses	3.32 (0.00)	3.22 (-3.06)	2.89 (-12.87)
Maize	0.08 (0.00)	0.06 (-22.16)	0.06 (-24.92)
Potatoes	3.72 (0.00)	2.33 (-37.29	2.07 (-44.37)

Percentage change of level of consumption is given in parentheses.
Source: Authors' calculations

commodities under consideration, reduced by 19.57% in scenario 2 where only own price elasticities were considered. Similarly, a decrease of 25.42% in total consumption of the commodities was observed in scenario 3 with the cross-price effects.

3.2. Change in average monthly household expenditure

Table 4 depicts the pre COVID-19 average expenditure, expenditure after the SCL is imposed and the percentage change in monthly household expenditure for each food commodity under consideration.

The total change in the expenditure for commodities which underwent SCL hikes are also shown in Table 4. In scenario 1, a clear increase of 25.41% was observed due to the perfectly inelastic price response whereas, both other scenarios showed a decrease in expenditure by 1.96% and 7.99% in scenario 2 and 3, respectively after imposing the new SCL. The change in total food expenditure of a household in Sri Lanka is also calculated, keeping the rest of the food expenditure unchanged. An increase of 2.88% was observed in the first scenario and a drop of 0.22% and 0.96% was observed in scenario 2 and 3, due to the control of imports through SCL hikes.

Considering the change in the expenditure of food commodities, under scenario 1, the highest increase in expenditure was observed for edible oils (73.52%), followed by potatoes (43.37%) and maize (33.07%) and the lowest increases were observed for pulses (4.57%) and fresh fish (6.51%). The increase in expenditure in scenario 1 is identical to the increase in the price levels due to the SCL. In scenarios 2 and 3, the changes in expenditure levels across commodities are varied.

In scenario 2, increases in the expenditure levels were observed in dry fish (5.33%), maize (3.59%), vegetables (2.77%), pulses (1.37%) and sugar (0.12%) and decreases were observed for potatoes (-10.72%), edible oils (-10.68%), dairy products (-2.11%), fruits (-0.47%) and fresh fish (-0.29%). Increases in the expenditure levels were observed for dry fish (3.59%), dairy products (3.43%) and sugar (0.12%) in scenario 3 and decreases were observed for fruits (-23.47%), potatoes (-20.80%), edibles oils (15.82%), fresh fish (-13.23%), pulses (-8.88%), vegetables (7.03%) and maize (-0.09%).

Table 5 shows the complements and the substitutes of each commodity as reflected by the price elasticities and respective change in price and the change in expenditure on the commodity. The changes in expenditure

Table 4. Change in average monthly household expenditure due to the increase in the SCL

	Pre-COVID expenditure (Rs.)	Post-COVID expenditure (Rs.)		
		Scenario 1 (perfectly inelastic demand)	Scenario 2 (inelastic demand-own price effect)	Scenario 3 (inelastic demand- with cross price effect)
Fruits	25.21	31.00 (22.96)	25.09 (-0.47)	24.03 (-23.47)
Dry fish	205.80	231.55 (12.51)	216.77 (5.33)	204.51 (3.59)
Fresh fish	202.85	216.06 (6.51)	202.27 (-0.29)	188.69 (-13.23)
Vegetables	173.79	218.22 (25.56)	178.61 (2.77)	153.88 (-7.03)
Edible oils	341.85	593.18 (73.52)	305.36 (-10.68)	250.84 (-15.82)
Dairy products	116.57	134.91 (15.74)	114.11 (-2.11)	112.06 (3.43)
Sugar	417.34	481.59 (15.40)	417.83 (0.12)	417.83 (0.12)
Pulses	401.64	420.00 (4.57)	407.14 (1.37)	379.74 (-8.88)
Maize	3.67	4.88 (33.07)	3.80 (3.59)	3.20 (-0.09)
Potatoes	219.34	312.28 (42.37)	195.84 (-10.72)	190.54 (-20.80)
Total		2,643.67 (25.41)	2,066.82 (-1.96)	1,939.59 (-7.99)
Rest	17,005	17,005	17,005	17,005
Total food expenditure	19,114	19,649 (2.80)	19,072 (-0.22)	18,931 (-0.96)

Source: Authors' calculations

Table 5. SCL induced price increases of substitutes and complements

Commodity	% Change in Expenditure	Complements			Substitutes		
		Commodity	Elasticity	% change in price	Commodity	Elasticity	% change in price
Fruits	-23.47	Edible oils	-0.10	73.52	Fresh fish	0.05	6.51
		Potatoes	-0.02	42.37			
		Maize	-0.22	33.07			
		Vegetables	-0.10	25.56			
		Dairy products	-0.03	15.74			
		Dry fish	-0.02	12.51			
		Pulses	-0.06	4.57			
Dry fish	3.59	Maize	-0.14	33.07	Edible oils	0.03	73.52
		Vegetables	-0.02	25.56	Potatoes	0.04	42.37
		Fruits	-0.04	22.96	Dairy products	0.05	15.74
		Fresh fish	-0.02	6.51			
		Pulses	-0.01	4.57			
Fresh fish	-13.23	Edible oils	-0.10	73.52	Fruits	0.03	22.96
		Potatoes	-0.02	42.37	Dairy products	0.07	15.74
		Maize	-0.17	33.07			
		Dry fish	-0.01	12.51			
Vegetables	-7.03	Edible oils	-0.03	73.52	Potatoes	0.01	42.37
		Maize	-0.15	33.07	Dairy products	0.05	15.74
		Fruits	-0.06	22.96	Fresh fish	0.03	6.51
		Dry fish	-0.05	12.51			
		Pulses	-0.01	4.57			
Edible oils	-15.82	Potatoes	-0.02	42.37	Maize	0.02	33.07
		Vegetables	-0.06	25.56			
		Fruits	-0.01	22.96			
		Dry fish	-0.03	12.51			
		Fresh fish	-0.07	6.51			
		Pulses	-0.04	4.57			
Dairy products	3.43	Potatoes	-0.03	42.37	Edible oils	0.16	73.52
		Maize	-0.19	33.07	Fruits	0.03	22.96
		Vegetables	-0.03	25.56	Dry fish	0.02	12.51
		Pulses	-0.11	4.57	Fresh fish	0.14	6.51
Pulses	-8.88	Edible oils	-0.04	73.52	Fresh fish	0.06	6.51
		Maize	-0.09	33.07			
		Vegetables	-0.09	25.56			
		Dairy products	-0.07	15.74			
		Dry fish	-0.07	12.51			
Maize	-0.09	Vegetables	-0.08	25.56	Edible oils	0.02	73.52
		Fruits	-0.04	22.96	Potatoes	0.01	42.37
		Dairy products	-0.01	15.74	Pulses	0.01	4.57
		Dry fish	-0.09	12.51			
		Fresh fish	-0.07	6.51			
Potatoes	-20.80	Edible oils	-0.09	73.52	Maize	0.03	33.07
		Vegetables	-0.02	25.56	Dry fish	0.04	12.51
		Dairy prod ucts	-0.06	15.74			
		Fresh fish	-0.07	6.51			
		Pulses	-0.01	4.57			

associated with scenario 3, in which own price and cross price effects are considered, are given in Table 5.

It can be observed that the composite effect of the price changes in the respective complementary goods, may have resulted in the decrease in expenditure in the commodities such as fruits, fresh fish, vegetables, edible oils, dairy products, pulses, maize and potatoes. For example, the decrease in expenditure of fruits may have resulted due to the composite complementary effect of edible oils, potatoes, maize, vegetables, dairy products, dry fish and pulses and the change in prices which is larger than the effect of price hikes in substitutes.

The decrease in expenditure on the same commodities can be explained using the substitution effect which is the case of a small price increase in substitute commodities (see D2 inFigure 1). When considering the example of maize, the composite complementary effect of vegetables, fruits, dairy products, dry fish, and fresh fish may have overridden the effect of a larger price change in substitutes, which such are edible oils, potatoes and pulses. The price increase of those substitutes may be smaller than the price increase in maize. Hence the consumers would move away from maize resulting a decrease in expenditure.

Where a large price change in a substitute commodity results in an increase in the expenditure of the commodity which can be observed in dry fish and dairy products. In dry fish, the composite effect of the large price change of the substitutes which are edible oils, potatoes and dairy products, may have caused the increase in expenditure on dry fish and this effect may have overridden the composite effect of the price changes in the complements such as, maize, vegetables, fruits, fresh fish and pulses.

3.3. Change in nutrient intake.

The average energy intake from products under consideration prior to COVID-19 was 34,211.3 kilo calories of energy, 6294 grams of carbohydrate, 934 grams of protein and 561.9 grams of crude fat. After imposing the SCL, a change in nutrient intake was not observed in scenario 1 given the limiting condition of perfect inelasticity. A decrease in nutrient intake was observed in scenarios 2 and 3. A total decrease of 17.6% in energy intake, 14.2% in carbohydrate intake, 6.8% in protein intake and 38.1% in crude fat intake was observed in scenario 2 where only own price elasticities were considered. Similarly, a decrease of 22.4%, 18.5%, 15.8% and 42.5% of energy, carbohydrate, protein, and crude fat intake respectively was observed in scenario 3.

The largest drop in nutrient intake was observed for crude fat in both scenarios. This may have resulted mostly due to the drop of consumption levels coupled with a large price increase of edible oil which accounts for a 75% of the total crude fat spread out among the 10 identified food products (Table 2). The second major drop was observed in energy levels. As 35% and 33% of the energy intake is supplied by sugar and pulses respectively and the drop in consumption levels of these commodities may have caused the energy drop to a greater extent. Reduction of carbohydrates may have mostly resulted from the reduction in the consumption levels of sugar and pulses as sugar contributed for 50% and pulses contributed for 31% of the carbohydrate intake based on the identified list of food products. Pulses which accounted for 74% of the total protein intake from the products under consideration, is a likely factor causing the drop in protein levels.

4. SUMMARY AND CONCLUSIONS

The study evaluated the changes in levels of consumption, average expenditure, and the nutrient intake of the households in Sri Lanka due to the increases in SCL by the government as a response to COVID-19 global pandemic, during the period of March – August 2020. The analysis was performed for 54 HS commodities which were aggregated into 10 product categories considering 3 scenarios pertaining to elasticity measures. In the first scenario, which reflected immediate responses of consumers, commodities were considered as perfectly inelastic in the price response and

therefore, there were not any changes observed in the level of consumption and with regard to the nutrient intake, a 25.4% increase in the level of expenditure was observed.

In scenario 2, which captures short run response, a decline in the level of expenditure by 1.96% and 19.5% decrease in the level of consumption based only on own price elasticities was identified. In scenario 3, which captures medium run responses, where both own and cross price effects are considered, a decline of 25.4% and 7.99% was observed in the level of consumption and expenditure, respectively. In both cases a clear drop of nutrient intake in terms of levels of energy, carbohydrate, protein, and crude fat was also observed.

From these findings, it can be concluded that the increase in SCL may have caused an adverse impact on the welfare of households in Sri Lanka in terms of reduction in levels of consumption and the intake of nutrients. Reduction in nutrient intake could have a negative impact on the poverty levels and long-term impact with regard to the formation of human capital.

It should be noted that the results of the present study have slightly over-estimated the adverse effects of food import restrictions on the intake of nutrients since it has not considered the likely impact of increase in farm-gate prices on domestic production of import substitutes and the nutritional effects of related consumption. Therefore, further studies in evaluating long term effects of food import restrictions, taking into consideration the adjustments made by the farming community, is recommended. However, authors are of the view that even if such beneficial effects are included, there will be considerable negative effects on the consumption of food and nutrient intake by the affected populace in the country, owing to the imposition of restrictions on importation of identified foods.

REFERENCES

Cabinet decisions (28.05.2020). Retrieved from https://www.dgi.gov.lk/news/cabinet-decisions/2035-cabinet-decisions-2020-05-28-2020-05-29

Central Bank of Sri Lanka (2020). BOX 2: COVID-19 and Sri Lanka: challenges, policy responses and outlook. In *Annual report 2019*. Retrieved from https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/annual_report/2019/en/13_Box_02.pdf

Deaton, A. (1989). Rice prices and income distribution in Thailand: a non-parametric analysis. *The economic journal, 99*(395), 1-37. doi: 10.2307/2234068

Department of Census and Statistics (2016). *Household income expenditure survey report of Sri Lanka*. Colombo, Sri Lanka: Department of Census and Statistics.

Department of Census and Statistics (2018). *Statistical abstract of the democratic socialist republic of Sri Lanka*. Colombo, Sri Lanka: Department of Census and Statistics.

Ivanic, M., & Martin, W. (2008). *Implications of higher global food prices for poverty in low-income countries*. Policy Research Working Paper No. 4594. Washington DC: World Bank. doi: 10.1596/1813-9450-4594

Jensen, R. T. and Miller, N. H. (2008). The impact of food price increases on caloric intake in China. *Agricultural economics, 39*, 465-476. doi: 10.1111/j.1574-0862.2008.00352.x

Kansiime, M. K., Tambo, J. A., Mugambi, I., Bundi, M., Kara, A., & Owuor, C. (2020). COVID-19 implications on household income and food security in Kenya and Uganda: Findings from a rapid assessment. *World development*, *137*, 105199. doi: 10.1016/j.worlddev.2020.105199

Lokuge, M. N., Zivkovic, S., Lange, K., & Chidmi, B. (2019). Estimation of a censored food demand system and nutrient elasticities: a cross-sectional analysis of Sri Lanka. *International food and agribusiness management review*, *22*(5), 717-730. doi: 10.22004/ag.econ.292444

Martin, A., Markhvida, M., Hallegatte, S., & Walsh, B. (2020). Socio-economic impacts of COVID-19 on household consumption and poverty. *Economics of disasters and climate change, 4*(3), 453-479. doi: 10.1007/s41885-020-00070-3

Ministry of Finance (n.d.), *Extraordinary gazettes of Democratic Socialist Republic of Sri Lanka.* Retrieved from http://oldportal.treasury.gov.lk/circulars-gazettes-acts

Minot, N. (2010). *Transmission of world food price changes to African markets and its effect on household welfare*. Paper to be presented at

the COMESA policy seminar "food price variability: causes, consequences, and policy options". 25-26 January, Maputo, Mozambique under the Comesa-MSU-IFPRI African Agricultural Markets Project (AAMP). 2010.-53.

Mottaleb, K. A., Mainuddin, M., & Sonobe, T. (2020). COVID-19 induced economic loss and ensuring food security for vulnerable groups: Policy implications from Bangladesh. *PloS one*, *15*(10), e0240709. doi: 10.1371/journal.pone.0240709

Singh, I., Squire, L., & Strauss, J. (1986). *Agricultural household models: Extensions and applications*. Baltimore, MD: Johns Hopkins University Press.

Standard Tables of Food Composition in Japan (2015). Laboratory of Food Function, Department of Food and Nutrition, School of Life Studies, Sugiyama Jogakuen University, 508 pp (Japanese with English). Retrieved from https://www.mext.go.jp/en/policy/science_technology/policy/title01/detail01/sdetail01/sdetail01/1385122.htm

Weerahewa, J., & Kodithuwakku, S. S. (2011). The global economic crises and their effects on food and nutrition security in Sri Lanka. *Journal of international agricultural trade and development*, *7*(1), 71.

Annex 1. *Aggregations of HS codes and HIES of the product categories to match with elasticity estimates of Lokuge et al. (2019)*

HS code	Description	HIES category	Product category used by Lokuge et al. (2019)
'08081000	Fresh apples	Apples	Fruits
'08041020	Fresh or dried dates Dried	Dates	
'08041010	Fresh or dried dates Fresh		
'08061000	Fresh grapes	Grapes	
'08051010	Fresh or dried oranges Fresh	Oranges/ mandarin	
'08094000	Fresh plums and sloes	Plums	
'12024200	Groundnuts, shelled, whether or not broken (excluding seed for sowing, roasted or otherwise cooked)	Groundnuts	
'08083000	Fresh pea + detailed label not available	Other fresh fruits	
'16041400	Prepared or preserved tunas, skipjack and Atlantic bonito, whole or in pieces (excluding minced)	Balaya (dry)	Dry fish
'16041200	Prepared or preserved herrings, whole or in pieces (excluding minced)	Hurulla (dry)	
'16041300	Prepared or preserved sardines, sardinella and brisling or sprats, whole or in pieces (excluding minced)	Salaya (dry)	
16041500	Prepared or preserved mackerel, whole or in pieces (excluding minced)	Seer (dry)	
'16041600	Prepared or preserved anchovies, whole or in pieces (excluding minced)	Sprats (dry)	
'16042000	Prepared or preserved fish (excluding whole or in pieces)	Other dried fish	
'16041900	Prepared or preserved fish, whole or in pieces (excl minced and salmon, herrings, sardines,		
'16041100	Prepared or preserved salmon, whole or in pieces (excluding minced)	Canned fish (Salmon)	Fresh fish

HS code	Description	HIES category	Product category used by Lokuge et al. (2019)
'07031020	Edible vegetables and certain roots and tube: Onions, shallots, garlic, leaks and other alliaceous:	Bombay onions	Vegetables
'07031010	Fresh or chilled onions and shallots, Red onions	Red onions	
'07032000	Garlic, fresh or chilled	Garlic	
'09042110	Fruits of the genus Capsicum or of the genus Pimenta, dried, neither crushed nor ground + detailed	Green chilies	
'15131121	Crude coconut oil Other :Virgin coconut oil	Coconut oil	Edible oils
'15131129	Crude coconut oil Other :Other		
'15131990	Coconut oil and its fractions, whether or not refined, but not chemically modified (excluding crude) in bulk		
'15131910	Coconut oil and its fractions, whether or not refined, but not chemically modified (excluding crude) in bulk		
'15131119	Crude coconut oil In bulk :Other		
'15132900	Palm kernel and babassu oil and their fractions, whether refined, but not chemically	Vegetable oil	
'15119020	Palm oil and its fractions, whether or not refined (excluding chemically modified and crude)		
'15119090	Palm oil and its fractions, whether or not refined (excluding chemically modified and crude): Palm		
'15132100	Crude palm kernel and babassu oil		
'15111000	Crude palm oil		
'15171090	Margarine (excluding liquid)Other	Margarine	
'15162000	Vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified,		
'15171030	Margarine (excluding liquid) + detailed label not available +		
'15121900	Sunflower-seed or sunflower oil and its fractions, whether refined, but not chemically	Other oils and fats	
'15079000	Soya-bean oil and its fractions, whether or not refined (excluding chemically modified and crude)		
'15119010	Palm oil and its fractions, whether refined (excluding chemically modified and crude): Palm		
'15179000	Edible mixtures or preparations of animal or vegetable fats or oils and edible fractions of		
'04031000	Yoghurt, whether flavoured or containing added sugar or other sweetening matter, fruits,	Yogurt	Dairy products
'04039000	Buttermilk, curdled milk and cream, kephir and other fermented or acidified milk and cream,	Curd	

HS code	Description	HIES category	Product category used by Lokuge et al. (2019)
'17019110	Refined cane or beet sugar, containing added flavouring or colouring, in solid form Sugar	Sugar	Sugar
'17011400	Raw cane sugar, in solid form, not containing added flavouring or colouring matter (excluding cane		
'17019930	Cane or beet sugar and chemically pure sucrose, in solid form (excluding cane and beet sugar containing		
'17011300	Raw cane sugar, in solid form, not containing added flavouring or colouring matter, obtained		
'17019910	Cane or beet sugar and chemically pure sucrose, in solid form (excluding cane and beet sugar containing		
'17019190	Refined cane or beet sugar, containing added flavouring or colouring, in solid form Other	Other sweeteners	
'17019990	Cane or beet sugar and chemically pure sucrose, in solid form (excluding cane and beet sugar containing		
'07134012	Dried, shelled lentils, whether or not skinned or split Massor dhal (red lentils) whole or split	Dhal massoor	Pulses
'07134022	Dried, shelled lentils, whether or not skinned or split Whole or split yellow lentils :Split		
'07134011	Dried, shelled lentils, whether skinned or split Masoor dhal (red lentils) whole or split		
'07134021	Dried, shelled lentils, whether or not skinned or split Whole or split yellow lentils: Whole		
'07132010	Dried, shelled chickpeas "garbanzos", whether skinned or split: Dried leguminous vegetables,	Gram	
'07132020	Dried, shelled chickpeas "garbanzos", whether skinned or split: Dried leguminous vegetables,		
07131020	Dried, shelled peas "*Pisum sativum*", whether skinned or split: Dried leguminous vegetables,		
'10059000	Maize (corn), other than seeds	Maize	Maize
'07019000	Fresh or chilled potatoes (excluding seed)	Potatoes	Potato

Effects of COVID-19 induced trade policies on processed food exports from South Asia: A GTAP analysis

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ABSTRACT

A number of countries made changes to their agri-food policy framework to adapt to challenges of COVID-19 pandemic. This study analyzes the welfare and trade effects of changes in policies pertaining to agri-food exports and imports. The Global Trade Analysis Project (GTAP) model and database (Version 10) was used in this study. Five different policy experiments were designed to simulate the effects of changes in import and export taxes on processed food imposed by China, Saudi Arabia, Pakistan and India with special emphasis on processed food trade of South Asia. The results show that a 25% reduction in import taxes by China and Saudi Arabia improves global welfare by USD 431.9 and 79 million respectively. An introduction of a 10% export tax by Pakistan and India depresses global welfare by USD 672 and 204 million respectively. A decrease in global welfare by USD 362 million can be observed if all four policy changes are made simultaneously. Moreover, a 25% reduction in import tax by China and Saudi Arabia declines welfare by USD 3.27 and 13 million respectively and export tax by India and Pakistan decreases welfare by USD 838.6 and 11.4 million respectively in the South Asian region. An improvement of USD 835.1 million, if all four policy changes are made simultaneously, can be observed in South Asia. It was found that reductions in import taxes on processed food by China caused an improvement in industrial production and exports of processed food and agriculture in Bangladesh, India, and Sri Lanka. In contrast, the imposition of export taxes on processed food by India and Pakistan caused a reduction in industrial production and exports of processed food for imposing policy countries and positive impact for competitors. These results indicate that overall effect of the policy response of the COVID-19 by major trading partners was largely beneficial for the exporters of processed food in South Asian countries.

Key words: Economy-wide effects, Trade policies, Agri-food, South Asia, GTAP

1. INTRODUCTION

The COVID-19 pandemic, at its onset, was a health crisis but it soon become an economic crisis that called for unprecedented measures. The outbreak significantly impacted the global economy in the short-run and the Gross Domestic Product (GDP) has fallen by 2 percent below the benchmark for the world, 2.5 percent for developing countries, and 1.8 percent for industrial countries (Maliszewska *et al,* 2020). Governments around the world have changed policies to regulate their health, labor, transport, trade, agriculture, and food sector using a variety of border measures (quotas,

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licenses, taxes, subsidies, *etc*). Many countries have tried to keep trade open to reduce the negative impact on vulnerable populations around the world. Some other countries have implemented inward-looking measures such as export bans, import restrictions, and subsidies to import-substituting industries to reduce dependence on imported goods and improve self-reliance. With respect to policies implemented in agriculture and food sectors, liberalization or some restriction on food imports and tightening of food exports have been observed. For example, Bolivia, China, Kenya, Singapore, Mongolia, Samoa, Saudi Arabia, and Uzbekistan have liberalized imports through reductions/eliminations of tariffs on agricultural raw materials import, while some countries such as Bhutan, Cambodia, Egypt, Kuwait, and Pakistan have imposed export restriction on processed food and agriculture products such as cereals, dairy, vegetables, meat, etc. (Market Access Map, COVID-19 Temporary Trade Measures, 2020).

A number of authors have evaluated the economic effects of these policy responses. Park *et al*, (2020) have claimed that government policy responses could soften the COVID-19 impact by 30-40 percent reducing the global economic loss to 4.5- 5.9 percent of global GDP. McKibbin and Fernando (2020) provided preliminary estimates of the economic cost of the COVID-19 crisis by using a global hybrid of a Computable General Equilibrium (CGE) model and a Dynamic Stochastic General Equilibrium (DSGE) model. Their findings showed that depending on the epidemiological scenario considered, the GDP loss can range from USD 283 to 9,170 billion worldwide. Maliszewska *et al*, 2020 simulated the effect of increasing the trade costs on GDP and trade as an impact of COVID-19, using a standard global CGE model. They found that with higher trade costs, the price of a unit of imports and exports increases, and productivity losses. Moreover, they claimed that exports at the global level are expected to decrease by 2.5% and the biggest GDP losses are expected in East Asia and Pacific (EAP) countries due to their relatively deep integration through trade and direct impact on tourism. The most impacted are exports of services but in the case of China, the biggest decline in exports is registered in manufacturing goods.

According to the authors' knowledge, no attempt had been made so far to evaluate the effect of policy measures as a response to COVID-19 on the export of processed food products. Processed food are obtained from transforming agriculture raw products by employing technology and innovation. Processed food products can significantly contribute to economic recovery in COVID-19 post era in particularly South Asian countries as they are endowed with agriculture, livestock and marine resources. Demand for processed food is expected to grow continuously in response to diet upgrades resulting from rising incomes, growing health consciousness, and urbanization. Thus, ability to expand processed food exports into the world market would provide an important impetus for their economic development. This study attempts first compiles various regulations imposed on import and exports of agri-food, i.e., agricultural raw materials as well as processed food, during March-August, 2020. Second, it analyzes the effect of these policies on the export of processed food from Bangladesh, India, Pakistan, and Sri Lanka.

The remainder of this paper is organized as follows; the second section presents an overview of all policy responses to COVID-19 in the case of food and agriculture products. A review of the literature on the CGE model and Global Trade Analysis Project (GTAP) is presented in the third section. Methods of analysis and data sources are presented in the fourth section. The fifth section presents results and discussion and the last section presents conclusions and recommendations.

2. POLICY ANALYSIS USING APPLIED GENERAL EQUILIBRIUM MODELS

Literature provides ample evidences on the use of economic models to quantify the consequences of pandemics (McKibbin, 2004; Bloom *et al*, 2005; Burns *et al*, 2006; Lee,

McKibbin and Sidorenko, 2006). Several CGE models have been applied to study the impact of pandemics and crisis (Arndt and Lewis, 2001; Lee & McKibbin 2004; Bell et al., 2004; McKibbin & Sidorenko 2006; Weerahewa and Meilke, 2009). A few recent studies used the CGE model to find the impact of COVID-19.

McKibbin and Fernando (2020) have evaluated the global macroeconomic impacts of COVID-19 by applying the CGE model. They simulated 7 different scenarios using GTAP and reported that a contained outbreak could significantly impact the global economy in the short run and the GDP loss can range from 283 to 9,170 billion dollars worldwide. Maliszewska *et al* (2020) have experimented with 4 different scenarios in employment, international trade costs, consumption tax on international tourism, and services demand to find the economic impact of COVID-19 using a CGE model. They claimed that services and trade faced the biggest negative shock during the COVID-19 outbreak. Moreover, they illustrated that some policy changes like the increase in export tax have a negative effect on export, this result was based on the evaluation of China and Thailand event. The same result was obtained by Fugazza (2020) when he was evaluating the impact of the COVID-19 pandemic on commodities exports to China by the same method (Annex 1).

Similarly, Park *et al*, 2020 applied a CGE model using GTAP to simulate some scenarios related to the changes in trade cost, productivity, consumption, and investment growth to find the economic impact of COVID-19 government policy responses that could soften the negative impact by 30-40%. Lahcen *et al* (2020) employed a CGE Model and standard emissions coefficient calculations in Input-Output modeling to find the Impact of COVID-19 on economy and greenhouse gas emissions, and they reported that COVID-19 pandemic damages economies considerably while a reduction in emissions of greenhouse gas is less than proportionate (Annex 1).

Literature depicted that CGE models are useful analytical tool in the context of the COVID-19 pandemic as they can help evaluate policy options by identifying the economic channels through which the primary effects of the outbreak manifest themselves. CGE models are suited to examine the research question of this paper because they consistently consider the effects of a policy measure in trade for all related sectors.

3. METHODS OF ANALYSIS

3.1. The GTAP Model, Data and Policy Scenarios

Following Weerahewa and Meilke (2009), de Morel et al (2020), and McKibbin and Fernando (2020), a CGE modeling approach is used for the analysis. The GTAP model (version 10) database is used in this study. This approach was chosen as it allows us to calculate welfare changes at a country level in response to trade policies implemented by partner countries. This section describes our specification of the GTAP model, the data set used in our analysis, and the hypothetical policy scenarios used to assess the economic impacts of COVID-19 in the export of processed food from South Asian countries. The GTAP model is a neoclassical multi-region, multi-sector, static, applied general equilibrium model that assumes perfect competition and constant returns to scale and provides a framework for assessing the effects of policy changes on resource allocation by clarifying who will gain and who will lose (Hertel, 1997). The model is based on national or regional input-output tables and it fully tracks bilateral trade flows between all the countries in the database.

The most recent version of GTAP (version 10) consists of 65 sectors and of them only 19 sectors cover agri-food items. Of the 19 sectors, nine product categories namely; fish, meat of mammals, other meats, vegetable and animal oils, dairy products, processed rice, sugar, beverage and tobacco and prepared food products, which includes preserved fish, meat, vegetables, fruits and cereals, bakery products, cocoa, and chocolate, were identified as processed food product categories (Annex 10). Paddy, wheat, other cereal, vegetable and fruits, oilseeds, sugar crops, fiber crops,

other crops, live animals, and raw milk were identified as agriculture products. The model used in this study consists of seven individual countries (Bangladesh, India, Pakistan, Sri Lanka, China, Singapore, Saudi Arabia) and six regions (South East Asia, Rest of South Asia, Oceana, North America, EU, and the Rest of the World), one agriculture sector and three processed food sub sectors (cereals, meat, and other processed food), three non-agriculture sectors (manufacture, extraction, and services), and three factors of production (land, labor, and capital). The model is calibrated to data on output, imports, exports, consumption and government demand, employment of labor and capital, intermediate inputs, and prices in 2014 for each sector and region included in the model.

3.2. Development of Policy Scenarios:

We started by considering policies representing to the agriculture and food trade implemented by different countries in the world as a response for COVID-19 as reported by Food Export Tracker and COVID Policy Response platforms of the International Food Policy Research, and COVID-19 Temporary Trade Measures of the Market Access Map. According to the dataset, all trade policies have been categorized into two main groups; the first group is restrictions which are included imports and exports prohibition, increased taxes, and Non-Tariff Measures (NTMs), and the second group is liberalizations that are enhanced by reduction or elimination of import taxes. The substantial portion of countries in the world has been implemented restriction rather than liberalizations on agri-food products in the world due to Sanitary and Phytosanitary (SPS) reasons, cope the local demand and enhancing food security or some countries have been imposed restrictions for support of local producers. Countries such as Pakistan, Tajikistan, Belarus, Cambodia, Egypt, Russia, Turkey, Kyrgyzstan, Romania and etc., have imposed an export ban to enhance domestic food security mostly in essential food such as cereal, onion/ garlic, vegetable oils, and dairy products (Annex 6). While a few countries such as Indonesia, China, India, Panama, and South Africa with imposing Non-Tariff Measures (NTMs) such as certificate requirement, restricted the imports of live animals, onions/ garlic, rice, and some other agricultural products due to SPS reasons (Annex 7). Moreover, some other countries such as China, Russian Federal, Mauritius, Kazakhstan, Sri Lanka and etc., in response to the COVID-19 crisis has imposed import prohibitions on meats, live animals, poultry products, cereals, and vegetables which are mostly exported from China due to the SPS reasons (Annex 2).

Conversely, a substantial number of countries, including Kenya, Gibraltar, China, Ethiopia and Uzbekistan have reduced import taxes on essential food like rice, wheat, edible oils, dairy products, sugar, and some vegetables. Whereas, Saudi Arabia, Singapore, Colombia, El Salvador, Bolivia were the major countries that removed all import taxes from agri-food products (Annex 4 and Annex 5).

Although most countries around the world implemented policies related to agricultural raw products and processed food, Table 1 shows that the values of processed food that were subjected to regulations were larger than that of agriculture. Therefore, in this study, the policy experiments were designed to capture only changes related to policies on processed food trade. Among all countries which imposed import liberalization policies on agri-food, the size of import of processed food was substantially bigger in China and Saudi Arabia. Moreover, China and Saudi Arabia are important trade partners for South Asia's processed food exports. Export worth of processed food from South Asia to the China and Saudi Arabia were USD 19,710 million and USD 6,313 million respectively in 2018. In case of introducing policies related to the export restriction, Pakistan and India were the countries that implemented export restrictions on processed food products (Table 1). Therefore, China, Saudi Arabia, India and Pakistan were selected for the experiments to simulate of import liberalization and export restriction respectively. Five different policy experiments related to the policies imposed

Table 1. Trade measures by selected countries as a response to COVID-19 crisis during January- October 2020.

Type of policy	Country	Commodity category	Specific commodity Categories	Value of trade from the World in 2018 (USD Million)
Import liberalization	Singapore	Agri-food	Agriculture	6,957
			Processed Food	8,990
	Saudi Arabia	Agri-food	Agriculture	8,557
			Processed Food	9,208
	Gibraltar	Agri-food	Agriculture	28
			Processed Food	37
	China	Agri-food	Agriculture	36,699
			Processed Food	76,742
	Kenya	Agri-food	Agriculture	1,280
			Processed Food	981
Export restrictions	Pakistan	Agri-food	Agriculture	1,800
			Processed Food	1,115
	Algeria	Agri-food	Agriculture	0.09
			Processed Food	248
	Russia	Agri-food	Agriculture	386
			Processed Food	1,410
	Viet Nam	Agriculture	Agriculture	2.4
	Ukraine	Processed food	Processed food	3
	Kyrgyzstan	Agri-food	Agriculture	1.5
			Processed Food	0.5
	India	Agri-food	Agriculture	4,500
			Processed Food	6,800

Note: Agriculture= agricultural raw products, Processed food = value added products, and Agri-food= both agricultural raw and value added products
Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January- October 2020.

by the world for response to COVID-19 were designed to simulate the effects of changes in import and export tax by China, Saudi Arabia, Pakistan and India on processed food exports from South Asia. Bangladesh, Pakistan, India, and Sri Lanka was considered as South Asia in this study because these four countries account for 98% of South Asia's trade. The GTAP simulation adopted in this section involved the 25% unilateral removal of ad valorem import tariffs by Saudi Arabia and China for processed food sectors and introduced 10% export tax on processed food by Pakistan and India. In all scenarios we assume that other countries do not retaliate by changing their own import/ export or domestic policies. Table 2 sets out the simulation scenarios.

4. RESULTS AND DISCUSSION

The baseline equilibrium of the GTAP model is already been calibrated to COVID-19 free world. The policy scenarios are developed to reflect the trade policy response of trading partners of South Asia. The GTAP model simulated with the policy scenarios reflects the world equilibrium in the presence of COVID-19 policies in the status quo. The following sections present the modeling results for every five scenarios described in the previous section. They show the percentage changes in prices, and quantities produced, exported, and imported, in various regions by two main sectors (Agriculture and Processed food), due to reduction in import taxes by China and Saudi Arabia and the imposition of export taxes by India and Pakistan relative to the baseline (2014). The resulting welfare changes in each region along with the welfare decomposition results are presented.

4.1. Import Liberalizations

Scenario 1 and 2 representing the 25 percent reduction of import taxes on processed food by China and Saudi Arabia. The effect of

Table 2. Simulation Scenarios

	Scenarios	Description
Import Liberalizations	UIL – China	Unilateral Import Liberalization of processed food products (China unilaterally reduces existing import tariffs on processed food sectors by 25%)
	UIL – Saudi Arabia	Unilateral Import Liberalization of Processed Food sector (Saudi Arabia unilaterally reduces existing import tariffs on processed food sector by 25%)
Export Restrictions	UER – Pakistan	Unilateral export restrictions of Processed Food Sectors (Pakistan unilaterally imposed export tax on processed food sectors by 10%)
	UER – India	Unilateral export restrictions of Processed Food Sectors (India unilaterally imposed export tax on processed food sectors by 10%)
All	UIL-UER	Total of all scenarios

Note: fish, meat of mammals, other meats, vegetable and animal oils, dairy products, processed rice, sugar, beverage and tobacco and prepared food products.

these liberalizations on processed food export from South Asian countries has evaluated. With the reduction on import tax by China and Saudi Arabia, an increase in exports and local production in South Asia is expected. The lower international prices and higher domestic prices in consideration sector is resulted of a rise in exports from South Asia. Higher domestic prices will encourage producers to produce more and will increase the production. Import liberalization will improve total welfare and a greater allocative efficiency gains that overweigh the Terms of Trade (TOT) losses.

4.1.1. Import Liberalization by China and Saudi Arabia

As shown in Figure 2, when China reduced the import taxes of processed food the domestic price of processed food is reduced in China by 0.12 percent. This reduction of import tax associate with a small increase in domestic price in India, Bangladesh, and Sri Lanka. Domestic production of processed food is associated with a reduction of 0.53 percent in China and an increase in South Asian countries with a very small portion. The openness of processed food products by China was associated with the increase in the export of processed food and agriculture in India and Bangladesh, while the greater increase in exports of agriculture products was observed in all South Asian countries.

Reduction of import tax (25 percent) by China leads to an increase of 12.5 percent of imports in China and a decrease in Pakistan and Sri Lanka by 0.03 and 0.01 percent respectively. Implemented of 25 percent reduction of import taxes by Saudi Arabia associated with a reduction in the export of processed food by South Asian countries (Figure 1 and Figure 2).

Table 2 and Annex 8 and Annex 9 presents the results of the welfare effects of the various scenario options adopted in the processed food sector. The results revealed that total welfare improved in countries which reduced import taxes on processed food ($ 178 million in China and $ 116 million in Saudi Arabia). Improvements in welfare associated with processed food sector liberalization scenarios are caused by greater allocative efficiency gains in China and Saudi Arabia. Openness in China increased welfare and allocative efficiency in Bangladesh, Sri Lanka, the rest of South Asia, and ROW, while India and Pakistan lose their efficiency and welfare. This policy change by China is associated with an increase of TOT in all South Asian countries except Pakistan. Liberalization of processed food in Saudi Arabia has improved welfare in Bangladesh ($0.15 million), ROW ($ 0.30 million) and lost welfare in India ($ 8.8 million), Pakistan ($ 4.2 million), Sri Lanka ($ 0.46 million) and ROW ($ 26.46 million). The exceeds the allocative efficiency gains in India results in the overall decline in the welfare and TOT effect with

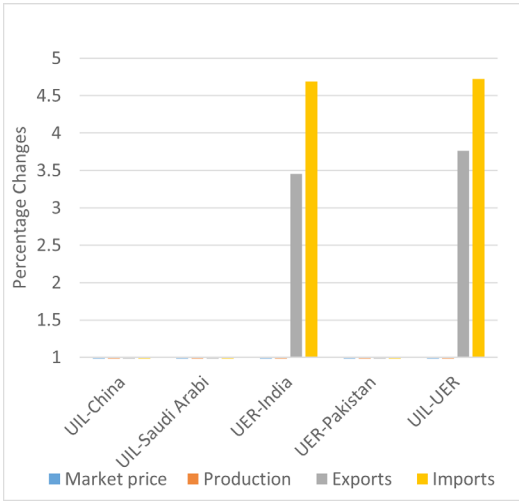

Figure 1A: Percentage changes in market price, production, exports and imports in Bangladesh

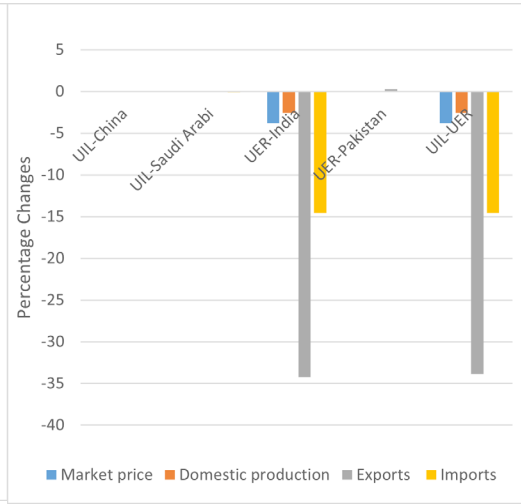

Figure 1B: Percentage changes in market price, production, exports and imports in India

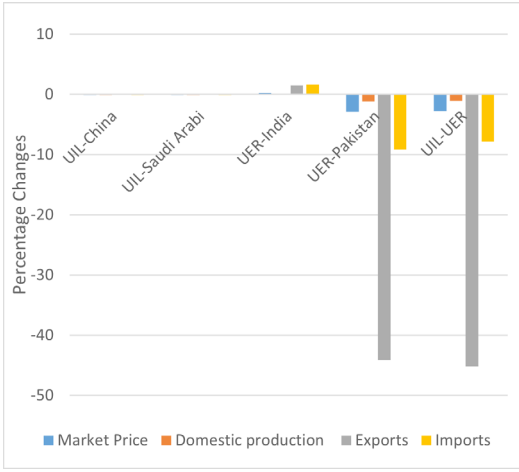

Figure 1C: Percentage changes in market price, production, exports and imports in Pakistan

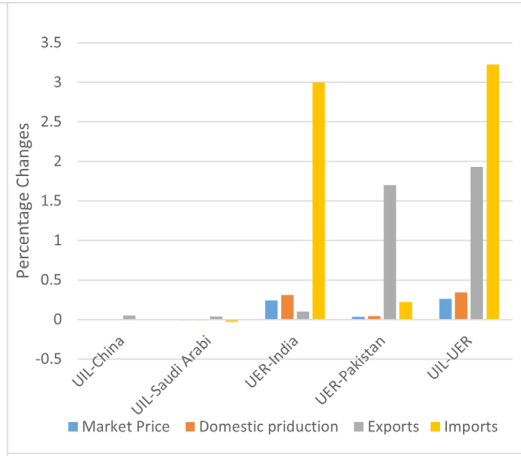

Figure 1D: Percentage changes in market price, production, exports and imports in Sri Lanka

Figure 1. *Percentage changes in market price, production, exports and imports of Bangladesh, India, Pakistan and Sri Lanka*

openness in the processed food sector by Saudi Arabia.

4.2. Export Restrictions

Scenarios 3 and 4 representing the imposing 10 percent export taxes on processed food by India and Pakistan respectively. With the introduction of an export tax, a reduction in exports and a reduction in local production is expected. The higher international prices and lower domestic prices in the consideration sector are resulting in a reduction in exports. Lower domestic prices will attract resources away from the sector and will increase the production in other sectors to an increase in exports in other sectors despite the potential for lower exports in aggregate. For reach to

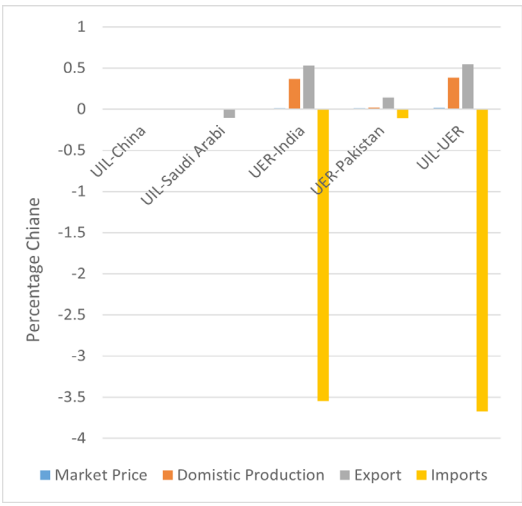

Figure 2A: Percentage changes in market price, production, exports and imports in Bangladesh

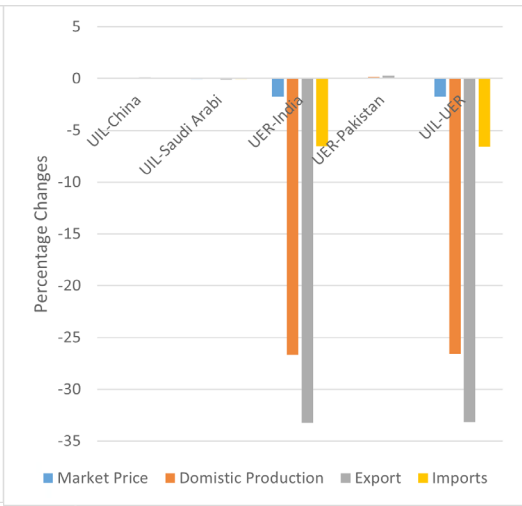

Figure 2B: Percentage changes in in market price, production, exports and imports in India

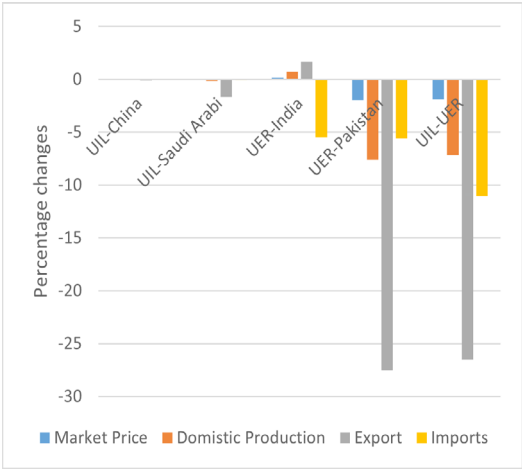

Figure 2C: Percentage changes in market price, production, exports and imports in Pakistan

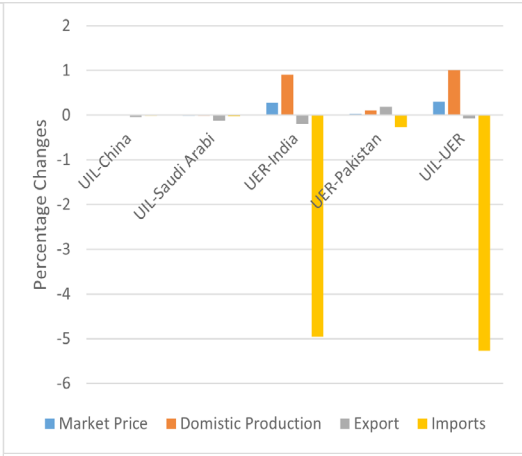

Figure 2D: Percentage changes in market price, production, exports and imports in Sri Lanka

Figure 2. Percentage changes in Market price, Domestic production, Exports, and Imports of Processed Food under alternative trade policy scenarios

Source: Authors' simulation results using GTAP Database Version 10

a balance trade condition a decline in total imports is expected. The country imposing the export tax leads to an increase in the terms of trade because such change will lead to an increase in international export prices and a reduction in international import prices. It is possible that such an increase could lead to welfare improvements if they are large enough to offset allocative efficiency losses. If welfare changes are concerned, an export tax will lead to a reduction in global welfare, and improve the welfare in the country imposing the export tax.

4.2.1. Export Taxes by India and Pakistan

As shown in Figure 2, when India imposes a 10 percent export tax on all processed food, the domestic price of processed food is lowered in India by only 1.73, and the price of processed food increases elsewhere (*e.g.,* 0.28 percent in Sri Lanka and 0.01 percent in Bangladesh). Moreover, introducing export tax on processed food had more effect on domestic price of agriculture in imposing export tax countries. The domestic price in agriculture has dropped by 3.81 percent in India (Figure 1).

Export taxes on processed food by India leads to a 26.6 and 2.6 percent reduction in domestic production of processed food and agriculture products respectively, it leads to 33.25 percent reduction in Indian processed food exports (Figure 2). The lower level of exports from India results in increase of exports from Sri Lanka and Bangladesh, and a significant drop in processed food imports by countries such as Sri Lanka (4.9 percent), Bangladesh (3.5 percent), and Pakistan (5.4 percent), and a 0.91, 0.73 and 0.37 1.55 percent increase in domestic processed food production in Sri Lanka, Pakistan and Bangladesh (Figure 2).

The same results was observed when export taxes on processed food imposed by Pakistan but only the percentage of changes is different. Export tax by Pakistan leads a reduction on domestic price of processed food and agriculture products by 1.97 and 2.93 percent respectively and increase in other countries mostly in Rest of South Asia (0. 39 percent). The reduction on domestic price lead to decrease of domestic production of processed food by 7.58 percent in Pakistan and increase in India (0.14 percent), Sri Lanka (0.11 percent), and Bangladesh (0.02 percent). By reduction of domestic production a significant drop in Pakistan's exports (27.5 percent) was observed. It allowed the other countries in the region to increase their processed food exports (*e.g.,* 0.26 percent in India, 0.19 percent in Sri Lanka and 0.14 percent in Bangladesh). Reduction of Pakistan's exports of processed food has a negative effect on import of all South Asian countries except India. The effect of export tax by India was bigger than export tax by Pakistan on other South Asian countries (Figure 1 and Figure 2)

The key welfare results are summarized in Table 3 and the welfare decomposition results are presented in Annex 8 and Annex 9, which indicates the losses and gains associated with changes in allocative efficiency (A1), terms of trade (E1: relative prices for exports and imports), and relative prices of savings and investment (F1). The imposition of a 10 percent

Table 3. The change in equivalent variation (EV) associated with reduction of 25% in import tax and imposition of 10 % export tax processed food (US$ million), by region

Policy Scenarios	UIL- China	UIL - Saudi Arabia	UER - India	UER- Pakistan	UIL-UER
Bangladesh	0.97	0.15	-29.82	3.32	-25.33
India	-3.27	-8.85	913.09	4.05	906.52
Pakistan	-1.64	-4.20	9.66	40.61	46.54
Sri Lanka	0.28	-0.46	-25.65	1.54	-24.18
Rest of South Asia	0.39	0.30	-28.62	-38.12	-68.48
Singapore	-1.94	-1.45	-8.92	-2.34	-14.66
Saudi Arabia	-0.16	116.59	-134.14	-10.65	-26.78
China	178.03	-22.16	-68.52	-20.17	66.19
South East Asia	8.82	-6.57	-417.89	-25.46	-442.04
Oceania	24.94	-6.21	50.20	0.57	69.52
North America	72.60	-21.89	-55.38	27.02	22.36
EU	53.38	60.24	51.71	0.52	168.33
Rest of World	99.54	-26.46	-927.72	-184.92	-1040.51
Total	**431.93**	**79.03**	**-672.00**	**-204.02**	**-362.53**

Source: Results of simulation performed using GTAP version 10.

processed food export tax results in an increase in Indian welfare of $ 913 million. The welfare decomposition results indicate that India gain allocative efficiency. However, favorable terms of trade turn the total welfare effects positive. The terms of trade effect is prominent for processed food in India. When India imposes export taxes on processed food, the terms of trade improve for Pakistan and it decreases for other South Asian countries. Only Pakistan's welfare has improved and other South Asian countries and ROW suffer welfare losses as a result of India's export tax on processed food. For example, Sri Lanka loses $ 25.65 million, Bangladesh loses $ 29.82 million, and Other South Asia loses $28.62 million. Pakistan, as a processed food exporting country, gains $9.66 million. The ROW region has the greatest welfare loss ($927.7 million), while total worldwide losses are $407.8 million.

However, the introduction of 10 percent export tax on processed food by Pakistan increased the Pakistan's welfare of $ 40.6 million dollars but Pakistan incurs the allocative efficiency losses ($ 92.2 million) and also terms of trade has a positive effect on processed food in Pakistan. Furthermore, by introducing 10 percent export taxes on processed food by Pakistan, welfare has improved in Pakistan, India, Bangladesh and Sri Lanka respectively highest being in Pakistan ($40.61 million). Due to this policy change, Pakistan and India incurs the loss in allocative efficiency. Welfare has declined in ROW ($ 184.9 million) and total worldwide losses are $87.5 million as a results of export tax on processed food by Pakistan.

4.2.2. Processed food categories under import liberalization and export taxes

In this section, the effect of import liberalization and export restriction scenarios on production and exports of specific processed food categories have been evaluated. The results reveal that introduction of 10% export tax by Pakistan has large positive effect in production and export of cereals, meat and other processed food categories in Bangladesh, India and Sri Lanka, while the highest being in Sri Lanka in export of meat. Reducing 25% import tax by China have shown a positive effect in export of cereals, meat and other processed food from India and Pakistan, whereas a small negative was observed in export of other processed food and meat from Bangladesh and Sri Lanka respectively (Figure 3).

4.2.3. Import liberalization by China and Saudi Arabia and imposing export taxes by India and Pakistan

When all liberalizations and restrictions policy changes implemented on processed food there is a welfare loss of $ 362.5 million (Table 2), but this hides the fact that India gains welfare ($ 906.5 million) and Pakistan ($ 4.5 million) while all other countries in the region lose welfare. $ 24.18 million in Sri Lanka, $ 25.3 million in Bangladesh, and $ 68.5 million in South Asia region. This comprise of all policy changes on processed food results in significant reductions in domestic price and production levels for most of processed food and agricultural items in all South Asian countries. Highest drop in domestic production was in India by 26.6 percent and in Pakistan by 7.2 percent (Figure 1 and Figure 2).

When all policy changes were considered, exports of processed food fall precipitously across the region, highest was in India (33.2 percent) followed by Pakistan (26.5 percent). Although the largest reductions in exports are in agriculture products. However, imports of processed food and agriculture products have declined in all South Asian countries, highest declined being in Pakistan by 11percent. This results indicated that effect of 10 percent imposing export tax on processed food by India and Pakistan has more effect on South Asian processed food exports compare the 25 percent reduction of import tax on processed food by China and Saudi Arabia. Overall, the impacts of these policy changes on the welfare of South Asian countries are mixed. A welfare gain can be observed in India and Pakistan and some competitors of South Asian (China, Oceania, North America and EU) and a welfare loss for other countries in South Asia and close trading partners (Singapore, Saudi Arabia, South East Asia and Rest of the World).

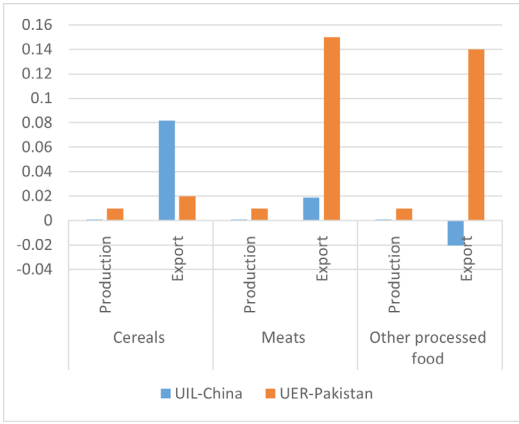

Figure 3A: Percentage changes in production and exports in Bangladesh

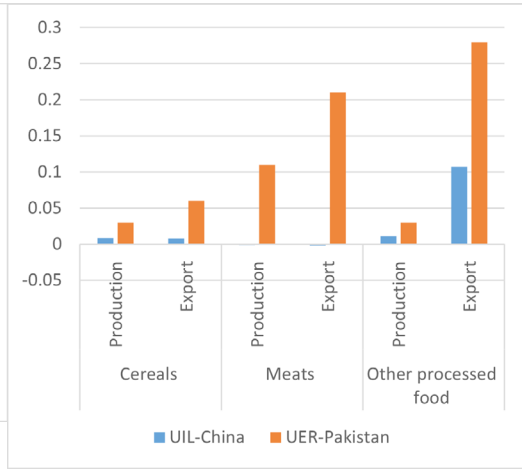

Figure 3B: Percentage changes in production and exports in India

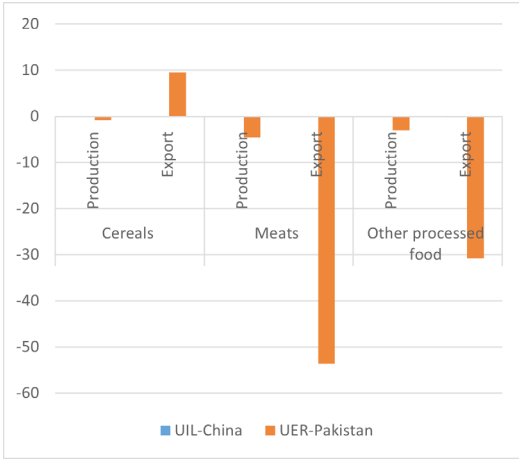

Figure 3C: Percentage changes in production and exports in Pakistan

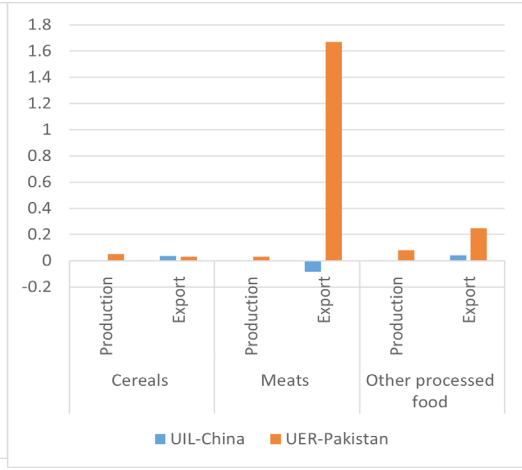

Figure 3D: Percentage changes in production and exports in Sri Lanka

Figure 3. Percentage changes in Domestic production, and Exports of specific categories of Processed Food under alternative trade policy scenarios

Source: Authors' simulation results using GTAP Database Version 10

5. CONCLUSIONS

The results presented above show the importance of trade policy responses to COVID-19 crisis by other countries in the World for the South Asian economy. Although our results depend on the base parameters and assumptions of Armington elasticities that is contained in the GTAP model, which significantly influence the terms of trade effects. The results revealed that while implementation of India's trade restrictions through export taxes may improve welfare in India, but these policies harm other countries in South Asia and elsewhere. However, when Pakistan imposes an export taxes, a welfare gain can be observed for a few of their competitors like India, Bangladesh and Sri Lanka. Even though the primary objective of these restrictive policies was to reduce domestic price levels

in the country imposing them, the reductions in the domestic production and export levels would be larger than the reductions in domestic price levels as evident in India and Pakistan. Thus, export taxes could allow a country to achieve welfare gains through the effects of the taxes on their terms of trade but can be negatively effects other component of an economy. In contrary case implemented unilateral import liberalizations can play a role in improving welfare in the implementing liberalization country. However, a welfare loss observed in some South Asian countries due to import liberalization by China and Saudi Arabia. The overall export share of agri-food increases in South Asia with more contribution from agriculture sector. Increased of domestic agricultural and processed food products for imports could offset the higher domestic prices faced by the consumers. The simulation results conclude that export restrictions as a policy to response COVID-19 by South Asian countries has several negative effect in the region economy while the South Asian region can gain from unilateral import liberalization implemented by other countries. These results indicate that overall effect of the policy response of the COVID-19 by major trading partners was largely beneficial for the exporters of processed food in South Asian countries.

ACKNOWLEDGMENTS

This study was carried out with the support of the SAARC Agricultural Center (SAC), Dhaka, Bangladesh.

REFERENCES

Abiad, A., Arao, R. M., & Dagli, S. (2020). The economic impact of the COVID-19 outbreak on developing Asia. London: Centre for Economic Policy Research

Ali, S., Fugazza, M., & Vickers, B. (2020). Assessing the Impact of the COVID-19 Pandemic on Commodities Exports from Commonwealth Countries.

Arndt, C., & Lewis, J. D. (2001). The HIV/AIDS pandemic in South Africa: Sectoral impacts and unemployment. *Journal of International Development: The Journal of the Development Studies Association*, *13*(4), 427-449.

Bell, C., Devarajan, S., & Gersbach, H. (2004). Thinking about the long-run economic costs of AIDS. *The macroeconomics of HIV/AIDS*, *96*, 128-129.

Bloom, E., De Wit, V., & Carangal-San Jose, M. J. (2005). Potential economic impact of an avian flu pandemic on Asia.

Burns, A., Van der Mensbrugghe, D., & Timmer, H. (2006). *Evaluating the economic consequences of avian influenza* (p. 6). Washington, DC: World Bank.

COVID-19 Temporary Trade Measures, Market Access Map, International Trade Centre, *www.macmap.org*

Danielle, R., and Nilam, P. (2020). COVID-19 Policy Response (CPR) portal [dataset]. Washington, DC: International Food Policy Research Institute (IFPRI). https://www.ifpri.org/project/covid-19-policy-response-cpr-portal

de Morel, L. L., Wittwer, G., Gamperle, D., and Leung, C. (2020). The Potential Local and Regional Impacts of COVID-19 in New Zealand with a Focus on Tourism.

Hertel, T. W. (1997). *Global trade analysis: modeling and applications*. Cambridge university press.

Hertel, T. W. (1997). Global Trade Analysis: Modeling and Applications. Cambridge University Press.

Laborde, D. Abdullah, M., and Marie, P. (2020). COVID-19 Food Trade Policy Tracker [dataset]. Washington, DC: International Food Policy Research Institute (IFPRI). https://www.ifpri.org/project/covid-19-food-trade-policy-tracker

Lahcen, B., Brusselaers, J., Vrancken, K., Dams, Y., Paes, C. D. S., Eyckmans, J., & Rousseau, S. (2020). Green recovery policies for the COVID-19 crisis: modelling the Impact on the economy and greenhouse gas emissions. *Environmental and Resource Economics*, *76*(4), 731-750.

Lee, G. O., & Warner, M. (2005). The Consequences of the SARS Epidemic for China's Employment and Human Resources. *The Journal of Comparative Asian Development*, *4*(1), 9-28.

Lee, J. W., & McKibbin, W. J. (2004). Globalization and disease: The case of SARS. *Asian Economic Papers*, *3*(1), 113-131.

Maliszewska, M., Mattoo, A., & Van Der Mensbrugghe, D. (2020). The potential impact of COVID-19 on GDP and trade: A preliminary assessment.

McKibbin, W. J., & Fernando, R. (2020). The Global Macroeconomic Impacts of COVID-19: Seven Scenarios.

McKibbin, W. J., & Sidorenko, A. (2006). *Global macroeconomic consequences of pandemic*

influenza (p. 79). Sydney, Australia: Lowy Institute for International Policy.

Park, C. Y., Villafuerte, J., & Abiad, A. (2020). Updated Assessment of the Potential Economic Impact of COVID-19.

Weerahewa, J., & Karl, M. (2009). South Asian Trade Integration: The welfare implications of Export Taxes. Journal of International Agricultural Trade and Development. Vol. 5(2): 227-254.

Annex 1. A review of literature on using CGE Model based analysis on COVID_19 shocks

Authors	Topic	Model	Policy Shocks	Results
McKibbin and Fernando, March, 2020	"Global Macroeconomic Impacts of COVID-19"	Global hybrid DSGE/CGE, GTAP 6 sectors and 24 countries	7 scenarios Different attack rate and case fatality rate for China	Contained outbreak could significantly impact the global economy in the short run. The scale of costs that might be avoided by greater investment in public health systems in all economies, particularly in less developed countries depending on the epidemiological scenario considered, the GDP loss can range from USD 283 to 9,170 billion worldwide.
Maliszewska et al, April, 2020	"Potential Economic Impact of COVID-19"	CGE model/GTAP 27 countries and 29 sectors	4 scenarios: Drop in employment by 3%, Raises the international trade costs by 25%, increase 50% consumption tax on international tourism, drop in services demand by 15%.	The biggest negative shocks was recorded in services and trade. Increase of export tax has declined the export. Export of manufacture products were the most effected sector in China and Thailand.
Park et al May, 2020	Economic Impact of COVID-19	CGE model/GTAP 42 countries/ regions and 52 sectors	5 scenario: Increase of trade cost (tourists), decrease in productivity cuts consumption and investment growth, Increase of trade costs for industries, macroeconomic stimulus	The potential economic impact accounting for 30% of the overall decline in global output. Government policy response could soften the COVID- 19 impact by 30-40%
Fugazza, April 2020	Impact of the COVID-19 pandemic on commodities exports to China	CGE Model 5 sector and 4 country/ region	2 scenarios, Increase of imports with different percentage from Commodity Dependent Developing Countries (CDDCs).	Energy products faced a strong negative import demand. CDDCs exports of mentioned products expected to fall
Lahcen et al, July 2020	Impact of COVID-19 on economy and greenhouse gas emissions	CGE Model/ calculations in I/O modelling. 12 basic sectors to capture the supply side, and 12 products/services	4 scenarios, Decrease in working time, drops in overall demand	COVID-19 pandemic damages economies considerably. Reduction in Emissions is less than proportionate.

Annex 2. Appendix Table 2. Import prohibition on agri-food products by the World as response to COVID 19 crisis due to the SPS reasons.

Imposed Countries	Effected countries	Date of Announcement	Date Ending	Commodities covered	Total Import Value/Mill$
China	All countries	17-Aug-20	Unknown	Meat, fish and seafood and Poultry products	35,571
Nigeria	All countries	13-Jul-20	Unknown	Maize or corn	14
Philippines	Brazil	17-Aug-20	Unknown	Poultry products	47
Sri Lanka	All countries	9-Apr-20	9-July-20	Vegetable, Fruits	435
Bhutan	All countries	25-Mar-20	Unknown	Fruits , Vegetable, Meat	24
Egypt	China	2-Sep-20	Unknown	Garlic, Carrots, Green Ginger	7.1
Georgia	China	28-Jan-20	Unknown	Live Animal, Fish	1.22
Jordan	China	2-Feb-20	Unknown	Animal base products, Vegetable base products	63.5
Kazakhstan	China	3-Feb-20	22/4/2020	Fruits	83.9
Mauritius	China, Italy, Iran, South Korea, Switzerland, and EU	16-Mar-20	3/6/2020	live Animal, Fish	110
Russian Federation	China	30-Jan-20	21-May-20	Live fish	267.7
Pakistan	Afghanistan	21-May-20		All products	581
Uzbekistan	All countries	3-Apr-20		Chicken meat, fish, milk, and yogurt, butter, eggs , onion, carrot, veggies, flour, grain products , sunflower, sugar, pasta, yeasts	732.31

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January- October 2020.

Annex 3. Increases of import tariff on agri-food products by the world as response to COVID 19 crisis to all countries.

Imposed policy Countries	Date of Announcement	Date Ending	Measure Description	Commodities covered	Total Import Value/Mill$
Iraq	2-Apr-20	1-Apr-22	Additional import duties for strengthen protection	Agricultural products	2,041.90
Seychelles	7-Apr-20	Unknown	To encourage local farmers to produce more to ensure food security in the country.	Pork, Poultry	8.1

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January- October 2020.

Annex 4. Elimination of import tariff on agri-food products by World as a response to COVID 19 crisis to all other countries.

Imposed policy Countries	Date of Announcement	Date Ending	Commodities Covered	Total Import Value/Mill$
Bolivia	8-Apr-20	2 years	Wheat and Maslin	14.7
Singapore	16-Apr-20	Unknown	agricultural products	359,008.2
Saudi Arabia	31-Mar-20	July-2020	All imports	144,335
Colombia	4-Jul-20	30/6/2020	Maize, Grain sorghum, Soya beans, oil cake	1,890.1
El Salvador	4-Mar-20	Unknown	Beans, Maize, rice	204.2
Anguilla	13-Apr-20	3-Oct-20	Rice, Sugar, Flour, Chicken , Milk, Fresh or chilled vegetables, Can vegetables, Fresh or chilled fruits , can fruits, water	5.3
Gibraltar	15-Mar-20	Unknown	all classes of goods (except for the tobacco, fuel, and alcohol)	8,607.1
Mongolia	3-Jan-20	3/6/2020	food wheat, seed wheat, all types of food rice, triangular rice, millet, sugar and vegetable oil	66.4
Morocco	4-Jan-20	31/12/2020	wheat, lentils, chickpeas, beans and dried beans	1,015.8

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January-September 2020.

Annex 5. Reduction of import tariff on agri-food products by the World as a response to COVID 19 crisis to all other countries.

Imposed policy Countries	Date of Announcement	Date Ending	Commodity covered	Total Import Value/Mill$
Saint Kitts and Nevis	26-Mar-20	25-Sep-20	vegetables, fruits, juices	10.52
China	2-Jun-20	Unknown	Agriculture products, Meat	113,441.7
Suriname	30-Mar-20	Unknown	Food	179.6
Turks and Caicos Islands	4-Jan-20	Unknown	Food	53.3
Uzbekistan	4-Mar-20	31/12/2020	flour, poultry, dairy, sugar, vegetable oils	730
Kenya	4-Jan-20	Unknown	All goods (VAT from 16% to 14%)	17,220.30
Ethiopia	14-17/Apr/20		1.73 million quantity of Rice, 3.2 million quantity of Sugar, 18.1 million quantity of Wheat and 104.3 million quantity of edible oil are free of import tax	1615.7
Mali	10-Apr-20	10/July/ 20	Rice, Milk	124.3
Eurasian Economic Union	13-Apr-20	30/6/2020	potatoes, onions, garlic, carrots, cabbage, pepper, wheat, long grain rice, buckwheat, prepared foods for infants, juices	1,602.90
Gibraltar	15-Mar-20	Unknown	Agriculture products	8,663.10

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January-September 2020.

Annex 6. Export ban on agri-food products by the World as a response to COVID 19 crisis to all other countries.

Imposed policy countries	Date of Announcement	Date Ending	Commodities covered	Total Export Value/Mill$
El Salvador	26-Mar-20	31-Dec-20	Beans	1.1
Kazakhstan	22-Mar-20		Buck wheat, wheat flour, white sugar, potatoes, Carrots, Turnips beetroot, onions, cabbage, sunflower seeds, sunflower seed oil	658.85
Pakistan	29-Mar-20 29/ Apr/20		Onion, Edible item, wheat flour	5,037.3
Tajikistan	25-Apr-20	Unknown	Wheat flour, cereals, egg, potatoes, meat	20.23
Algeria	7-May-20	Unknown	Semolina, flour, pulses, rice, pasta, oils, sugar, coffee, mineral water, tomato paste, food preparations, milks in all its forms including those intended for children, fresh vegetables and fruit with the exception of dates, red and white meats	2,194.23
Armenia	10-Apr-20		Onions, garlic, turnips, rye, rice, buckwheat, millet, cereals, whole meal and granules from cereal grains, peeled buckwheat, prepared foods from buckwheat, crushed and uncrushed soybeans and sunflower seeds.	51.49
Belarus	1-Apr-20	3-Jul-20	Onions, garlic, turnips, rye, rice, buckwheat, millet, cereals, whole meal and granules from cereal grains, peeled buckwheat, prepared foods from buckwheat, crushed and uncrushed soybeans and sunflower seeds.	203
Cambodia	5-Apr-20	20-May-20	Rice, White rice, fish	421.47
Egypt	28-Mar-20	15-Sep-20	Pluses(Beans, peas, lentils)	36.07
Honduras	31-Mar-20	Unknown	Red beans	0
North Macedonia	20-Mar-20		Wheat and mesline, Wheat flour	1.7
Russia	1-Apr-20	30-Jun-20	Onions, garlic, turnips, rye, rice, buckwheat, millet, cereals, whole meal and granules from cereal grains, peeled buckwheat, prepared foods from buckwheat, crushed and uncrushed soybeans and sunflower seeds. Processed grain, corn	9,584.39
Serbia	21-Mar-20		Sunflower oil, Molasses, yeast	101.57
Syria	8-Apr-20		eggs, cheese and yogurt, canned and packed cereals and beans	305.15
Thailand	26-Mar-20	30-Apr-20	Eggs	3.9
Turkey	8-Apr-20		Lemon	17.9
Ukraine	9-Apr-20		Buckwheat, buckwheat grain	21.58
Viet Nam	10-Apr-20	1-May-20	Rice	2434.3
Romania	10-Apr-20	16-Apr-20	Wheat, barley, oat, maize, rice, wheat flour	3,081.94

Imposed policy countries	Date of Announcement	Date Ending	Commodities covered	Total Export Value/Mill$
Gana	11-May-20		Soybean	10.85
Moldova	15-Apr-20		Grains	232.12
Ukraine	5-Apr-20		Wheat	3004.35
Kyrgyzstan	23-Mar-20		Wheat , flour, vegetable oil, sugar, chicken eggs, rice, pasta,	1341.17
Jordan	6-Apr-20	22-Apr-20	Food products	729.93
Kuwait	12-Mar-20	Unknown	Foodstuffs	407.48
Myanmar	3-Apr-20	1-May-20	Rice	782.42
North Macedonia	1-Apr-20	30-Apr-20	wheat, meslin, wheat flour	1.707
Philippines	27-Mar-20	Unknown	Rice	0.543
Sudan	25-Apr-20	Unknown	maize, sorghum	27.718
Mali	17-Apr-20	Unknown	Food Products (rice, millet, sugar, milk, pasta)	9.1
India	14- Oct-20	Unknown	Onion, Onion seed, rice	10,085

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January-October 2020.

Annex 7. Imposing NTMs on agri-food imports by the World by as a response to COVID 19 crisis to all other countries.

Imposed Countries	Date of Announcement	Date Ending	Measure Description	Commodities covered	Total Import Value/Mill$
Indonesia	18-Mar-20	31/5/2020	Import certification requirements	Onion and garlic	553.9
China	2-Dec-20	Unknown	Implementation of nine facilitation measures(agricultural administrative approvals)	Agriculture products	100,424
Indonesia	21-Apr-20	Unknown	Certification requirement	Live animals	608.9
Panama	17-Mar-20	Unknown	Increase the import quota of 230,000 tons of rice.	Rice	29.2
South Africa	9-Apr-20	Unknown	Certification requirements	Live animals and animal products	523
India			Licensing or permit requirements to export	Rice	4.4

Sources: COVID-19 Temporary Trade Measures, Market Access Map and COVID-19 Policy Response (CPR) portal dataset, from January- October September 2020.

Annex 8. The change in the equivalent variation (EV) associated with the reduction of a 25 percent of import taxes on processed food by China and Saudi Arabia (US$ million), by region

Policy Scenarios	**UIL- China**				**UIL - Saudi Arabia**			
Regions	**Allocative efficiency (A1)**	**Terms of Trade (E1)**	**Saving and Investment (F1)**	**Total EV**	**Allocative efficiency (A1)**	**Terms of Trade (E1)**	**Saving and Investment (F1)**	**Total EV**
Bangladesh	0.56	0.63	-0.22	0.97	0.03	0.28	-0.16	0.15
India	-4.21	2.68	-1.74	-3.27	4.29	-9.48	-3.67	-8.85
Pakistan	-0.22	-0.48	-0.94	-1.64	-0.51	-2.28	-1.41	-4.20
Sri Lanka	-0.03	0.37	-0.06	0.28	-0.04	-0.20	-0.22	-0.46
Rest of South Asia	0.06	0.34	-0.02	0.39	0.03	0.35	-0.07	0.30
Singapore	-0.16	-1.42	-0.36	-1.94	-0.28	-0.68	-0.48	-1.45
Saudi Arabia	0.00	1.15	-1.31	-0.16	81.28	-23.25	58.56	116.59
China	441.05	-288.34	25.31	178.03	-1.69	-2.93	-17.54	-22.16
South East Asia	-1.96	12.25	-1.48	8.82	-0.17	-4.50	-1.90	-6.57
Oceania	1.38	24.86	-1.29	24.94	-1.02	-3.98	-1.21	-6.21
North America	0.42	68.92	3.25	72.60	-1.16	-11.66	-9.06	-21.89
EU	-17.16	78.99	-8.45	53.38	1.87	67.56	-9.18	60.24
Rest of World	12.21	100.01	-12.68	99.54	-3.60	-9.23	-13.64	-26.46
Total	431.95	-0.02	0.002	431.93	79.02	-0.01	0.02	79.03

Source: Results of the GTAP Simulations

Notes:
EV = equivalent variation (welfare); AE = allocative efficiency; TOT = terms of trade; IS = investment-savings effect.
EV = AE + TOT + IS.

Annex 9. The change in the equivalent variation (EV) associated with the imposition of a 10 percent of export taxes on processed food by India and Pakistan (US$ million), by region

Policy Scenarios	UER- India				UER- Pakistan				UIL-UER			
Region	Allocative efficiency (A1)	Terms of Trade (E1)	Saving and Investment (F1)	Total EV	Allocative efficiency (A1)	Terms of Trade (E1)	Saving and Investment (F1)	Total EV	Allocative efficiency (A1)	Terms of Trade (E1)	Saving and Investment (F1)	Total EV
Bangladesh	-8.95	-22.87	1.99	-29.82	0.90	2.47	-0.05	3.32	-7.46	-19.44	1.56	-25.33
India	223.43	986.79	-297.12	913	-7.37	9.00	2.41	4.05	219.03	988.16	-300.67	906.52
Pakistan	-0.20	6.34	3.52	9.66	-92.25	210.96	-78.09	40.61	-91.24	215.58	-77.80	46.54
Sri Lanka	-12.10	-13.83	0.27	-25.65	1.99	-0.86	0.41	1.54	-10.03	-14.59	0.44	-24.18
Rest of South Asia	1.15	-24.69	-5.08	-28.62	15.85	-59.68	5.71	-38.12	17.54	-87.11	1.09	-68.48
Singapore	0.25	-15.15	5.99	-8.92	0.08	-3.52	1.11	-2.34	-0.12	-20.80	6.26	-14.66
Saudi Arabia	24.02	-156.26	-1.89	-134.14	6.15	-16.84	0.05	-10.65	109.78	-193.31	56.74	-26.78
China	-89.08	-139.32	159.87	-68.52	-12.56	-43.18	35.57	-20.17	337.99	-474.98	203.19	66.19
South East Asia	-263.44	-166.70	12.25	-417.89	-17.67	-11.39	3.61	-25.46	-283.81	-170.70	12.47	-442.04
Oceania	-5.46	48.67	6.98	50.20	-1.67	0.49	1.75	0.57	-6.80	70.10	6.22	69.52
North America	-18.45	-15.11	-21.82	-55.38	8.36	22.65	-3.99	27.02	-10.74	65.02	-31.91	22.36
EU	-117.03	119.28	49.46	51.71	-18.60	7.85	11.27	0.52	-150.97	276.28	43.01	168.33
ROW	-407.88	-604.70	84.85	-927.72	-87.58	-117.38	20.04	-184.92	-487.76	-631.26	78.51	-1040.51
Total	-673.73	2.45	-0.73	-672.00	-204.38	0.54	-0.18	-204.02	-364.58	2.94	-0.88	-362.53

Source: Results of the GTAP Simulations

Notes:
EV = equivalent variation (welfare); AE = allocative efficiency; TOT = terms of trade; IS = investment-savings effect.
EV = AE + TOT + IS.

Annex 10. GTAP (version 10) aggregation of agri-food products.

Types of Agri-food	Categories	Description
Agriculture	Paddy , Wheat	
	Maize	(Sorghum, Barley, Rye, Oats, Millets, Other cereals)
	Vegetables	(Fruits, Nuts, Edible roots and tubers, Pulses)
	Oil seeds	
	Sugar crops	
	Fiber crops	
	Spice and aromatic products	
	Live Animal	
	Raw milk	
Processed Food	Fish and Aquaculture	(Marin and fresh water Fish and Aquaculture)
	Meat of Mammals	(Meat of Buffalo, Goats, Sheep, Camels, horses and other mammals)
	Other Meat	(Meat of pigs, Rabbits, Poultry, other meat and edible offal, Preserved and flours of meat.)
	Animal and Vegetable Oils	(Animal and vegetable oils, oil cake, Margarine)
	Dairy Products	
	Processed Rice	(Semi or wholly milled, or husked)
	Sugar and Molasses	
	Food Preparation	(Preserved fish, crustaceans, molluscs, Preserved vegetables and fruits, nuts, Cereals and vegetable flours and meals, Groats, meal and pellets of cereals , Bakery products, Cocoa, Chocolate and sugar confectionery, Food products)
	Beverage and tobacco products	

Source: Prepared by authors based on the GTAP (version 10) product aggregation

NATIONAL SCIENCE FOUNDATION

Section 5

Environment

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Environment: Introduction

Sarath Kotagama and Ajith De Alwis

Covid-19 an "Emerged Infectious Disease" – turned into a pandemic. The response to the pandemic situation resulted in the "normal" lifestyle and systems have been affected. The vast shutdowns and restrictions that became necessary to fight coronavirus in the country has had rapid and profound impacts on the environment. Further, action to prevent the recurrence of the pandemic has also been implemented. Taking note of the impacts to the environment, actions to reverse the situation to a "new normal" has been taken and in some situations planned for the future. To document, review and elaborate on the impacts and future actions are crucial to ensure that the "new normal" is properly defined, understood and executed. Rhetoric by many that the "new normal" is going to be the same despite the vast changes that have happened to the environment is a myth. The "new normal" will definitely be a blend of what was and anew aspects as responses to the COVID impacts. These new aspects are not only going to be those that are to prevent any such occurrences in the future, but also responses to the breakdown of the developed system. To understand and respond to move into the "new normal", it will be prudent to document and strategize proper actions in the future. For this, the environmental situation according to two of the three components – NATURAL, BUILT & STRUCTURED, and THEORETICAL (Kotagama, 1998), were researched.

In the NATURAL environment component, the aspects of how the Covid impacts the elements such as biodiversity, ecosystems, fauna and flora (disturbed, undisturbed, whatever is left?), protected areas etc. (e.g. impact on exploitation of resources both legal and illegal wildlife); in the Lithosphere – soils, geology etc. (e.g. Enhanced soil degradation through neglect, or soils improvement through neglect?); and Hydrosphere – water (e.g. quality change resulting from reduced disposals) was considered.

In the BUILT & STRUCTED Environment component where humans are present. Having migrated from caves to special dwellings and then creating a varied system of services and amenities, the great human migration to cities has many environmental issues. However, certain practices both known, and unknown continue to put pressure on us, to change. The recent emergence of the covid suspected to be from a wet market, where perhaps species come together which under normal natural circumstances will not happen is to be recognized as an element of the built environment scenario. Wet market is an artificial construct of ours. Similarly in response to the pandemic, activities such as maintaining "social distancing", virus/bacteria free surfaces, proper ventilation etc. will impact design considerations.

Covid-19 has made us to rethink and rekindle the importance of the long overdue changes in the natural and built environment. Of course, the overarching climate change has been dictating us to do this for quite some time. Sri Lanka having so many pluses as a mid-size island and a biodiversity, which we can truly make us proud, should understand the importance of change for sustainability. The pandemic can accelerate these changes. Aspects of "Regenerative Agriculture", adequate Protected Areas, sustainable use of our biodiversity should be seriously considered as focal areas in the "new normal". Cities, and infrastructure, including buildings have been some of the main elements that have been causing negative impacts on the environment. Trends in "greening' now has a new meaning in the light of Covid. The emerging cities with possible thrust of "working from home", which clearly indicate environmental positive aspects will impinge built environment immensely. The thrust to Decarbonize the BUILT and STRUCTURED ENVIRONMENT has to be visited and resonated. The scientists of Sri Lanka responded with 06 presentations, 01 in biodiversity, 04 related to the built environment, and 01 in general environment. A brief summary is provided below..

Biodiversity

1. Post COVID-19 agriculture: The way forward

The presentation covered the research and development studies conducted by the NIFS over several decades to produce two major types of biofertilizers as viable alternatives for imported chemical fertilizers. The data presented include scientific information on these novel fertilizers. The results obtained from extensive field trials conducted in several locations in the country closely interacting with mandated state institutions, private sector companies, NGOs and rural farmers, showed positive results. The reversion to natural processes in agriculture through the use of "regenerative" approaches was considered a need in the "New Normal" society to be ensure stable natural ecosystem services, to avoid any future emerging infectious diseases that might become pandemics.

Built Environment

2. Water and wastewater-based epidemiological risk and surveillance of Sars-COV implications for Sri Lanka

Although, the virus airborne, studies have focused on the fate of viruses in the urban water cycle. A study has been conducted on viruses that replicate and transmit via fecal-oral route. Evidence suggests high viability of occurrence of the virus in sewage and hospital wastewater, originating from fecal matter.

This article presented discussions and attentive measures for the urban wastewater systems, which indicated the occurrence and survival of SARS-CoV-2 in water and wastewater in Sri Lanka extensively. Epidemiological risk associated with water is determined by properties of the liquid. Matrix Wastewater surveillance of SARS-CoV-2 is a prominent tool concerning COVID-19 progression. Routine detection of surface water contaminations by sewage in Sri Lanka as a surveillance method of SARS-CoV-2 is highlighted.

3. Rethinking urban public space design in the adaptive re-use of built environment in the post pandemic era

Many cities in Sri Lanka are still on the front lines battling the COVID-19 pandemic, and highly urbanized areas have felt the most concentrated effects of the virus. Hence, the proper design in urban planning and development to face the virus without spreading it among the people of the city is needed. Keeping this in mind, a conceptual guideline was developed based on the responses from the study.

4. Can green cleaning be readily implemented in the public realm for COVID 19?

Proper cleaning and disinfecting of public buildings are compulsory to prevent the transmission of Corona virus. The manual content analysis showed that the most required general cleaning design measures are timely repair, hybrid ventilation and increased natural lighting, space allocation for janitor's closet, service elevators, staircases, enclosed & separated garbage chutes, proper drainage systems and cleanable surface materials. Both public health administrators and the public itself will be benefitted through these mechanisms and a healthy and a safe public realm can be ensured.

5. Significance of sustainable urban planning and development in pandemic scenario, Covid-19; Social, economic and environmental perspectives in Sri Lanka

Understanding this, over the past few decades, numerous research has been undertaken on the impacts of a wide range of disasters on urban areas, and necessary planning, recovery, mitigation and adaptation measures that need to be taken to deal with those disasters. In this regard, the recent pandemic offered an unprecedented opportunity to understand how urban areas might be affected by pandemics and what actions are needed to minimize the impacts and enhance urban pandemic resilience. Against this situation, the main objective of the study was to comprehend the significance of the urban planning and development in pandemic scenarios and its impact from the social, economic and environmental perspectives. Based on the case study findings and preliminary review, a conceptual guideline was developed with recommendations related to the socio-economic, environmental factors, urban management, transportation and urban design that can be used in post COVID-19 urban planning and development.

General Environment

6. COVID-19 and Environment: Lessons Learned

The unprecedented impacts of the COVID-19 pandemic have forced economies to redirect their efforts in achieving developmental goals that were in line with the trajectory of the old pre-pandemic world. However, in the backdrop of the still lingering pandemic, the new normal demands that we rethink and reevaluate these goals. Despite the burdening effects of the pandemic, it has provided us with many lessons to be incorporated into achieving these renewed goals especially with relation to addressing environmental concerns and the climate change crisis.

Water and wastewater-based epidemiological risk and surveillance of SARS-CoV-2: Implications for Sri Lanka‡

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ABSTRACT

Ever since the first outbreak in Wuhan, the novel acute respiratory syndrome-coronavirus (SARS-CoV-2) has wiped off over 3.8 million people across the globe. Recent reports manifest the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in water and wastewater. Evidence suggests high viability of occurrence of the virus in sewage and hospital wastewater, originating from fecal matter. Transportation of SARS-CoV-2 from these municipal sewage systems to the wastewater treatment plants is highly prominent and sampling the composition for genetic fingerprint in these wastewater reveals the presence of the SARS-CoV-2 virus. The transmission of SARS-CoV-2 to water and wastewater enhances the epidemiological risk associated with the spreading of COVID-19 through the water. Furthermore, wastewater surveillance of SARS-CoV-2 is currently identified as a prominent tool used in tracking and understanding the risk associated with COVID-19 progression in a community. However, water and wastewater-based surveillance and/or risk assessment have no attention received in Sri Lanka. Further, measures of spread spreading would be in vain with the renewed risk of exposure of the virus from liquid matrices, especially in densely urbanized communities.

Key words: Epidemiological risk, SARS-CoV-2, Water contamination, Wastewater surveillance

1. INTRODUCTION

The swift outbreak of coronavirus disease (COVID-19) has dramatically impacted diverse aspects of human life worldwide. To date, since the incidence in Wuhan city, China (Zhu et al., 2020), more than 175 million patients have been identified throughout the world affected by COVID-19 (*COVID-19 Map - Johns Hopkins Coronavirus Resource Center*) . Similarly, over 200,000 patients and more than 2,000 deaths have been identified from Sri Lanka so far. The causative agent of the deadly ongoing pandemic of COVID-19 was officially designated as severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) (Bivins et al., 2020). The primary route of SARS-CoV-2 transmission among individuals is the respiratory droplets of an infected person or the direct contacts created by contact with an infected individual and the virus transmission through the nose, mouth, or eyes (Patel et al., 2020).

The frequently reported symptoms of COVID-19 include cough, fever, and difficulty in breathing, and as an uncommon symptom, diarrhea is also reported. Furthermore, several studies have reported SARS-CoV-2 in the urine and feces of infected individuals (Bivins et al., 2020; Thompson et al., 2020). Despite the serious respiratory disorders associated

‡ **Invited Paper**

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with COVID-19, SARS-CoV-2 is reported to impair diverse organs, including the gastrointestinal tract, by weakening the activity of the angiotensin-converting enzyme (ACE) 2 receptors (Xiao et al., 2020). As described in Cheung et al., (2020), RNA of SARS-CoV-2 was detected in fecal samples of infected patients even after producing negative results for respiratory samples. Similarly, the frequency of detecting viral RNA in fecal samples is more extensive in comparison to diarrhea-like gastrointestinal symptoms (Cheung et al., 2020). This marks the release of active viral particles or viral RNA from symptomatic and asymptomatic individuals, eventually releasing into natural waters and wastewater treatment systems.

Moreover, viral particles of SARS-CoV-2 and their RNA fragments have been identified from municipal sewage, sludge derived from wastewater treatment plants, medical wastewater, wastewater released from passenger flights and ships, river water, and partially treated wastewater (Tran et al., 2021). The current knowledge on the wastewater-based epidemiological risk of COVID-19 transmission manifests the importance of understanding the wastewater surveillance of SARS-CoV-2 as a critical factor in managing the public health risk and screening the circulation of the virus in a specific region (Ahmed et al., 2021; Bhattacharya et al., 2021) Water/wastewater based epidemiological risk and its surveillance play a quick and easy role in the early detection of disease spreading in a particular community than conventional techniques; it is advantageous for a country like Sri Lanka with densely populated urban centers and limited resources. However, lack of motivation, collaboration, and indulgence have hindered the use of water/wastewater-based risk assessment and surveillance. Therefore, this chapter focuses on producing insight to extend the understanding on the portals of water contamination by SARS-CoV-2, the epidemiological risk associated with SARS-CoV-2 in water and wastewater surveillance.

2. PORTALS OF WATER CONTAMINATION BY SARS-COV-2

As mentioned in recent findings, the survival of SARS-CoV-2 in the natural environment, especially in the water, is estimated from hours to days (Thakur et al., 2021). However, still limited knowledge exists concerning the SARS-CoV-2 virus in water with different constituents such as temperature, UV exposure, disinfectants, adversarial microorganisms, dissolved organic matter, suspended solids, etc. (Paul et al., 2021). Thus, research towards understanding the fate and transport of SARS-CoV-2 concerning the water cycle is essential to implement strategies to curb its effects (Figure 1).

2.1. Wastewater

Municipal wastewater is a complex matrix that includes pathogens, dissolved organic matter, nutrients, colloids, suspended solids, plastics/microplastics, heavy metals, etc. These materials can interact and form strong or weak complexes with the SARS-CoV-2 modifying the resident times in the environment (Aydogdu et al., 2021). The genetic material of SARS-CoV-2 has been detected in municipal wastewater samples from many countries, including the Netherlands, Italy, Spain, France, Turkey, UAE, India, Japan, Australia, and the USA, indicates its presence (Ahmed et al., 2020; Haramoto et al., 2020; Medema et al., 2020; Randazzo et al., 2020) (Table 1). Usually, sewage can be contaminated with coronavirus when the wastewater comes in contact with saliva, sputum, feces, vomit, urine, and bathing water of infected people (Han et al., 2020). Even a single infected person has the ability to spread lots of SARS-CoV-2 genomic copies into sewage. High viral load variation has been reported in clinical samples taken from different sources of infected people, namely, around 104 to 1014 copies/L in sputum and saliva, around 106 to 1011 copies/L in feces, and around 105 to 108 copies/L in urine (Feng et al., 2021).

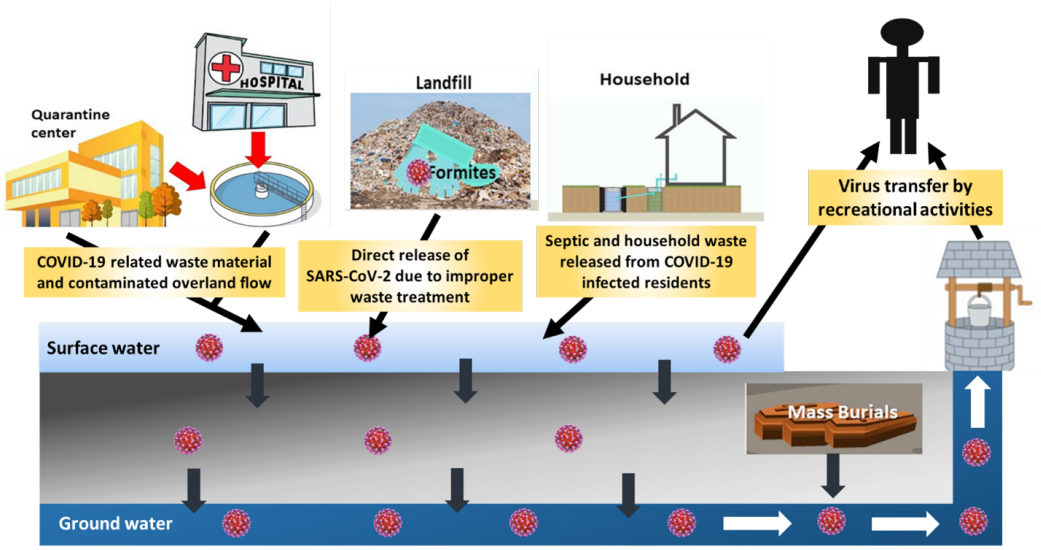

Figure 1. Portals of water contamination by SARS-CoV-2

Sewage generated from locations such as quarantine centers, infected people residing in buildings and houses, and hospitals, particularly infectious disease units, has a greater capability to contain SARS-CoV-2 (Carducci et al., 2020). Unfortunately, Sri Lanka has no attempts to assess the environmental release of SARS-CoV-2. Sewage systems of buildings can be contaminated with coronavirus due to the cross-transmission from sanitary plumbing systems (Gormley et al., 2017). Wastewater delivered from buildings and the watersheds above wastewater treatment plants (WWTPs) may contain coronavirus and potential inefficiency of the wastewater treatment could leave the virus in the discharges (Giacobbo et al., 2021). Generally, in many countries, the influent of WWTPs have been detected low amount of SARS-CoV-2, genomic copies are ranged from 20 copies/L to 107 copies/L. Factors such as the dissimilarities in sampling and quantification methods, high viral load variation in feces, and the presence of rainwater in sewers have led to the above differences and high range of the virus content in wastewater (Giacobbo et al., 2021).

2.2. Surface water and groundwater

Surface water bodies, namely streams, rivers, tanks, reservoirs, and the sea, can get contaminated with SARS-CoV-2 mainly due to the accumulation of coronavirus containing wastewater and runoff. This may lead to fecal-oral virus transmission (Cahill and Morris, 2020). Wastewater treated from WWTPs discharged into the natural environment may have the potential to release the contagious virus into surface water (Carducci et al., 2020). Especially in developing countries wastewater treatment process could be inefficient (Langone et al., 2020). However, developed countries such as Italy also showed SARS-CoV-2 in river samples, probably due to the contamination with inefficiently treated wastewater (Rimoldi et al., 2020). Further, mismanaged waste disposal (biomedical and personal protective belongings) contaminates surface waters to some extent. Also, lack of wastewater treatment facilities and insufficient sanitary infrastructure in many areas lead to the immediate release of feces and untreated sewer from hospitals, quarantine centers, and infected people residing houses to water sources. This has been commonly seen in countries such as Brazil, Nicaragua, and Ecuador, which is possible in urban centers in Sri Lanka (Guerrero-latorre et al., 2020). Hence, it increases the virus contamination in the environment. Similarly, sewage accumulation-driven virus contamination can be identified in refugee camps and low-income rural areas (Al Huraimel et al., 2020).

Table 1. Occurrence of SARS-CoV-2 in water and wastewater

Sampling location		Water type	Method of virus detection		Virus Concentration (copies/L)	Reference
County	**City**		**Virus concentration method**	**Virus detection method**		
Australia	Brisbane, Queensland	Untreated WW	Electronegative membrane-direct RNA extraction; ultrafiltration	qPCR	1.2×10^2	(Ahmed et al., 2020)
USA	Southern Louisiana.	Untreated WW	Ultrafiltration, adsorption-elution method using electronegative membrane	RT -qPCR	3.2log10	(Sherchan et al., 2020)
		Secondary treated WW and Chlorine disinfected final effluents			Not detected	
France	Paris	Untreated WW	Ultracentrifugation	RT-qPCR	$>10^{6.5}$	(Wurtzer et al., 2020)
		Treated WW			$\sim 10^5$	
Brazil	Florianopolis Santa Catalina	Urban sewage	-	Real time RT-PCR	5.49-6.68 log10	(Fongaro et al., 2021)
Netherlands	Amsterdam, Den Haag, Utrecht, Apeldoorn, Amersfoort	Sewage WW	Ultrafiltration	Real-time RTPCR	2.6 – 2200 x 10^3	(Medema et al., 2020)
Japan	Ishikawa, Toyama	WWTP influent	PEG 8000 precipitation	qRT-PCR	2.1×10^4– 4.4×10^4	(Hata et al., 2021)
Turkey	Istanbul	Wastewater	Centrifugation	RT-qPCR	0.0 – 2.6×10^4	(Kocamemi et al., 2020)
China	Wuchang, Fangcang Hospital, Wuhan	Hospital WW	Centrifugation	AgPath-ID™ One-Step RTPCR Kit	- 0.05-1.87 x 10^4	(Zhang et al., 2020)
Equador	Quito	Urban river water	Skimmed milk flocculation method followed by centrifugation	RT-qPCR	2.91 x 10^5 - 3.19 x 10^6	(Guerrero-latorre et al., 2020)

**WWTP –wastewater treatment plant, *WW-wastewater*

Another possible surface water contamination with SARS-CoV-2 can be happened by raw sewage accumulation due to leakages, blockages, and system failures in sewage systems (Ahmed et al., 2020). Furthermore, raw sewage can be released with the urban runoff and flood events during tidal infiltration and heavy rainfalls resulting in combined sewer overflows (Langone et al., 2020). Similarly, underground sewage line damages imply groundwater contaminations with SARS-CoV-2. However, the vulnerability of groundwater contamination is less than surface water as the infiltrating contaminated water or wastewater filters through the soil (Carducci et al., 2020; Langone et al., 2020).

Also, there is a limited possibility to contaminate surface water from coronavirus via surface runoff happening in landfill sites where contaminated facemasks and other sanitary items have been disposed (Thakur et al., 2021). Sri Lanka uses two sea outfalls to discharge urban stormwater and other materials into the ocean. This may also have implications for the contamination of coastal areas.

Meanwhile, the burial of SARS-CoV-2 victims without proper containment could be lead to groundwater and surface water contamination with the virus, especially in the case of mass burial in areas of high transmissivity (Thakur et al., 2021). Further studies are required regarding SARS-CoV-2 contamination of groundwater sources to have a better understanding. Countries like Sri Lanka, where the groundwater is shallow and vulnerable due to high transmissivity and dense population (Vithanage et al., 2012), may lead to groundwater contamination especially in the coastal aquifers; however, merely, no attempts have been taken place.

3. EPIDEMIOLOGICAL RISK OF SARS-COV-2 FROM WATER & WASTEWATER

The persistence of SARS-CoV-2 in natural water and wastewater is evident, as explained in many studies (Giacobbo et al., 2021). However, the primary factor concerning the virus persistence in liquid matrices, including natural water and wastewater, is the infectivity and the epidemiological risk associated with the prevalence of virus particles. This could be correlated with the factors associated with the survival of SARS-CoV-2 in liquid matrices and their resistance towards specific conditions (Giacobbo et al., 2021; Tran et al., 2021). The factors affecting the growth of SARS-CoV-2 in aqueous environments are affected by the temperature, pH, and concentration of organic matter, electrical conductivity, and suspended solids (Tran et al., 2021). Surprisingly, as reported in Zhang et al., (2020), the SARS-CoV-2 virus discharged with feces of certain COVID-19 patients is protected from the disinfection procedure of medical wastewater due to specific organic compounds present in feces. Therefore, the survival of the discharged viral particles is dependent upon the virus's destructive or retention properties of the liquid matrix.

Similarly, the survival of the SARS-CoV-2 virus is dependent upon the type of the water matrix. This intern is associated with the disease spread and the epidemiological risk. As reported in Bivins et al., (2020), the survival of SARS-CoV-2 is prominent in tap water compared to sewage, with a 90% reduction in the infectious viral particles from 1.7 to 1.5 days. Similarly, the same study reports less persistence of SARS-CoV-2 RNA than infectious SARS-CoV-2 virus particles in aqueous matrices. Furthermore, Ahmed et al., (2020), report an extended loss of SARS-CoV-2 vial RNA at 4–37 °C from tap water, raw sewage, and autoclaved sewage than of mouse hepatitis virus under the same conditions. This provides evidence for the low survival potential of SARS-CoV-2 in water matrices, which is advantageous in terms of epidemiological risk from water. However, terrifyingly, Kang et al., (2020), report the spread of COVID-19 in a high-rise apartment building in Guangzhou, China, due to the bioaerosolization of wastewater contaminated with fecal and urine contaminants of COVID-19 infected patients. This study highlights the importance of providing attention to the epidemiology of COVID-19 through water and wastewater.

Concerning the epidemiological risk of SARS-CoV-2 transmission through drinking water, WHO provides evidence for the absence of active SARS-CoV-2 particles or SARS-CoV-2 viral RNA in drinking water following disinfection, however, bathing and swimming are prohibited yet in natural and man-made freshwater pools. Similar certification is provided by the United States Environmental Protection Agency (USEPA, 2020) as well.

4. WASTEWATER SURVEILLANCE OF SARS-COV-2

Wastewater surveillance of SARS-CoV-2 provides successful ventures in monitoring the persistence of the virus and the epidemiological risk associated with the transmission of the virus among humans, which is identified as a promising strategy in tracking the spread and the reemergence of SARS-CoV-2 (Cervantes-Avil´es et al., 2021). As presented in the studies of Chen et al., (2020), SARS-CoV-2 viral RNA was detected in the feces of infected individuals for 7-10 days after observing negative results for pharyngeal swabs. Similar observations are produced by Cheung et al., (2020), depicting the risk of wastewater contamination by viral RNA and the importance of wastewater surveillance in COVID-19. Conversely, Randazzo et al., (2020), report the release of SARS-CoV-2 RNA into wastewater systems even before the inaugural cases were reported in the areas of sample collection. Indeed, wastewater surveillance could be highlighted as a strategy for the early indication of disease incidence.

Several limitations and a lack of optimizations need attention in detecting and quantifying SARS-CoV-2 in wastewater samples. However, there are several crucial steps to be followed in the successful detection of SARS-CoV-2 from wastewater. These include specific sampling conditions and timing, the potential inactivation pathways of the virus, removal of any available impurities, virus concentration and detection, and the quantification of the viral genetic units (Cervantes-Avil´es et al., 2021). Concentrating the virus from the wastewater sample is extremely important for its successful detection even at low concentrations. This is highlighted with the varying concentrations of SARS-CoV-2 detected from fecal samples of different individuals. Successful detection of SARS-CoV-2 is reported by employing concentration methods such as PEG precipitation, ultrafiltration, and electronegative membrane adsorption from municipal wastewater in countries such as Australia, the USA, and France (Ahmed et al., 2020; Kitajima et al., 2020). However, in wastewater surveillance of SARS-CoV-2 in regions with low COVID-19 prevalence, a significant sample volume of wastewater may be required to be processed for successful viral detection. The most commonly used method in the detection of SARS-CoV-2 in wastewater samples is the reverse transcriptase quantitative polymerase chain reaction (RT-qPCR) and reverse transcription-polymerase chain reaction (RT-PCR) (Ahmed et al., 2020; Haramoto et al., 2020; Medema et al., 2020). The replacement of infectious cell culture assays with PCR-based techniques is noticeable in detecting viruses in samples like wastewater with a fewer viral load (Hamouda et al., 2021).

The cost associated with the detection of SARS-CoV-2 in wastewater is governed by the type of test used for the detection and the measures taken in enhancing the rate of virus detection (Patel et al., 2020). As recommended in many studies the precision of the virus detection is enhanced with the use of multiple primers or probes in the detection process (Medema et al., 2020), however, this, in turn, increases the cost associated with the virus detection. Digital PCR is currently highlighted as the most successful and sensitive method for SARs-CoV-2 detection in wastewater. However this method is extensively expensive compared to q-PCR (Patel et al., 2020). The practice of proper quality assurance methods is critical for the successful wastewater surveillance of SARS-CoV-2. The use of well-controlled and optimized methods for pre-conditioning and virus concentration with improved efficiency will help in achieving the target outcome of wastewater surveillance of SARs-CoV-2. In order to reduce the misspend cost of SARS-

CoV-2 detection in wastewater, the use of methods with high recovery rates and high detection frequency could be employed. The emergence of standard methods and quality assurance strategies for the accurate evaluation of SARS-CoV-2 spread in wastewater is critically important. In Sri Lanka, the utilization of human and physical resources in the Central Environemntal authority and the water board for this purpose is critically highlighted.

Wastewater surveillance of SARS-CoV-2 confers the possibility of identifying the pattern of SARS-CoV-2 spread among communities. This advantage is pronounced especially among communities with poor sanitation practices and infrastructure (Bhattacharya et al., 2021). As reported by (F. Ahmed et al., (2021), the distance between the sampling locations used to monitor SARS-CoV-2 was observed to be insignificant towards the detected gene concentration. Accordingly, this study implies the possibility of utilizing wastewater surveillance as a successful venture in acquiring knowledge on the risk assessment of COVID-19 in a specific area. Furthermore, Kumar et al., (2021), designates wastewater surveillance of SARS-CoV-2 as an early warning tool in producing meaningful predictions and conclusions on COVID-19 hotspots within a given community. Thus, the capability of utilizing wastewater surveillance in developing early management strategies is impressive. The occurrence of SARS-CoV-2 in wastewater was observed even before the substantial rise of COVID-19 patients all over the world (Wurtzer et al., 2020). Similarly, several studies have provided experimental evidence for the spread of SARS-CoV-2 via wastewater even prior to presenting initial COVID-19 cases by national authorities (Randazzo et al., 2020). Moreover, the increase in SARS-CoV-2 viral load in wastewater precisely correlates with the increase in the fatality rate of COVID-19 (Bhattacharya et al., 2021). These suggest the potential and importance of deploying wastewater surveillance of SARS-CoV-2 as a successful system in monitoring the disease prevalence among communities.

Even though wastewater surveillance of SARS-CoV-2 and monitoring SARS-CoV-2 in sewage are identified as successful methods of COVID-19 surveillance, in practical scenarios, countries like Sri Lanka with low-resource settings require to harbor more practical approaches regarding this context (Kreier, 2021). However, the wastewater surveillance of SARS-CoV-2 is critically essential in countries practicing poor wastewater management strategies, as this could create a danger for the fecal-oral transmission of COVID-19 and in producing secondary transmission towards human and the environment. This fact is more pronounced with the evidence of *E.coli* occurrence in the rivers and streams of Sri Lanka indicating the sewage contaminations. As produced in Mallawatantri et al., (2016), the Kelani river basin is continuously contaminated with fecal contaminants throughout the year. Therefore, the importance of routine detection of surface water contaminations by sewage in Sri Lanka as a surveillance method of SARS-CoV-2 is highlighted.

5. SUMMARY AND FUTURE PERSPECTIVES

In a situation where the whole world struggles to overcome the COVID-19 pandemic, wastewater surveillance plays a significant role in detecting the virus spread. However, there are specific research gaps to be urgently filled for the successful wastewater detection for SARS-CoV-2. These include the comparative information regarding the removal efficiency of SARS-CoV-2 from wastewater using different methods, the methods of SARS-CoV-2 contamination of water and viral abundance in raw and treated wastewater to generate risk assessment, successful means of disinfection, and the requirement of using specific disinfectant agents based on the viral load for the complete removal of SARS-CoV-2 from wastewater. Similarly, practical aspects including the optimization of molecular approaches to determine the infective viral occurrence, enhancing the sensitivity of current methods, and developing novel methods in achieving extended sensitivity for SARS-CoV-2 detection and enhanced scientific

understanding on the lowest infectious amount of SARS-CoV-2 from waste and aerosols will help in further approaches of wastewater surveillance of SARS-CoV-2.

Sri Lanka, being a tropical country, where urban and river flooding is common with intense rainfalls, frequently reported overflows of sewage persists. Another potential source of SARS-CoV-2 exposure into the water is improperly operated septic systems initially designed to decontaminate the incoming pathogen. Virus outbreaks have continually been reported with septic tanks pertaining to high densities that further leached into the environment. The proper management of septic systems in Sri Lanka will assist in removing SARS-CoV-2 from wastewater in the same way that it does with other harmful viruses. Similarly, avoiding the on-site disinfection of waste material, especially from hospitals and quarantine centers retaining COVID-19 patients is severely crucial in lowering the threat of releasing SARS-CoV-2 into natural waters as it fails in disinfecting the effluent water. The persistence of fecal-to-oral route transmission and infectivity into humans is still uncertain, especially in a developing nation like Sri Lanka, where there is high dependence on utilizing mainstream rivers and shallow dug wells for potable water. Indeed, proper actions are required concerning releasing untreated domestic wastewater containing SARS-CoV-2 into natural water matrices. It further becomes more crucial to explore, more than ever before, the aspects of pathways and mechanisms in the urban environment and interactions with the virus of this vivid nature.

REFERENCES

Ahmed, W., Angel, N., Edson, J., Bibby, K., Bivins, A., O'brien, J. W., Choi, P. M., Kitajima, M., Simpson, S. L., Li, J., Tscharke, B., Verhagen, R., Smith, W. J. M., Zaugg, J., Dierens, L., Hugenholtz, P., Thomas, K. V. & Mueller, J. F. (2020). First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. *Science of The Total Environment,* 728, 138764. https://doi.org/10.1016/j.scitotenv.2020.138764

Al Huraimel, K., Alhosani, M., Kunhabdulla, S. & Stietiya, M. H. (2020). SARS-CoV-2 in the environment: Modes of transmission, early detection and potential role of pollutions. *Science of The Total Environment,* 744, 140946. https://doi.org/10.1016/j.scitotenv.2020.140946

Ahmed, F., Islam, M. A., Kumar, M., Hossain, M., Bhattacharya, P., Islam, M. T., Hossen, F., Hossain, M. S., Islam, M. S., Uddin, M. M., Islam, M. N., Bahadur, N. M., Didar-ul-Alam, M., Reza, H. M., & Jakariya, M. (2021). First detection of SARS-CoV-2 genetic material in the vicinity of COVID-19 isolation Centre in Bangladesh: Variation along the sewer network. *Science of the Total Environment*, *776*, 145724. https://doi.org/10.1016/j.scitotenv.2021.145724

Aydogdu, M. O., Altun, E., Chung, E., Ren, G., Homer-Vanniasinkam, S., Chen, B., & Edirisinghe, M. (2021). Surface interactions and viability of coronaviruses: Surface interactions and viability of coronaviruses. *Journal of the Royal Society Interface*, *18*(174). https://doi.org/10.1098/rsif.2020.0798rsif20200798

Bhattacharya, P., Kumar, M., Islam, M. T., Haque, R., Chakraborty, S., Ahmad, A., Niazi, N. K., Cetecioglu, Z., Nilsson, D., Ijumulana, J., van der Voorn, T., Jakariya, M., Hossain, M., Ahmed, F., Rahman, M., Akter, N., Johnston, D., & Ahmed, K. M. (2021). Prevalence of SARS-CoV-2 in Communities Through Wastewater Surveillance—a Potential Approach for Estimation of Disease Burden. *Current Pollution Reports*, 160–166. https://doi.org/10.1007/s40726-021-00178-4

Bivins, A., Greaves, J., Fischer, R., Yinda, K. C., Ahmed, W., Kitajima, M., Munster, V. J., & Bibby, K. (2020). Persistence of SARS-CoV-2 in Water and Wastewater. *Environmental Science and Technology Letters*, *7*(12), 937–942. https://doi.org/10.1021/acs.estlett.0c00730

Cahill, N., & Morris, D. (2020). Recreational waters – A potential transmission route for SARS-CoV-2 to humans? *Science of the Total Environment*, *740*, 140122. https://doi.org/10.1016/j.scitotenv.2020.140122

Carducci, A., Federigi, I., Dasheng, L., Julian R, T., & Marco, V. (2020). Making waves: Coronavirus detection, presence and persistence in the water environment: State of the art and knowledge needs for public health. *Water Research*, *179*, 115907. https://doi.org/10.1016/j.watres.2020.115907

Cervantes-Avil´es, P., Moreno-Andrade, I., & Carrillo-Reyes, J. (2021). Approaches applied to detect SARS-CoV-2 in wastewater and perspectives. *Journal of Water Process*

Engineering, *40*(40). https://doi.org/https://doi.org/10.1016/j.jwpe.2021.101947

Chen, Y., Chen, L., Deng, Q., Zhang, G., Wu, K., Ni, L., Yang, Y., Liu, B., Wang, W., Wei, C., Yang, J., Ye, G., & Cheng, Z. (2020). The presence of SARS-CoV-2 RNA in the feces of COVID-19 patients. *Journal of Medical Virology*, *92*(7), 833–840. https://doi.org/10.1002/jmv.25825

Cheung, K. S., Hung, I. F. N., Chan, P. P. Y., Lung, K. C., Tso, E., Liu, R., Ng, Y. Y., Chu, M. Y., Chung, T. W. H., Tam, A. R., Yip, C. C. Y., Leung, K., Fung, A. Y., Zhang, R. R., Lin, Y., Cheng, H. M., Zhang, A. J. X., To, K. K. W., Chan, K., & Yuen, K. (2020). Gastrointestinal Manifestations of SARS-CoV-2 Infection and Virus Load in Fecal Samples From a Hong Kong Cohort : Systematic Review and Meta-analysis. *Gastroenterology*, *159*, 81–95.

COVID-19 Map - Johns Hopkins Coronavirus Resource Center. (n.d.). Retrieved June 12, 2021, from https://coronavirus.jhu.edu/map.html

Feng, B., Xu, K., Gu, S., Zheng, S., Zou, Q., Xu, Y., Yu, L., Lou, F., Yu, F., Jin, T., Li, Y., Sheng, J., Yen, H. L., Zhong, Z., Wei, J., & Chen, Y. (2021). Multi-route transmission potential of SARS-CoV-2 in healthcare facilities. *Journal of Hazardous Materials*, *402*(August 2020), 123771. https://doi.org/10.1016/j.jhazmat.2020.123771

Fongaro, G., Hermes, P., Sobral, D., Souza, M., Carlos, E., Elisa, M., Rogovski, P., André, M., Hartmann, F., Paula, A., Felipe, L., Oliveira, V. De, Luiza, M., & Wagner, G. (2021). The presence of SARS-CoV-2 RNA in human sewage in Santa Catarina, Brazil, November 2019. *Science of the Total Environment*, *778*. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.146198

Giacobbo, A., Rodrigues, M. A. S., Zoppas Ferreira, J., Bernardes, A. M., & de Pinho, M. N. (2021). A critical review on SARS-CoV-2 infectivity in water and wastewater. What do we know? *Science of the Total Environment*, *774*, 145721. https://doi.org/10.1016/j.scitotenv.2021.145721

Gormley, M., Aspray, T. J., Kelly, D. A., & Rodriguez-Gil, C. (2017). Pathogen cross-transmission via building sanitary plumbing systems in a full scale pilot test-rig. *PLoS ONE*, *12*(2), 1–13. https://doi.org/10.1371/journal.pone.0171556

Guerrero-latorre, L., Ballesteros, I., Villacrés-granda, I., & Granda, M. G. (2020). SARS-CoV-2 in river water : Implications in low sanitation countries. *Science of the Total Environment*, *743*. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.140832

Hamouda, M., Mustafa, F., Maraqa, M., Rizvi, T., & Aly Hassan, A. (2021). Wastewater surveillance for SARS-CoV-2: Lessons learnt from recent studies to define future applications. *Science of the Total Environment*, *759*. https://doi.org/10.1016/j.scitotenv.2020.143493

Han, H., Luo, Q., Mo, F., Long, L., & Zheng, W. (2020). SARS-CoV-2 RNA more readily detected in induced sputum than in throat swabs of convalescent COVID-19 patients. *The Lancet Infectious Diseases*, *20*(6), 655–656. https://doi.org/10.1016/S1473-3099(20)30174-2

Haramoto, E., Malla, B., Thakali, O., & Kitajima, M. (2020). First environmental surveillance for the presence of SARS-CoV-2 RNA in wastewater and river water in Japan. *Science of the Total Environment*, *737*, 140405. https://doi.org/10.1016/j.scitotenv.2020.140405

Hata, A., Hara-Yamamura, H., Meuchi, Y., Imai, S., & Honda, R. (2021). Detection of SARS-CoV-2 in wastewater in Japan during a COVID-19 outbreak. *Science of the Total Environment*, *758*, 143578. https://doi.org/10.1016/j.scitotenv.2020.143578

Kang, M., Wei, J., Yuan, J., Guo, J., Zhang, Y., Hang, J., Qu, Y., Qian, H., Zhuang, Y., Chen, X., Peng, X., Shi, T., Wang, J., Wu, J., Song, T., He, J., Li, Y., & Zhong, N. (2020). Probable Evidence of Fecal Aerosol Transmission of SARS-CoV-2 in a High-Rise Building. *Annals of Internal Medicine*, *173*(12), 974–980. https://doi.org/10.7326/M20-0928

Kitajima, M., Ahmed, W., Bibby, K., Carducci, A., Gerba, C. P., Hamilton, K. A., Haramoto, E., & Rose, J. B. (2020). SARS-CoV-2 in wastewater: State of the knowledge and research needs. *Science of the Total Environment*, *739*. https://doi.org/10.1016/j.scitotenv.2020.139076

Kocamemi, B. A., Kurt, H., Hacıoglu, S., Yaralı, C., Saatci, A. M., & Pakdemirli, B. (2020). First Data-Set on SARS-CoV-2 Detection for Istanbul Wastewaters in Turkey Authors Marmara University , Department of Environmental Engineering , Istanbul , Turkey Saglik Bilimleri University , Faculty of Medicine , Department of Medical Biology , Istanbul. *MedRxiv*, *April*, 2–11.

Kreier, F. (2021). The myriad ways sewage surveillance is helping fight COVID around the world. *Nature*. https://doi.org/10.1038/d41586-021-01234-1

Kumar, M., Joshi, M., Shah, A. V, Srivastava, V., & Dave, S. (2021). First wastewater surveillance-based city zonation for effective COVID-19 pandemic preparedness powered

by early warning: A study of Ahmedabad, India. *MedRxiv*. https://doi.org/https://doi.org/10.1101/2021.03.18.21253898

Langone, M., Petta, L., Cellamare, C. M., Ferraris, M., Guzzinati, R., & Mattioli, D. (2020). SARS-CoV-2 in water services: Presence and impacts. *Environmental Pollution*, *268*, 8. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7550914/pdf/main.pdf

Mallawatantri, A., Rodrigo, A., & Silva, K. De. (2016). *Medium to Long-term Multi-Stakeholder Strategy and Action Plan for Management and Conservation of Kelani River Basin.* (Issue February 2018).

Medema, G., Heijnen, L., Elsinga, G., Italiaander, R., & Brouwer, A. (2020). Presence of SARS-Coronavirus-2 RNA in Sewage and Correlation with Reported COVID-19 Prevalence in the Early Stage of the Epidemic in the Netherlands. *Environmental Science and Technology Letters*, *7*(7), 511–516. https://doi.org/10.1021/acs.estlett.0c00357

Patel, M., Chaubey, A. K., Pittman, C. U., Mlsna, T., & Mohan, D. (2020). Coronavirus (SARS-CoV-2) in the Environment: Occurrence, Persistence, Analysis in Aquatic Systems and Possible Management. *Science of the Total Environment*, 142698. https://doi.org/10.1016/j.scitotenv.2020.142698

Paul, D., Kolar, P., & Hall, S. G. (2021). A review of the impact of environmental factors on the fate and transport of coronaviruses in aqueous environments. *Npj Clean Water*, *4*(1). https://doi.org/10.1038/s41545-020-00096-w

Randazzo, W., Truchado, P., Cuevas-Ferrando, E., Simón, P., Allende, A., & Sánchez, G. (2020). SARS-CoV-2 RNA in wastewater anticipated COVID-19 occurrence in a low prevalence area. *Water Research*, *181*, 115942. https://doi.org/10.1016/j.watres.2020.115942

Rimoldi, S. G., Stefani, F., Gigantiello, A., Polesello, S., Comandatore, F., Mileto, D., Maresca, M., Longobardi, C., Mancon, A., Romeri, F., Pagani, C., Cappelli, F., Roscioli, C., Moja, L., Gismondo, M. R., & Salerno, F. (2020). Presence and infectivity of SARS-CoV-2 virus in wastewaters and rivers. *Science of the Total Environment*, *744*, 140911. https://doi.org/10.1016/j.scitotenv.2020.140911

Sherchan, S. P., Shahin, S., Ward, L. M., Tandukar, S., Aw, T. G., Schmitz, B., Ahmed, W., & Kitajima, M. (2020). First detection of SARS-CoV-2 RNA in wastewater in North America: A study in Louisiana, USA. *Science of the Total Environment*, *743*, 140621. https://doi.org/10.1016/j.scitotenv.2020.140621

Thakur, A. K., Ramanathan, A. L., Bhattacharya, P., & Kumar, M. (2021). Environmental Resilience and Transformation in Times of COVID-19. *Environmental Resilience and Transformation in Times of COVID-19*, 95–102. https://doi.org/10.1016/c2020-0-02703-9

Thompson, J. R., Nancharaiah, Y. V, Gu, X., & Lin, W. (2020). Making waves: Wastewater surveillance of SARS-CoV-2 for population-based. *Water Research*, *184*.

Tran, H. N., Le, G. T., Nguyen, D. T., Juang, R. S., Rinklebe, J., Bhatnagar, A., Lima, E. C., Iqbal, H. M. N., Sarmah, A. K., & Chao, H. P. (2021). SARS-CoV-2 coronavirus in water and wastewater: A critical review about presence and concern. *Environmental Research*, *193*, 110265. https://doi.org/10.1016/j.envres.2020.110265

USEPA. (2020). *Coronavirus and Drinking Water and Wastewater*. https://www.epa.gov/coronavirus/coronavirus-and-drinking-water-and-wastewater

Vithanage, M., Engesgaard, P., Villholth, K. G., & Jensen, K. H. (2012). The Effects of the 2004 Tsunami on a Coastal Aquifer in Sri Lanka. *Ground Water*, *50*(5), 704–714. https://doi.org/10.1111/j.1745-6584.2011.00893.x

Wurtzer, S., Marechal, V., Mouchel, J., Maday, Y., Teyssou, R., Richard, E., Almayrac, J., & Moulin, L. (2020). *Evaluation of lockdown impact on SARS-CoV-2 dynamics through viral genome quantification in Paris wastewaters*. https://doi.org/10.1101/2020.04.12.20062679

Xiao, F., Tang, M., Zheng, X., Liu, Y., Li, X., & Shan, H. (2020). Evidence for gastrointestinal infection of SARS-CoV-2. *Gastroenterology*, *158*(6), 1831–1833.

Zhang, D., Ling, H., Huang, X., Li, J., Li, W., Yi, C., Zhang, T., Jiang, Y., He, Y., Deng, S., Zhang, X., Wang, X., Liu, Y., Li, G., & Qu, J. (2020). Potential spreading risks and disinfection challenges of medical wastewater by the presence of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) viral RNA in septic tanks of Fangcang Hospital. *Science of the Total Environment*, *741*, 140445. https://doi.org/10.1016/j.scitotenv.2020.140445

Zhu, N., Zhang, D., Wang, W., Li, X., Yang, B., Song, J., Zhao, X., Huang, B., Shi, W., Lu, R., Niu, P., Zhan, F., Ma, X., & N, D. (2020). A Novel Coronavirus from Patients with Pneumonia in China, 2019. *The New England Journal o f Medicine*, 727–733. https://doi.org/10.1056/NEJMoa2001017

Post Covid-19 agriculture: The way forward

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ABSTRACT

The corona pandemic has had disastrous effects on global as well as local economies. Every country had to review and organize plans to recover from its ill effects on their economies. Currently the number one priority for Sri Lanka is the allocation of additional funds to contain and control the pandemic and provide relief to the people. Food production and food security are vital sectors that also need attention to prevent hunger and social unrest.

This paper will briefly cover the research and development efforts of the National Institute of Fundamental Studies (NIFS) that have produced two groups of low cost, eco-friendly biofertilizers which could significantly minimize the application of imported chemical fertilizers in agriculture without any reduction in crop yields. Widespread use of such fertilizers could make agriculture less dependent on imported fertilizers and make food production in Sri Lanka more self reliant and self sufficient. Unlike soluble chemical fertilizers which pollute the environment and contribute significantly to increase in environmental diseases, biofertilizers enhance organic matter development, improve beneficial soil microbial activity and make agriculture less polluting and more sustainable. Less soil and water pollution will decrease the incidence of kidney diseases, cancer and other environmentally related illnesses which are prevalent particularly among the farming communities of Sri Lanka, the backbone of agriculture. If biofertilizer use can be popularized, the Covid pandemic could be considered as a blessing in disguise which caused a revolutionary turning point in crop production in Sri Lanka to a truly benign activity.

Key words: Biofertilizers, Covid impact, Eco-friendly agriculture, Pollution reduction, Self reliant agriculture

1. INTRODUCTION

The Covid-19 pandemic has had a devastating impact on the global economy estimated to be in the region of 3.5 trillion US dollars. All countries big and small had to postpone their regular activities and divert their attention to meet the enormous challenges to control the virus and contain the rapid spread of the pandemic and minimize the death and devastation it was causing among their populations. Besides strengthening health services and providing immediate relief to the affected people, strengthening food production and establishing food security received high priority in Sri Lanka. Foremost among the government decisions was the reduction of all foreign imports in order to save foreign exchange and overcome the immediate necessity of minimizing the country's debt burden. A major imported component for agriculture in Sri Lanka is chemical fertilizers and any alternative that could reduce their application is an enormous relief to its economy. The conventional alternatives available are organic fertilizers such as composts, green

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manure, animal dung, crop residues etc. All these dead substrates provide nutrients to plants from their biomasses after further microbial decomposition into assimilable forms. Therefore they are required in large quantities to replace the nutrients provided by chemical fertilizers. Organic materials also take time to become available and are not quite suitable for short term crops like cereals, pulses and most vegetables. The best alternatives appear to be biofertilizers which are living entities that establish intimate associations with targeted host plants and continue to provide nutrients from external substrates. For example nitrogen fixing microorganisms like rhizobia form symbiotic root nodules with leguminous plants and fix nitrogen from air which is an external substrate. Similarly increased microbial biomass triggered by biofilm biofertilizers get intimately associated with the root systems and enhances nutrient use efficiency by the targeted host plants from inorganic and/or organic substrates. Because of these unique features, biofertilizers are not needed to be added in large quantities and they are suitable for short term crops. This paper will review the development of biofertilizers by the NIFS. The principal hypothesis was to examine to what extent these microbial fertilizers could replace the use of chemical fertilizers in agriculture. Even if a part reduction is achievable, it would be of immense economic and ecological benefit to the country and its people.

2. METHODOLOGY

One of the foremost areas of study undertaken by the NIFS was Biological Nitrogen Fixation (BNF) which is a key to sustainable crop production. Initial basic studies in this project were to isolate, characterize and identify (as far as possible) different nitrogen fixing microorganisms intimately associated with major crop plants of Sri Lanka, namely rice, maize, pulse legumes and short term vegetables.

2.1. Development of Rhizobial biofertilizer

Isolation and characterization of rhizobia from root nodules of healthy, commonly cultivated legume crops of Sri Lanka essentially followed the procedures described by Somasegeran and Hoben (1991). Isolations commence with streaking inoculants of suspensions obtained either from surface sterilized, split (large nodules) or crushed root nodules (small nodules) on differential, selective media such as Congo Red Yeast Mannitol Agar (CRYMA). Growth on this medium enables the identification of contaminants which absorb the red dye as different from relatively less coloured gummy colonies of potential rhizobia. Purification of rhizobia from these mixed colonies was done by successive sub-culturing on the same medium until pure, white, gummy colonies of rhizobia were obtained. Such purified colonies were then transferred to standard Yeast Mannitol Agar. An isolated culture is subjected to characterization of colony morphology, cell morphology after Gram staining, and culturing on Bromo thymol blue Yeast Mannitol Agar (BRYMA) medium to see whether it is fast growing and acid producing or non-acid producing and slow growing. These isolates are further characterized for their ability to utilize different sources of carbon substrates and examined on their tolerance to temperature, pH and salinity. Finally the characterized rhizobial isolates are authenticated against their original host plants by testing whether they can nodulate the host under laboratory conditions. A few of the commonly field applied strains as biofertilizer inoculants have also been subjected to molecular analysis and identified based upon their 16S RNA sequences. In this manner a germplasm of rhizobial isolates from different food and forage legumes cultivated in Sri Lanka was built up.

2.2. Development of inoculants

The first step to prepare a rhizobial inoculant for a particular host plant is to screen a few of the characterized and authenticated isolates in pot experiments under greenhouse conditions for effective nodulation and efficient plant growth. The best strain is then cultured in 100 ml of Yeast Mannitol Broth (YMB) in 250 ml conical flasks under continuous, mild, rotary shaking. These cultures are used to inoculate 6

to 8 L of YMB with mild aeration as a semi-mass culture in a 10 L aspirator bottle. Strict sterile conditions are maintained to ensure that the culture remains uncontaminated (Figure 1). Once a sufficient cell density (10^8 – 10^{10} cells/ml) was obtained, 15 ml aliquots were removed under aseptic conditions, diluted 10 times to 150 ml and injected into 250 g of pre-prepared powdered coir dust enclosed in 200 µ gauge polypropylene bags and sterilized by autoclaving at 120°C and 1 kg/cm^2 pressure for 20 minutes. The inoculated bags were incubated at 28°C for 7 days to mature and covered in (250 µ gauge) black polythene covers and labelled with instructions for use. Finally the inoculant packet is enclosed in an attractive cover depicting the relevant crop legume and marketed (Figure 2 a & b).

2.3. Field testing and field application

Prior to the release of an inoculant it is field tested preferably in more than one location where the crop is widely cultivated. It had been our practice to conduct field tests as much as possible in farmer's fields for two reasons. These fields mimic the actual conditions of the small holder farmers more closely than those in research stations which are well maintained. Moreover if the tests give positive results acceptance of the technology by the farmers is that much easier. The usual plot size adopted for field testing was 2m x 4m and the treatments were (i) Control with no inoculation and N-fertilizer addition (ii) Test plot with inoculation and without N-fertilizer addition and (ii) Standard plot with the recommended level of N-fertilizer applied without inoculation. These treatments were replicated three times and wherever possible arranged on a randomized complete block design. Depending on the site this design was sometimes changed. Two well designed field trials with replicates were conducted to obtain N-fertilizer yield response curves for soybean and vegetable bean. The effects of the corresponding rhizobial inoculants were read off from these curves. While the trial with soybean was conducted in 2008 in collaboration with Plenty Foods PLC in one of its outsource farmer's fields, the trial with vegetable beans was conducted in a farmer's field in Ankumbura (near Kandy) in 2018 with the facilitation of the Provincial Department of Agriculture, Central Province.

Figure 1. A sterile semi-mass culture of a selected purified Rhizobial strain

(a)

(b)

Figure 2. (a) Inoculant packet preparation and (b) Marketed packet for vegetable bean

2.4. Large scale field applications and technology transfer

These activities were carried out in collaboration with the Department of Agriculture, Provincial Departments of Agriculture, Plenty Foods (Private) Limited and the Mahaweli Development Authority which facilitated the participation of farmers. Occasionally interested farmer groups often led by local Buddhist priests joined us to test this technology. It was an arduous task to wean the farmers away from the practice of applying chemical fertilizers to which they have been accustomed to, for six decades. Some of them did not believe that crop cultivation is possible without urea. Obtaining high yields with our inoculants in the trials conducted in farmers' own fields were helpful, but several farmers were hesitant to accept this novel technology. Field demonstrations of how to apply the inoculants (Figure 3a) and planting the treated seeds were conducted in several locations of crop cultivation (Figure 3b).

(a)

(b)

Figure 3. Demonstrations of (a) seed inoculation and (b) inoculated seed planting

The different sites and locations where field studies were done with crop legumes are shown in Figure 4.

2.5. Inoculation of the forage legume clover (Trifoleum repens L.)

Application of rhizobial inoculant technology to the highly nutritive forage legume clover was not difficult because it was done in a well managed, organized livestock farm run by Ambewela Farms (Private) Limited. The results of field testing followed by large scale field trials were reported in Kulasooriya et al (2017). The results were so convincing that the management has stopped urea application to clover cultivations since 2017, minimizing N-pollution of this highland water catchment area located next to Horton Plains.

2.6. Studies with Biofilm Biofertilizers (BFBF)

The development of BFBF includes the isolation of fungi and bacteria from the rhizosphere of the targeted crop plant, screening for efficacy and pathogenicity,

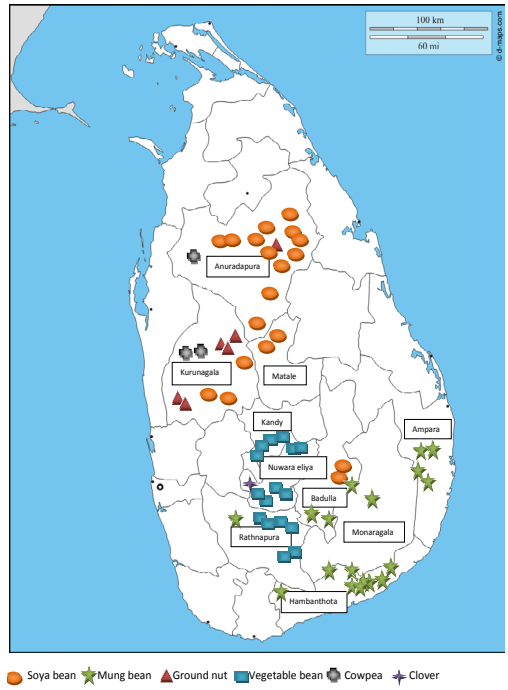


Figure 4. Sites where rhizobial inoculant trials were conducted

formulating biofilms and testing with the crop in greenhouse and field conditions. Small scale field testing as well as large scale field trials cwith Biofilm-Biofertilizers (BFBF) have been conducted in several locations covering all the agro-ecological regions of Sri Lanka. Commencing with tea (in collaboration with the Tea Research Institute), these experiments covered non-leguminous crops such as rice, maize, potato, carrot, leafy vegetables and even fruits like strawberry. A major brakthrough for BFBF came when large scale field trials conducted in collaboration with the Department of Agriculture (DoA) in several rice growing areas (Figure 5) gave really encouraging results.

Large scale (1 acre plot) rice field trials were conducted during Maha 2019/2020 and Yala 2020 seasons by the NIFS in collaboration with the DoA at 14 locations in 5 districts (Figure 5). The treatments included 90 kg NPK/ac only; 90 kg NPK/ac + BFBF (1 L/ac); 136 kg NPK/ac (DoA recommendation).

Figure 5. Districts where large scale BFBF field trials with rice were conducted

3. RESULTS

The isolated and characterized rhizobial culture collection at the NIFS today contains 204 rhizobial strains as stock cultures. The most commonly applied 5 strains used as field inoculants were subjected to molecular analysis and identified based upon their 16S RNA sequences.

The N-fertilizer response curves obtained for soybean and vegetable bean are given in (Figure 6 a & b). It is clear from both these curves that the yields obtained by the application of the inoculants were equivalent to those given under the highest level of recommended urea additions.

Reading from these curves it is seen that the yields obtained by inoculation coincide with the highest level of urea fertilizer application.

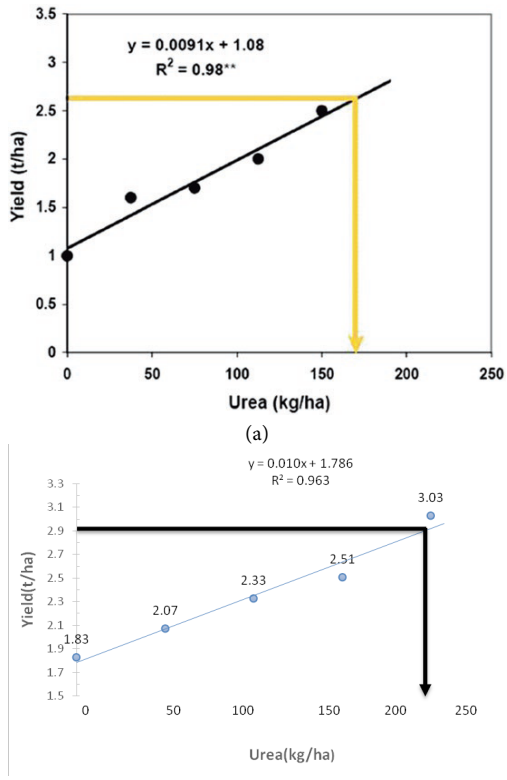


Figure 6. Yield response curves for urea applications to (a) soybean (*Glycine max* L) and (b) vegetable bean (*Phaseolus vulgaris* L)

All the field experiments conducted in farmers' fields with diiferent crop legumes where inoculation was compared with N-fertilizer additions, gave similar results (Figure 7 a, b, c, & d)

These results clearly show that the yields obtained by applying rhizobial inoculants were either equal or marginally above those obtained with the recommended levels of urea fertilizer.

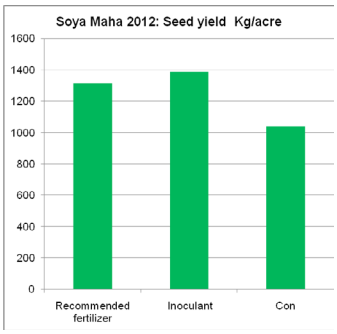
The nitrogen fixed by the endo-symbiotic rhizobia is supplied directly to the targeted host legume through its root nodules, whereas urea broadcast on to a field is freely available to all plants including weeds. Therefore a reduction in weed growth could be expected under inoculation. In a field trial conducted with vegetable beans weed biomasses under inoculation and urea application were recorded. The results showed a 70% reduction in weed growth under inoculation compared to N-fertilizer addition.

In all the experiments with BFBFs the results convincingly showed that they can replace all three major fertilizer additions of N, P & K by at least 50% without any reduction and sometimes with increases in yields. The Tea Research Institute even approved a recommendation for the application of BFBFs to nursery tea plants. With all other crops tested, similar results were observed.

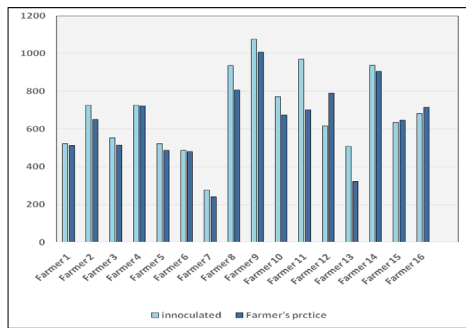
In 70% of the locations, grain yields of rice under BFBF treatments were significantly higher (by ca. 20%) than that of the 90 kg NPK/ac only and DoA treatments ($P < 0.05$). About 15,000 ac were cultivated with BFBF in Kurunegala & Ampara districts in Yala 2020. We have planned to increase the paddy land extent of the annual BFBF application to 150,000 ac this year.

4. DISCUSSION

It is evident from all these results that rhizobial inoculation has the potential to completely replace the application of urea to soybean, green gram, vegetable bean and groundnut without any reduction in yields. Presently these inoculants are marketed to farmers at very reasonable prices. For example, a 250 g packet of inoculants sufficient for seed



(a)



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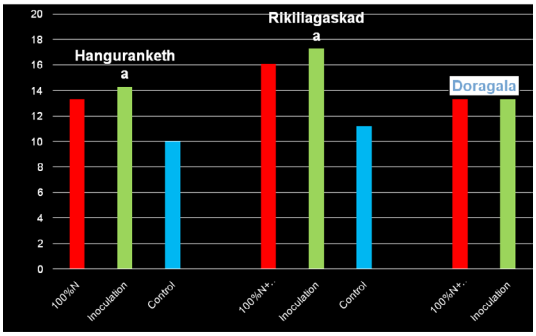

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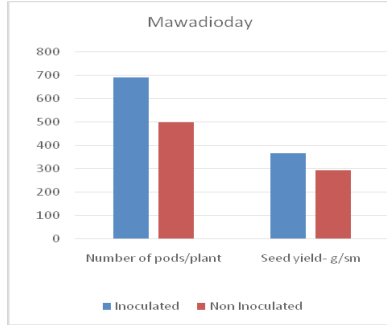

(d)

Figure 7. Yields obtained by rhizobial inoculation on (a) soybean (*Glycine max* L), (b) mung bean (*Vigna radiata* L), (c) vegetable bean (*Phaseolus vulgaris* L) and (d) groundnut (*Arachis hypogea* L) in comparison to urea application.

dressing and cultivation of one acre of soybean, green gram or groundnut is priced at only Rs.400/-. The equivalent of urea will cost the farmer more than Rs.1500/-. For vegetable beans a 100 g packet that can inoculate 1 kg of bean seeds is priced at Rs. 120/-. The recommended urea application for a hectare of bean cultivation is 220 kg.

Moreover rhizobial inoculants are applied as seed dressings as grams per hectare while urea has to be added in kilograms (150 kg/ha for soybean, 220 kg/ha for vegetable bean). Therefore farmers have to incur additional costs to transport, store and apply chemical fertilizers. These differences in weights become specially critical to vegetable bean farmers of the central mountain regions where this crop is widely cultivated in undulating terrains (Figure 8).

Since weed growth is much less under inoculation in comparison to urea application, farmers can also save on the cost of weedicide applications. All this goes to show that inoculation technology could significantly reduce the cost of production of legume crops.

All these legumes are highly nutritious pulse crops commonly consumed by the people of Sri Lanka, sometimes referred to as the 'poor man's protein diet'. Unfortunately Sri Lanka does not produce enough of these commodities and it is reported that we import 70% of our soybean and 40% of our green gram requirments. Even the Budget speech of 2020 mentioned that we are unable to produce the required amount of '*Thriposha*' (a highly nutritive preparation given to lactating mothers and infants) due to the shortage of soybean and maize. One of the remedies that can be implemented is to expand the cultivation areas of legume crops in Sri Lanka and offer attractive prices to the farmers for their produce. With rhizobial inoculantion the cost of production can be reduced significantly and if such a strategy is followed with enthusiasm the country could be self sufficient in these commodities within a short period. As these inoculants are locally produced this is self reliant self sufficiency.

Figure 8. Terrace cultivation of beans in Central mountains

If BFBF could be adopted in rice across the country we could save over Rs. 6 billion per annum in foreign exchange for the country and replace over 100,000 tonnes of Chemical Fertilizer being imported annually.The overall benefit of the BFBF use, including the saving on human health and the environment would be over a hundred billion rupees.

ConclusionAs such, it is proposed to take steps to promote the application of biofertilizers and bring about a revolution in agriculture from a costly, environmentally detrimental activity to a low cost, eco-friendly, sustainable system that could improve the health of the nation particularly of our farming communities which provide the invaluable service of food production.

5. ACKNOWLEDGEMENT

Financial assistance provided by Grant MSTR: 7/2/7 of the State Ministry of Skills Development, Vocational Education, Research & Innovation is gratefully acknowledged.

REFERENCES

Kulasooriya, S. A., Ekanayake, E. M. H. G. S., Kumara, R. K. G. K. and Sarath Bandara, A.M. (2017) Rhizobial inoculation of *Trifolium repens* L. in Sri Lanka. Journal of the National Science Foundation, Sri Lanka 45 (4): 361 – 366.

Somasegaran, P & Hoben, H. J. (1994). The Handbook for Rhizobia - Methods in Legume-Rhizobium-Technology, pp 450, Springer-Verlag, New York, USA.

BIBLIOGRAPHY

Howeison, J. & Herridge, D. (2005) "Foreword' Special issue, Australian Journal of Experimental Agriculture, 56: 45

Salas-Gonzales, et al. (12 authors) (2021). Coordination between microbiota and root endodermis supports plant mineral nutrient homeostasis. Science, 371, (6525): p.143. DOI: 10.1126/science.abd0695

Seneviratne, G., Thilakaratne, R. M. M. S., Jayasekera, A. P. D. A., Seneviratne, K. A. C. N., Padmathilake, K. R. E., and De Silva, M. S. D. L. (2009). Developing beneficial microbial biofilms on roots of non-legumes: a novel biofertilizing technique. In: Khan, M. S., Zaidi, A & Musarat, J (eds) Microbial Strategies for Crop Improvement, pp 51 – 62, Springer, Heidelberg.

Seneviratne, G., Jayasekera, A. P. D. A., De Siva, M. S. D. L. & Abeysekera, U. P. (2011). Developed microbial biofilms can restore deteriorated, conventional agricultural soils. Soil Biology Biochemistry, 43: 1059 – 1062.

Rethinking urban public space design in the adaptive re-use of built environment in the post pandemic era

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ABSTRACT

The ambiguous relationship between the built environment and the human becomes more obvious when the society encounters different disasters and pandemics. COVID 19 has disturbed the human population by causing more than 1.5. Million deaths and leaving everlasting impressions on disciplines of architecture, urban design and planning. This study aims to understand the potential approaches for creating more resilient urban public spaces in response to such pandemic situations. Methodology of this study is based on a combination of Comprehensive literature survey, Expert interviews with emerging issues in the domain of (1) Public space design and utilization and (2) perceptions, use and behaviour are analysed. Findings of this research reveals that, decentralized network of smaller green spaces, horizontal approaches with more available open spaces and improved infrastructure are some of the implications in the Architectural and Urban design disciplines. An extensive discourse is already underway on how the aftereffects of pandemic will transform our interaction with public spaces and their creation. Accordingly, this research explores the possibility of adaptive reuse of the existing built environment, and proposes recommendations focusing on urban public spaces to meet the requirements of the new normal and how such transformed public spaces could adapt to, or resist a recurrence of similar pandemics in future. This situation will change the patterns of behaviour in public space and the directions of spatial planning. Although the substance of the city will not change, a city undergoes continuous spatial transformation, adapting to socioeconomic needs with the consequences of the COVID-19.

Key words: Adaptive reuse, COVID 19, Post pandemic, Urban public space

1. INTRODUCTION

Since the end of the 2019, the Covid 19 outbreak has impacted the society in various ways starting in Wuhan, China. According to WHO (2020), SARS-CoV-2 or COVID-19 is an infectious disease caused by a new strain of Coronavirus family and it has disturbed the human population seriously by causing more than 1.5 Million deaths globally up to date and interrupting daily activities of the people around the world. This pandemic will continue to claim millions of infected patients and deaths further with the lockdowns which lead to unpredictable unemployment, hindered economic development and reduced productivity that will take years to recover (Löhner et al., 2020). In future, some changes in behaviors of day to day life will be permanent. For instance, working from home practice has been dominantly practiced and 'social distancing' has become an immediate precaution to prevent from spreading the virus. But, "Before developing medications

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for an epidemic, one solution is to go back to the physical and built environment to reduce its impact" (Megahed & Gohenim, 2020). As of now, COVID-19 has brought forth new challenges; and the built environment has a significant role to play in reducing its spread and also addressing the social and psychological needs of people during the pandemic (Wilder-Smith et al., 2020). As cited by Keenan, J. M. (2020) "Among climate change experts, the risks of infectious disease and pandemics have long been on the list of multi-hazards to anticipate" (Semenza and Menne, 2009).

In containing non-infectious diseases such as diabetes and high blood pressure, the provision of space for more physical activities can make significant contributions. Further, the mental health (well-being) could be enhanced by the built environment by facilitating social interaction among people. (Wilder-Smith et al., 2020). Within these planning activities there is increasing sophistication in separating 'risk' and 'resilience' as independent, but related, domains of management and policy (Linkov et al., 2018).In its most simplified distillation, 'engineering' resilience (and to a large extent 'disaster' resilience) speaks to the elastic and reversionary capacities of a system to return to pre-stimulus level of operational performance and material quality, which may ultimately lead to adaptive and maladaptive outcomes depending on aging effects and the associated costs of time and money in supporting such performance (Hosseini et al., 2016; Kurth et al., 2020).

Recognition of the future of research and practice through different domains of resilience and adaptation are significant in this crisis. Within the context of human experience in all its capacities for ingenuity, empathy, and moral responsibility instead of quantifications of socioeconomic indicators. It is reminded that learned resilience is a result of continuous human attempt, either it is the advancement of human health or the design of architecture and the built environment (Keenan, 2020, Amerio et al., 2020). Specific to the healthcare sector, considerations relating to the resilience and adaptive capacity of the built environment are central to managing the existing challenges associated with supply constraints, alternative forms of service delivery, and the broader continuity of operations (Keenan, 2020). Thus, to enhance the resilience for the post pandemic situation, rethinking on the adaptive capacity of the built environment is considered as a specific area to focus linking healthcare considerations and public space design. It is obvious from the past evidence, that the built environment has been adjusted and adapted to minimize the fear and danger from diseases and infections (Megahed & Ghoneim, 2020). The pandemics can impact on the urban built environment mainly in two ways; (1) the built environment along with its infrastructure, modes of transport, use of public spaces, and (2) social context including the community participation (Ahsan, 2020). Similarly, Honey-Rosés et al., 2020, have summarized the emerging issues and concerns with the COVID 19 episode in relation to the design aspects, perceptions, use and behaviours as well as with the inequities and exclusions in the society (Honey-Rosés et al., 2020).

Concludingly, with the referred literature; the domains of (1) Public space design and utilization and (2) perceptions, use and behaviour were identified as the key approaches for this study (Table 1).

As it seems that we have to live with COVID-19 at least for the next couple of years or so the issue has become very significant. It has become essential to conjecture what the "new-normal" will be in future. As to how long the world will have to live with the pandemic, and the post-pandemic scenario after its elimination has started a major dialogue among experts. Planners, urban designers, architects, landscape managers and journalists are already writing about how this crisis will transform our affiliation with public spaces. There is great uncertainty about how COVID-19 will impact future public space design, use and perceptions. How will people's relationship with public space change? How long will the changes persist? Will people's emotional connections with places change? (Honey-Rosés et al., 2020). Therefore, rethinking the public realm is an

indispensable consideration in the future of urban design.

This study aims to understand the potential approaches for creating more comfortable urban public spaces in response to pandemic situation. Identifying possible changes in the built environment, revealing new approaches of developing urban public spaces with the changes in perceptions, behaviour and use. Identifying the importance of adaptive reuse strategies to reduce the risk of transmission or prevention of spreading will be the main focus of this study. Apart from the main focus, this study intends to explore the emerging concerns of COVID-19 in local context and its socioeconomic effects on society and the built environment, and finally revealing the future multidisciplinary studies where it is required.

2. METHODOLOGY OF THE STUDY

Methodology of this study is based on a combination of Comprehensive literature survey and Public space assessment through expert interviews to assess the emerging issues and identified key approaches within the domain of (1) Public space design and utilization and (2) perceptions, use and behaviour. 15 experts in the disciplines of public space design were selected for the interviews. The emerging issues of the below mentioned aspects were assessed through a non-structured interview through online platform, Zoom. The interview was recorded with the full consent of the participants. The authors reviewed the interviews and the experts opinions under each theme was analysed. At the end of the analysis, adaptability to the local context is discussed with the suggestions by the experts (Table 2).

Table 1. Domains of key identified issues with COVID 19 pandemic

Ahsan, 2020	• Infrastructure • Social context	• Public space design and utilization • Perceptions, use and behaviour
Honey-Rosés et al., 2020	• Design • Perceptions, use and behaviour • Inequities and exclusions	
(Pinheiro & Luís, 2020)	• behaviours • built environment (infrastructure, buildings, urban areas and green spaces)	
Megahed & Ghoneim, 2020	• Urban and Architectural Approaches • Construction strategies • Digital transformation	
(Amerio et al., 2020)	• psychological impacts (Perception related)	

Table 2. Emerging concerns in the domain of public space design and utilization and perceptions, use and behaviour in the post pandemic era

(1) Public space design and utilization	1.1 Will public open spaces be re-designed? Or repurposing /Adaptive reuse the spaces according to emerging needs?
	1.2 Whether the pandemic accelerates the mainstreaming of health criteria into the design of public spaces.
	1.3 Future possibilities and approaches of public open space planning needs in designing, uses, and practices.
	1.4 What would be the future of the large public spaces after the COVID 19?
	1.5 Do we need a new typology for public space?
	1.6 Whether the temporary transformations seen during the crisis inspire more permanent changes.
(2) perceptions, use and behaviour	2.1. Decrease in the number of people
	2.2. Changes in the Activity patterns
	2.3. Changes in the Perception

3. RESULTS AND DISCUSSION

According to the identified concerns of the domain of public space design and utilization and perceptions, use and behaviour in the post pandemic era, future potentials of the urban public spaces were discussed through expert interviews done with online surveys due to current pandemic situation and social distancing. Results of the literature survey and experts inputs has been discussed to identify local needs of future urban public space designing.

3.1. Public space design and utilization

3.1.1. Urban public open spaces repurposing - Adaptive reuse of open spaces according to emerging needs.

As the consequences of COVID-19, the World Health Organization (WHO) has declared the fast-spreading COVID-19 as a pandemic. People have been confined to their homes, which has significantly impacted their personal and social life. This trend reflects the needs of the very foundations of urban planning and architecture theory and practice for rethinking open public spaces (Allam & Jones, 2020; Haleem et al., 2020; Saadat et al., 2020). According to Megahed, N. A., & Ghoneim, E. M. (2020) Pandemics have impacted to transform the built environment because people are afraid to be infected and therefore, after this pandemic, architecture and urbanism will never be the same. The way people use the public spaces and interaction behaviour will depend on the post pandemic needs. Emotional and social functioning has distressingly been impacted by the COVID-19 by disturbing physical and mental health (Goniewicz et al., 2020; Pfefferbaum & North, 2020). Although the current global epidemic poses a challenge at all levels in the built environment, it will take time to develop an antivirus-enabled paradigm to reduce the potential risks or stop the virus from spreading (Megahed & Ghoneim, 2020).

Recognition of the future of research and practice through different domains of resilience and adaptation are significant in this crisis, means of human experience in all its capacities for ingenuity, empathy, and moral responsibility more than the quantifications of socioeconomic indicators (Keenan, 2020). Further, the COVID 19 has changed the way policy makers should rethink public space design and questioned how urban life could be managed in the wake of the pandemic. Recent studies on post pandemic urbanism have signified the following concerns. Would the pandemic motivate more urban improvements? Can cities be designed to reduce infections? Would the post-pandemic era generate new urbanism based on social distancing? More specifically, could COVID-19 be a catalyst for decentralization and walkable cities? It is clear how COVID-19 will impact future public buildings and spaces. However, would the lifespan of these impacts and reflections lasts for the future? What about the furniture materials, shared facilities and services? Whether the pandemic teaches us new lessons to rethink our public built environment and open spaces designs? (Megahed & Ghoneim, 2020).

These emerging questions in literature reflect the importance of rethinking on public open spaces considering post pandemic adaptation potentials. The expert interviews signify that the cost may be a limiting factor in re-designing public spaces because of the economic crisis due to the global pandemic situation. But it recognized that adaptive reuse of existing built environments and open spaces are the best way to face this crisis. Thus, there would have to be expansion of the width of existing walkways, major cycle-ways with recommended distancing and given standards by the experts in the healthcare sector. It might also be necessary to put up temporary notices, warnings and special signage specified to this post pandemic era to convince the public more effectively. Although the health sector has already made guidelines of urban public space design, the possibility of future pandemics should be taken into account in developing new-normal public space design guidelines and policies. Accordingly, the pandemic accelerates the mainstreaming of health criteria into the design of public spaces in the post pandemic era.

3.1.2. Future of urban public spaces and new design Approaches.

When the future of urban public spaces is considered, specific open space planning, possible design approaches, and practices should be recognized according to post pandemic user behavior and health care needs. New patterns and changes in spatial configurations should be manipulated by Architects, planners, and built environment professionals as they are keen to examine many social and spatial implications (Paital, 2020; Salama, 2020). As a result of the response of people to diseases, current architectural practices reflect that social distancing can change the future design and planning process (Budds, 2020; Chang et al.,2020). Because of this social distancing, horizontal expansion approaches using more available open spaces will be considered as critical design by Planners and architects to prevent the spread of infections and diseases (Liu, 2020; Novakovic, 2020).Our built environment will be rearranged and reshaped by policy makers with the opportunity given by the pandemic, soon before the next pandemic.

Megahed, N. A., & Ghoneim, E. M. (2020) have analysed two approaches called, "look step back to nature" and "look step forward to advanced technology" based on the lessons learned (Figure 1). It has been further discussed that the potentials of old urban typologies might reduce the possibility of urban densification, overcrowding and protection and Défense of the systems of our cities. Horizontal expansion, cities of lower density, decentralization, urban farming and more provisions for cycling and walking have been identified as dominant strategies for post pandemic urban design approaches in literature. Therefore, this study can be considered as an opportunity for Policymakers and planners to review planning theories and practices for further development.

According to the Experts inputs, smaller green spaces or neighbourhood parks, decentralized network of small green spaces and Community gardens were identified as the most suitable local context approaches in the post pandemic era. Large central parks or green spaces/ central green areas should be reconsidered, as the literature and experts have concluded that the risk of infection and

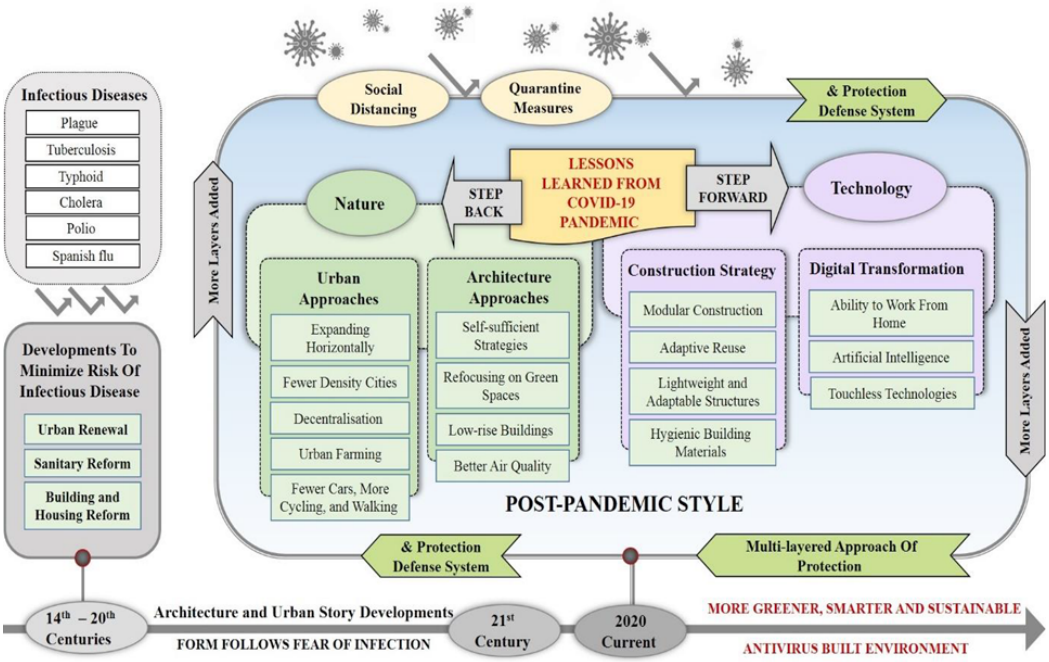

Figure 1. The proposed vision about the future of the antivirus-built environment by Megahed, N. A., & Ghoneim, E. M. (2020).

negative impacts are likely to increase. In addition, the decentralized network of smaller green spaces will help people to connect with nature and keep maintaining social distancing. It has both of the important physical and mental health benefits. To prevent infection and to maintain social distancing, it is essential to have more safe walkways and small roads for facilitating people and micro-mobility instead of depending only on mass public transportation.

Findings of the domain of Public space design and utilization, also recognized that horizontal approaches with more available open spaces could be essential to prevent the spread of infections and diseases. Improved infrastructure and even the changes in the behavioural patterns of the people are some of the implications in the Architectural and Urban design disciplines.

3.2. Perceptions, use and Behaviour

3.2.1. Decrease in the number of people

The first question in many minds in the current situation is whether people will behave similarly as before in the post COVID situation. Will people continue to flock in the public spaces as before with the health regulations? (Honey-Rosés et al., 2020). With the majority of people trying to shift their activities from the peak hours it can be expected that there will be temporal changes in the urban areas. (Salganik, 2019). With the outbreak, many activities were shifted from offices to homes. Work from home has become an essential step in minimizing the spread of the virus. The ones who deal with paperwork online can work comfortably, but the middle-class workers who need to work from their workplaces are faced with no other option but to visit their work places. (Valentino-DeVries et al., 2020). If this trend continues during the post pandemic era, then many of the urban public spaces will be used by the middle-income workers who leave for their work spaces while high income workers who work with the papers will continue to work from home. The high-income workers will mostly utilize the neighbourhood public spaces (Honey-Rosés et al., 2020).

According to the responses from the experts; with the decrease in the number of users, some spaces will eventually be underused. This low usage might be a permanent or a temporary scenario. The permanently neglected spaces can be used to develop spaces like urban forests which will contribute to long term benefits. While the temporary neglected spaces can be used for other alternative uses like temporary commercial spaces or for various functions as these activities will need extended spaces to function while following the safety guidelines.

3.2.2. Changes in the Activity patterns

Socializing and shopping can be identified as two major activities which impacts on the growth of urban public spaces (Solà-Morales & Geuze, 2008, Sennett, 2018). With the pandemic, many commercial activities have shifted to online platforms, with contact free deliveries and home shopping making the pandemic period more convenient for many urbanites. Shifting to online shopping is likely to produce less pedestrians in urban public areas yielding negative effects for small coffee shops, local stores and other small businesses which benefited from other major commercial activities (Honey-Rosés et al., 2020). When we use the urban public spaces, often we make contacts with strangers which leads to informal yet spontaneous relationships (Ahsan, 2020). The changed perceptions of the people, that anyone around would be a carrier of the virus will continue until this period is over. These might directly impact on socializing in urban public spaces. As Sri Lanka is a major tourist attraction, there are many cities which rely on the income from these tourists. With the pandemic, many of these cities will be remodelled to accompany the new restrictions. As tourists are one of major sources who brought the virus to the land, it is likely that many precautions will prevail even after the restrictions are lifted. COVID 19 has restricted access to large parks, shopping malls which accommodates a large number of people. This has led mainly the high-income families to shift to their neighbourhood markets and parks where the risk of transmission is low

(Dahmann et al., 2010). With these day-to-day practices there is a chance that the patterns and configurations of use of urban public spaces will change, reshaping the public areas in the post pandemic era (Honey-Rosés et al., 2020).

Experts claim that with the changes in the activities in commercial and tourist streets and people keeping their distance from each other, will result in chaotic free urban public spaces. Some of these pedestrian oriented spaces can be accommodated to the use of vehicles as people will feel secure in their personal space within the vehicle. Provisions to enjoy commercial and tourist activities within a secure space within their vehicles will have a positive impact on the business of small vendors as well.

3.2.3. Changes in the Perception

The people occupying urban public spaces are considered as an indicator that the particular space is functioning and healthy for use (Hajmir Sadeghi, 2012; Sadik-Khan & Solomonow, 2017). The Gehl Institute has also developed a protocol where the number of people staying or moving through a public space is used to indicate the success of the space (Gehl, 2010; Gehl & Svarre, 2013). Will this perception of the designers, scholars and other related individuals change with the new normal in the post pandemic era? William Whyte proposed that each public space has a carrying capacity of its own (Silverman, 1982), who further states that when the carrying capacity of any space has reached its limit, then the people will intuitively leave that space. The intuitive feeling of 'too many' will likely to be changed in the post pandemic era (Honey-Rosés et al., 2020). Normally for many urbanites, urban public spaces like parks, playgrounds, squares and plaza are some of the few places where they can feel calm, comfortable and warm in the midst of their busy lifestyles (Heffernan et al., 2014; Pugalis, 2009). However, the current situation has changed, where people feel insecure whenever they encounter a stranger leading to increased discomfort and insecurity. The adults will still recall their sweet relationships associated with several locations in public spaces in good old times, but the children and youth who stay a lot in online platforms due to the pandemic will miss their chance. These younger generations will have a different attitude to the sense of attachment and intimacy in public spaces when compared with the old generations (Honey-Rosés et al., 2020; Mitra et al., 2020). The changes in the perceptions on the carrying capacity will lead the designers to look for solutions to create personal spaces within public spaces. It is likely that the designers will redesign the existing spaces increasing the visual association between the strangers than the physical interactions.

4. CONCLUSION

An extensive discourse is already underway on how the aftereffects of pandemic will transform our interaction with public spaces and their creation. Accordingly, this research profoundly explores the possibility of adaptive reuse of the existing built environment, and proposes recommendations focusing on urban public spaces to meet the requirements of new normal and how such transformed public spaces could adapt to, or minimize the consequences of similar pandemics in future.

Findings of this study reveals that, decentralized network of smaller green spaces instead of central green areas, horizontal approaches with more available open spaces which could be essential to prevent the spread of infections and diseases for urbanites to breathe nature. Improved infrastructure and even the changes in the behavioural patterns of the people are some of the implications in the Architectural and Urban design disciplines. Decrease in the number of people, changes in activity patterns and changes in perceptions will create spaces which are temporary or permanently neglected and underused. The experts are suggesting that the permanently neglected spaces to be converted into spaces which promote urban ecology and biodiversity for long term benefits for the urban contexts. The temporary underused spaces can be used to accommodate the existing functions while following the health regulations, as the cost may be a limiting factor in re-designing public

spaces because of the economic crisis due to the global pandemic. But it is recognized that adaptive reuse of existing built environments and open spaces is the most effective way to face this crisis. Although the health sector has already been involved in making guidelines of urban public space design, the possibility of such pandemics should be taken into account in developing new-normal public space design guidelines and policies. Accordingly, the pandemic accelerates the mainstreaming of health criteria into the design of public spaces in the post pandemic era.

This situation will change the patterns of behaviour in public space and the directions of spatial planning. Although the substance of the city will not change, a city undergoes continuous spatial transformation, adapting to different economic conditions and responding to diverse social needs with the consequences of the COVID-19 pandemic. Concludingly, as a continuation to this study, exploration of additional emerging concerns of COVID-19 and its effects on society and the utilization of urban public spaces will unveil further research directions.

ACKNOWLEDGEMENT

This work is supported by the Accelerating Higher Education Expansion and Development (AHEAD) - DOR Grant affiliation with Ministry of Higher Education & University Grants Commission and funded by the World Bank.

REFERENCES

Ahsan, M. M. (2020). Strategic decisions on urban built environment to pandemics in Turkey: Lessons from COVID-19. *Journal of Urban Management*, *9*(3), 281–285. https://doi.org/10.1016/j.jum.2020.07.001

Allam, Z., & Jones, D. S. (2020). Pandemic stricken cities on lockdown. Where are our planning and design professionals [now, then and into the future]? *Land Use Policy*, *97*, 104805. https://doi.org/10.1016/j.landusepol.2020.104805

Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., Costantini, L., Odone, A., Costanza, A., Signorelli, C., Serafini, G., Amore, M., & Capolongo, S. (2020). COVID-19 Lockdown: Housing Built Environment's Effects on Mental Health. *International Journal of Environmental Research and Public Health*, *17*(16), 5973. https://doi.org/10.3390/ijerph17165973

Chang, D., Lin, M., Wei, L., Xie, L., Zhu, G., Dela Cruz, C. S., & Sharma, L. (2020). Epidemiologic and Clinical Characteristics of Novel Coronavirus Infections Involving 13 Patients Outside Wuhan, China. *JAMA*, *323*(11), 1092. https://doi.org/10.1001/jama.2020.1623

Dahmann, N., Wolch, J., Joassart-Marcelli, P., Reynolds, K., & Jerrett, M. (2010). The active city? Disparities in provision of urban public recreation resources. *Health & Place*, *16*, 431–445. https://doi.org/10.1016/j.healthplace.2009.11.005

Gehl, J. (2010). *Cities for people*. Island Press. http://site.ebrary.com/id/10437880

Gehl, J., & Svarre, B. (2013). Public Space, Public Life: An Interaction. In J. Gehl & B. Svarre, *How to Study Public Life* (pp. 1–8). Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-525-0_1

Goniewicz, K., Khorram-Manesh, A., Hertelendy, A. J., Goniewicz, M., Naylor, K., & Burkle, F. M. (2020). Current Response and Management Decisions of the European Union to the COVID-19 Outbreak: A Review. *Sustainability*, *12*(9), 1–1.

HajmirSadeghi, R. (2012). *The influence of urban parks on sustainable city via increase quality of life*. *51*, 10766–10770.

Haleem, A., Javaid, M., & Vaishya, R. (2020). Effects of COVID-19 pandemic in daily life. *Current Medicine Research and Practice*, *10*(2), 78–79. https://doi.org/10.1016/j.cmrp.2020.03.011

Heffernan, E., Heffernan, T., & Pan, W. (2014). The relationship between the quality of active frontages and public perceptions of public spaces. *URBAN DESIGN International*, *19*(1), 92–102. https://doi.org/10.1057/udi.2013.16

Honey-Rosés, J., Anguelovski, I., Bohigas, J., Chireh, V., Daher, C., Konijnendijk van den Bosch, C., Litt, J., Mawani, V., McCall, M., Orellana, A., Oscilowicz, E., Sánchez-Sepúlveda, H. U., Senbel, M., Tan, X., Villagomez, E., Zapata, O., & Nieuwenhuijsen, M. (2020). *The Impact of COVID-19 on Public Space: A Review of the Emerging Questions*. https://doi.org/10.31219/osf.io/rf7xa

Hosseini, S., Barker, K., & Ramirez-Marquez, J. E. (2016). A review of definitions and measures of system resilience. Reliability Engineering & System Safety, 145, 47–61. https://doi.org/10.1016/j.ress.2015.08.006

Keenan, J. M. (2020). COVID, resilience, and the built environment. *Environment Systems and Decisions*, *40*(2), 216–221. https://doi.org/10.1007/s10669-020-09773-0

Kurth, M. H., Ali, R., Bridges, T. S., Suedel, B. C., & Linkov, I. (2020). Evaluating Resilience Co-benefits of Engineering With Nature® Projects. *Frontiers in Ecology and Evolution*, *8*. https://doi.org/10.3389/fevo.2020.00149

Linkov, I., Trump, B. D., Poinsatte-Jones, K., Love, P., Hynes, W., & Ramos, G. (2018). Resilience at OECD: Current State and Future Directions. IEEE Engineering Management Review, 46(4), 128–135. https://doi.org/10.1109/EMR.2018.2878006

Liu, L. (2020). Emerging study on the transmission of the Novel Coronavirus (COVID-19) from urban perspective: Evidence from China. *Cities*, *103*, 102759. https://doi.org/10.1016/j.cities.2020.102759

Löhner, R., Antil, H., Idelsohn, S., & Oñate, E. (2020). Detailed simulation of viral propagation in the built environment. *Computational Mechanics*, *66*(5), 1093–1107. https://doi.org/10.1007/s00466-020-01881-7

Megahed, N. A., & Ghoneim, E. M. (2020). Antivirus-built environment: Lessons learned from Covid-19 pandemic. *Sustainable Cities and Society*, *61*, 102350. https://doi.org/10.1016/j.scs.2020.102350

Mitra, R., Moore, S. A., Gillespie, M., Faulkner, G., Vanderloo, L. M., Chulak-Bozzer, T., Rhodes, R. E., Brussoni, M., & Tremblay, M. S. (2020). Healthy movement behaviours in children and youth during the COVID-19 pandemic: Exploring the role of the neighbourhood environment. *Health & Place*, *65*, 102418. https://doi.org/10.1016/j.healthplace.2020.102418

Novakovic. (2020, March 29). Will COVID-19 Spell the End of Urban Density? Don't Bet On It. *Azure Magazine*. https://www.azuremagazine.com/article/will-covid-19-spell-the-end-of-urban-density-dont-bet-on-it/

Paital, B. (2020). Nurture to nature via COVID-19, a self-regenerating environmental strategy of environment in global context. *Science of The Total Environment*, *729*, 139088. https://doi.org/10.1016/j.scitotenv.2020.139088

Pfefferbaum, B., & North, C. S. (2020). Mental Health and the Covid-19 Pandemic. *New England Journal of Medicine*, *383*(6), 510–512. https://doi.org/10.1056/NEJMp2008017

Pugalis, L. (2009). *Achieving place quality*.

Saadat, S., Rawtani, D., & Hussain, C. M. (2020). Environmental perspective of COVID-19. *Science of The Total Environment*, *728*, 138870. https://doi.org/10.1016/j.scitotenv.2020.138870

Sadik-Khan, J., & Solomonow, S. (2017). *Streetfight: Handbook for an Urban Revolution* (Reprint edition). Penguin Books.

Salama, A. M. (2020). Coronavirus questions that will not go away: Interrogating urban and socio-spatial implications of COVID-19 measures. *Emerald Open Research*, *2*, 14. https://doi.org/10.35241/emeraldopenres.13561.1

Salganik, M. J. (2019). *Bit by Bit*.

Semenza, J. C., & Menne, B. (2009). Climate change and infectious diseases in Europe. *The Lancet. Infectious Diseases*, *9*(6), 365–375. https://doi.org/10.1016/S1473-3099(09)70104-5

Sennett, R. (2018). *Building and Dwelling: Ethics for the City* (Illustrated edition). Farrar, Straus and Giroux.

Silverman, W. (1982). The Social Life of Small Urban Spaces William H. Whyte, Washington, DC: The Conservation Foundation, 1980. 125 pp. $9.50 (paper) and 16mm color film, 55 minutes, 2 reels, sound. $750.00 (purchase), $75.00 (rental). New York: The Municipal Arts Society, 1980. *Urban Life*, *10*(4), 466–468. https://doi.org/10.1177/089124168201000411

Solà-Morales, M. D., & Geuze, A. (2008). *Manuel de Solà-Morales: A Matter of Things* (K. Frampton, Ed.). nai010 publishers.

Trump, B., & Keisler, J. (2018). Risk and resilience must be independently managed. *Nature*, *555*, 30–30. https://doi.org/10.1038/d41586-018-02567-0

Valentino-DeVries, J., Lu, D., & Dance, G. J. X. (2020, April 3). Location Data Says It All: Staying at Home During Coronavirus Is a Luxury. *The New York Times*. https://www.nytimes.com/interactive/2020/04/03/us/coronavirus-stay-home-rich-poor.html

Wilder-Smith, A., Chiew, C. J., & Lee, V. J. (2020). Can we contain the COVID-19 outbreak with the same measures as for SARS? *The Lancet Infectious Diseases*, *20*(5), e102–e107. https://doi.org/10.1016/S1473-3099(20)30129-8

Can green cleaning be readily implemented in the public realm for COVID 19?

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ABSTRACT

Today cities are in distress due to the fast spread of the COVID 19 pandemic. Proper cleaning and disinfecting of public buildings are compulsory to prevent the transmission of coronavirus. However, intensified cleaning has resulted in an increase of air contamination with harmful substances and accidents and exposures occurred due to the association of cleaning chemicals. Adopting safer and durable alternatives for cleaning and disinfection or to simply reduce the cleaning need has emerged as a significant future strategy. Green cleaning (GC) was introduced in the 1980s as a substitution for conventional cleaning. Under GC, designing and adapting the building structures to support cleaning and disinfection offered a durable remedy to exhaustive cleaning approaches.

Under a qualitative approach, this article explores the existing literature on GC methods attributes to building design. A literature review, case studies in public facilities were carried out followed by manual content analysis to identify the most suitable building design modifications that can be applied in the Sri Lankan public realm. The manual content analysis shows that the most required GC design measures are timely repair, hybrid ventilation and increased natural lighting, space allocation for janitor's closet, service elevators, staircases, enclosed & separated garbage chutes proper drainage systems and cleanable surface materials. Both public health administrators and the public itself will be benefitted through these mechanisms and a healthy and safe public realm can be ensured.

Key words: COVID 19, Green cleaning, Public facility design, Public health

1. INTRODUCTION

As urban expansion and urban population growth are a continuous phenomenon, urban life thrived for the past few years. Once coronavirus became a pandemic, cities were challenged with maintaining public services under the new normal. Public places such as hospitals, schools, service institutes (universities, banks, markets, shopping malls, libraries etc.,) are the most vulnerable to this pandemic.

When specific evidence concerning the transmission medium is investigated, scientific evidence supports that droplet and environmental contamination patterns through smaller airborne droplets which may deposit on surfaces are the most potential transmission mechanisms (Marnie & Peters, 2020). Proper cleaning and disinfecting of frequently touched surfaces is compulsory to prevent the transmission of coronavirus (Chang et al., 2020). However, intensified cleaning has resulted in an increase of total Volatile Organic Compounds (VOC) and Formaldehyde in the

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atmosphere which is harmful to the human (Rastogi et al., 2020). Moreover, a rapid increase in the number of exposures, accidents that occurred due to the association of cleaning chemicals has been reported. From January to March 2020, USA poison centers have received a total of 45,550 exposure calls related to cleaners and disinfectants, representing an overall increases of 20.4% and 16.4% compared to January to March 2019 and 2018 respectively (Chang et al., 2020).

Statistics emphasize the need for safer alternatives for cleaning and disinfection or simply to reduce the need for cleaning and disinfection. GC approach is known to fulfill the health and safety requirements ensuring effective cleaning practices (Quinn & Henneberger, 2015). This method intends to reduce levels of chemical, biological, and particulate contaminants that can compromise air quality, human health, building finishes, building systems and the environment (United State Green Building Council [USGBC], 2017). The alarming spread of coronavirus instigates finding a permanent defense mechanism. Under the GC approach designing and adapting the building structure to support cleaning and disinfection is a major initiative that facilitates effective and safer cleaning. To answer COVID pandemic, providing a resilient response to disease outbreaks in the form of "design for a pandemic" has become a point of discussion (Tokazhanov et al., 2020). Especially public facilities including government institution, places of worship, universities, schools, healthcare facilities, and other building owners must look into the possibility of reducing the potential for COVID 19 transmission through built environment (BE)-mediated pathways (Dietz, et al., 2020) (Pinheiro & Luís, 2020). This paper aims to identify potential GC design changes that can reduce virus transmission through air droplets and surface contamination and support the reduction of communal disease transmission in the future.

2. RESEARCH METHOD

Under a qualitative research approach, 03 main steps have been carried out to arrive at research conclusions. 1) Literature Review, 2) Case studies in public facilities, and 3) Manual content analysis. Figure 1 shows the adopted research method of this study.1st Step: A literature review was performed using the articles published on Scopus database Elsevier, Emerald Insight, Science Direct, IEEE XPLORE. Potential building design changes that were studied and proven by the scholars to reduce the COVID 19 transmission were identified under this step.

2nd Step: Six case studies were conducted in public facilities and the unit of analysis was building design features that supports cleaning. Interviews with personals related to the facility managing and operating (Facility managers, Housekeeping managers, operation & administrative officers) was conducted using a semi-structured interview guideline.

3rd Step: Manual content analysis was performed followed by a qualitative discussion

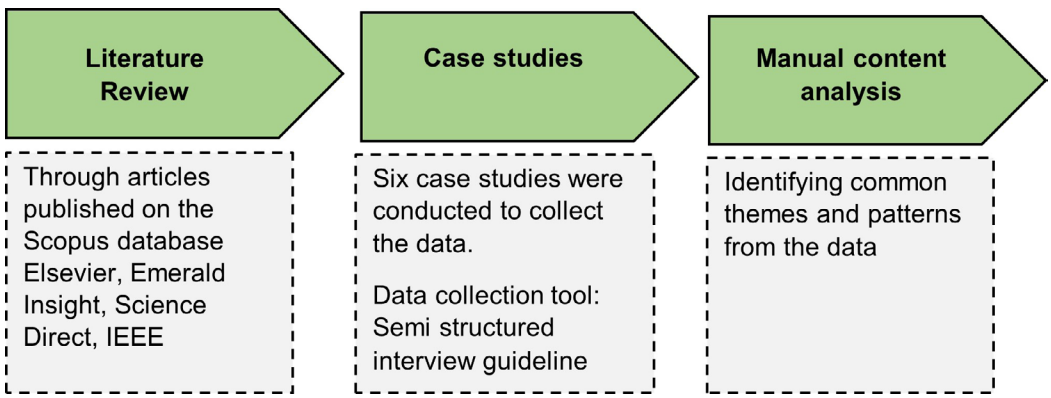

Figure 1. Research Method

to identify challenges faced during public facilities cleaning due to building design defects, to identify building design features that are been practiced to support cleaning during the pandemic, and to identify the required building design features to support cleaning during the pandemic.

Table 1 contains the details of the public facilities which were studied to conduct the study.

3. FINDINGS & DISCUSSION

3.1. Changes in cleaning practices due to COVID 19

COVID 19 pandemic changed the priorities around the world. The understated cleaning paradigm becomes the most important determinant of the built environment. Due to the multitude of users per day, public buildings require to swiftly adapt to the changes in the same magnitude as COVID 19. Cleaning and sanitizing, standards, guidelines were strictly enforced and multiple operational changes were executed to match the changing cleaning needs. Table 2 presents the operational changes found within the public facilities after and during COVID 19.

The sudden outbreak of COVID 19 has changed the standards and magnitude of cleaning. In all six public facilities, a deep cleaning procedure has been adopted to match the increased cleaning and sanitizing needs to effectively tackle the COVID 19 pandemic. Higher level of attention has been paid to publicly accessible, highly touched areas including lobbies, front desks, cafeterias, seating arrangements, elevators and common washrooms. Washing or wiping down surfaces with water and cleaning solutions was followed

Table 1. Case studies profile

Public facility	Facility Code	Building Profile	Interviewed personal
Main bank branch & Head office	B1	11 storey building with public access to basement floor, 1st and 2nd floor	Facility Manager
Shopping mall	B2	47-storey mixed use development with public access to first five storey including theatre, food courts and retail spaces.	Facility Manager
Shopping mall	B3	5 storey building with public access to all floors.	Engineer
Private Hospital	B4	11 storey building with public accessibility to 1-6th floors and 8-10th floor including a cafeteria.	Housekeeping Supervisor
Private Hospital	B5	One 9 storey building with public access to all floors including a cafeteria, one 7 storey building with public access to 5 floors, three other buildings with public access to designated areas.	Head of the Quality Department (HoD)
Government Hospital	B6	07 buildings including 4 which is fully publicly accessible and one building with public access to ground floor	Medical Superintendent

Table 2. Operational changes found within the public facilities after and during COVID 19

Operational changes / Public Facility	Changes of cleaning chemicals & disinfectants	Increased cleaning frequency	Increased usage of PPE	Increase in time taken to complete a cleaning task	Increase need for staff training and awareness programs	Additional cleaning staff recruitment	Increase need for storage space	Increase in cost of cleaning
B1	✓	✓	✓	✓	✓	✓		✓
B2	✓	✓	✓	✓	✓	✓	✓	✓
B3		✓	✓		✓	✓	✓	✓
B4		✓	✓	✓	✓	✓		✓
B5		✓	✓	✓	✓			✓
B6		✓	✓	✓	✓		✓	

by an application of disinfectant. B4 and B5 facilities follows a similar intensified cleaning routine which involves, spraying disinfectant to corridors, pathways, lobbies, common washrooms every two hours and wiping down the frequently touched surfaces using 70% alcohol solution. Besides healthcare facilities, disinfection was an addition to the cleaning procedure of other public facilities. Usage of personal protective equipment (PPE) was made mandatory by the administration of all public facilities and strict health and safety monitoring procedures are carried out conjunctively.

Most of the institutions prepared the custodians by providing staff training with the assistance of the Ministry of Health (MoH) to effectively clean the environment while protecting themselves. Further the management of facilities B1, B2, B3 and B4 had recruited additional custodians to strengthen the cleaning department. Public facilities B1 and B2 shifted from all-purpose cleaners to specific purpose cleaners such as glass cleaners, floor cleaners to effectively remove residues and coronavirus from the surfaces. Facilities, B2, B3 and B6 expand their storage spaces to accommodate increased cleaning supplies.

Consequentially, the cost of cleaning and disinfection increased in all public facilities due to the increased purchase of cleaning chemicals, tools and equipment, PPE's, labour rates, cost of training programs and cost of new recruitments. However, B6 was affected by the lack of resources and poor funds allocation to satisfy the cleaning requirements. The evidence suggests that public facilities are subjected to a variety of cleaning changes to tackle coronavirus.

3.2. Green cleaning building design measures practiced in Sri Lankan public buildings

The literature on green cleaning practices can be divided into 03 main parts: cleaning product selection, operational changes, and building design (Quan et al., 2011). Under building design features to support convenient and effective cleaning, the following features are formerly incorporated into the design before and during COVID 19 outbreak. Table 3 shows the GC design features adopted by Sri Lankan public buildings.

The results show that number of design changes were implemented by the public facilities during the aftermath of the COVID 19 pandemic. B1 was using epoxy floor coatings in car park and at the entrance, and resin countertops which facilitate easy cleaning. Public facility B1 had replaced their wooden

Table 3. Green cleaning building design features practiced in Sri Lankan public buildings

Building design feature	Before COVID (No of users)	After COVID (No of new users)
Designing heating, ventilation, air conditioning (HVAC) systems to remove air borne contaminants	B1,B4,B5	-
Properly designed ventilation systems (passive and mechanically powered)	B2,B3,B4,B5	-
Usage of self-cleaning materials	B4,B5	-
Usage of materials that requires less cleaning	B3,B4,B5,	B1,B4
Motion sensitive lights in common places (No touch surfaces)	B2,B5	B5 (expansion)
Automated faucets in common places (No touch surfaces)	-	B5
Sink & faucets designs which reduce splashing	B1	B2,B5
Building layout that makes housekeeping more efficient	B3,B4	B5
Reduction of horizontal surfaces	-	-
Self-disinfecting surfaces	B4,B5	-
Installation of air quality monitoring sensors in indoors	B5	B4,B5
Installation of High-Efficiency Particulate Air" (HEPA) filters	B5	B5 (expansion)
Installation of Ultraviolet Germicidal Irradiation (UVGI), Ultraviolet light devices	-	-

table tops of the service counters with glass and wooden chairs with stainless steel armrests. B4 had changed the wooden door handles of common washrooms to stainless steel door handles as engineering changes to support effective reduction of surface contamination. Motion sensitive lights in common places were installed by B2 and B5, even though, there were no new users, B5 had increased the number of motion sensitive lights in their facility. Before COVID 19, no organization had automated faucets in common places. During the pandemic, B5 had installed automated faucets in common wash rooms and cafeteria.

Considering both cleanliness and aesthetics, B1 was practicing sink & faucets designs that reduce water splashing. Public facility B2 and B5 had changed their sinks and faucets so that water splashing will be reduce and sinks will drain and dry out quickly. Public facility B3 and B4 was equipped with a building layout that supports effective cleaning. These includes designated and adequate space for janitor's rooms, properly placed and closing windows to reduce damp accumulation, separated service elevators and service rooms away from public areas, and properly enclosed separated drainage systems. B5 had partitioned the formerly clustered multiple front desks, reducing the risk of people gathering at once, especially during visiting hours.

Public facilities B4 and B5 were using self-disinfecting surfaces in their theaters. Only B5 had installed air quality monitoring sensors in indoors however during the pandemic, the facility expand the system by new sensors installations and B4 also initiated the installation of air quality sensors especially in isolated rooms. B5 facility had installed HEPA filters at the terminals of the ceiling mounted duct work, in compliance with the ASHRAE standard 62.1-2013. HEPA filters MERV rating of 17 and efficiency of 99.97% had been installed to capture impurities larger than 0.3 microns in diameter. Before or during COVID 19, no public facility was practicing reduction of horizontal surfaces and UVGI devices as design measures to face the outbreak of coronavirus.

In an enclosed public place, the role of HVAC becomes crucial to reduce indoor infection risk. Respondents from public facilities emphasize on the compliance to the ASHRAE standards by maintaining required level of fresh air intake and air flow. In B5 facility relative humidity was maintained at 50% and depending on the surgical environment required, indoor temperature varied from 190°c to 250°c. However, adequacy of maintaining the minimum levels of standard need to be further studied to identify whether it supports the removal of pathogen from the air. As the coronavirus escalated social distancing, surface cleaning and disinfectant become the most important determinants. For the past year, surviving the COVID 19 became the new normal. To function normally, rethinking and undergoing a change process has become critical for public facilities.

3.3. Cleaning challenges encountered due to building design deficiencies

Table 4 presents the identified building design deficiencies that challenge effective cleaning in public facilities and corresponding design changes to adopt and their implications. The consequences of coronavirus are changing the fundamental designs of built environment. The unfolding situation reminds the architects, planners, designers, facility managers to rethink the public facility structure. The obstacles faced during cleaning and disinfection are reshaping the design requirements to protect against viral outbreaks. Sri Lankan public facilities must reinforce with the above key changes. More partitions between spaces, widen doors and corridors, using abandoned staircases, installing sensors, and automated features have been initiated in public facilities as defense mechanisms against COVID 19.

Table 4. Cleaning challenges encountered due to building deficiencies, suggested design changes and implications for public facilities

Public Facility	Cleaning challenges faces due to building design	Suggested building design changes	Possible implications
B1	Lack of service elevator	Installation of service elevator	Facilitate safe garbage disposal, reduce the risk of virus, bacteria transmission through contact with contaminated wastes
	Smaller elevator cars (2 no's) that each accommodate only 8 persons at a time.	Construction of staircase	Reduce the need to use the elevator to even travel between adjacent floors and reduce crowding during the work start, lunch time and work end. Facilitate social distancing.
	Lack of staircase for the general use (only an emergency staircase is available)	Construction of staircase	Ensure social distancing compared to an elevator. Reduce the risk associated with tighter space, close proximity to others, multiple hand-contact surfaces in elevators.
	One access point to the water at the rear end of the floor to clean 4000 sq. ft.	Installation of more faucets within a floor prioritizing the locations	Easy access to water reduce the custodian's unnecessary movements and facilitate easy cleaning.
B2	Narrow corridors to access the cafeteria	Wider corridors & access points	Ensure social distancing, minimize direct contact, promote air circulation and reduce air concentration.
	Water penetration to the main entrance due to defects of the soffit design	Change the entrance roof design to prevent water penetrating to the indoors, Install rain gutters and downspout to properly drain the water	Reduce the cleaning needs and prevent bacteria, mold growth in damp surfaces.
	Higher number of glass walls within the indoors which are difficult to reach and clean (moveable ladders requires)	Compromise between the aesthetics and practical operation, combination of glass with other structural material	Reduce the cleaning needs
	Poorly placed gullies prevent water draining (Floods the car park even during a small rain)	Properly place adequate number of gullies and floor traps and ensure the surface drainability	Reduce the cleaning needs and ensure health and safety of the users
	Lack of exhaust in the fully air conditioned cafeteria	Install an exhaust ducts inside the cafeteria	The odor of the confined space will be significantly reduce and will be able to ensure health air quality level
	Lack of adequate space to store cleaning equipment	Space allocation for janitors closet	Facilitate effective cleaning and reduce virus transmission through cleaning tools & equipment.
	Lack of adequate space to store waste until pick up	Construct a garbage room	Garbage room will reduce the inappropriate stacking of garbage in the facility premises and ensure healthy environment

Public Facility	Cleaning challenges faces due to building design	Suggested building design changes	Possible implications
B3	Difficult to reach higher number of glass walls	Compromise between the aesthetics and practical operation, combination of glass with other structural material	Reduce the cleaning needs
	Damp accumulated areas due to water leakages	Replace or repair all the leaking faucets, pipes and ensure a proper damp proof membrane is in place	Reduce the cleaning needs and growth of mold, fungi, bacteria on the surfaces
	Inadequate natural ventilation	Construct proper openings for fresh air intake and ensure that indoor air quality is optimum	Reduce the concentration zones and airborne transmission. Ability to introduce fresh air by creating a cross flow.
B4	Susceptible materials for cleaning chemicals	Replacing Metal and Vinyl surfaces with materials that can withstand hypochlorite solution	The fast deterioration of the surfaces will be reduced and effective disinfection of the surfaces can be ensured
	Prevention of the usage of strong chemicals on Vinyl flooring	Replace the common areas vinyl flooring to tiles or other cleaning supportive material	Effective cleaning and disinfection can be ensured
	Lack of garbage and laundry chutes	Install chutes at appropriate places (non- medical areas)	Easy and safe garbage disposal, used linen can be easily transport to laundry room
	Faucets that splash water in the cafeteria	Replace the existing appliance with faucets that reduce splashing	Cleaning needs will be reduced and harmful pathogen transmission will be reduced
B5	Retained moisture on floors due to low temperature control in selected areas	Water repellent/ non absorbing materials	The surfaces will less affect by the low temperatures and will facilitate easy cleaning
	Air supply to isolated rooms through central air conditioning	Unitary air conditioning systems	Reduce the possibility of airborne transmission inside the entire building. Customized temperature control is possible. Reduce the risk of virus transmission throughout the facility
	Lack of continuous staircases	Properly constructed staircases	Facilitate social distancing. Reduce the risk associated with tighter space, close proximity to others
	Narrow corridors and narrow access	Wider corridors and doors	Ensure social distancing and reduce the physical contact due to close proximity
	Number of compartmentalised spaces within a limited space (crowded)	Partitioned office spaces	Discourage social interacting, reduce the cleaning frequency and
	Lack of proper drains with proper drainability	Construction of adequate number of properly enclosed drain pipes indoors and outdoors	Facilitate the safe discharge of waste water and ensure healthy environment

Public Facility	Cleaning challenges faces due to building design	Suggested building design changes	Possible implications
B5	Lack of proper natural ventilation	Hybrid ventilation	Reduce the concentration zones and airborne transmission. Ability to introduce fresh air by creating a cross flow.
	Lack of proper natural lighting	Increased natural lighting	Controlled sunlight is inactivating the virus residing on building surfaces. Act as a natural disinfectant. Reduce cleaning and disinfection needs.
	Disorganized and poorly arranged Mechanical, Electrical, Plumbing (MEP) systems	Arrange a designated area for MEP services and plan and lay the pipes (water, chilled water, gas), lines (electrical, telecommunication) in an organized manner.	In case of a breakdown maintenance is easy as well as the regular cleaning.
B6	Lack of service elevator	Installation of a service elevators	Facilitate safe garbage disposal, logistic support to the cleaning crew
	Lack of garbage chutes	Enclosed & separated garbage chutes	Facilitate safe garbage disposal and reduce the custodian's workload.
	Lack of space for cleaning supplies storage (No janitor's closets)	Space for janitors closet	Facilitate effective cleaning and reduce virus transmission through cleaning tools & equipment.
	Poorly repaired & maintained buildings	Timely repair, renovation of old buildings	Facilitate the convenient and effective cleaning. Reduce the risk of mold, fungi growth in poorly maintained areas. Easily adaptable for emergencies.
	Presence of water leakages and damp areas	Timely repair and replace the faulty faucets with high quality products	Will reduce the mold and bacteria growth and keep the environment dry and clean.
	Poorly enclosed drains & entirely exposed drains	Construct the drains with adequate depth and width to drain the waste water and cover the drains using cover slabs, Install gullies at correct places to support water removal from indoors	Reduce the collection of waste water in drains, reduce harmful bacteria transmission through water, Helps to keep a clean, damp free environment.

4. CONCLUSION

As proven from the complexity of the prevailing pandemic, public facilities are extremely vulnerable to virus contamination and transmission. The responsibility of creating a safe and healthy environment through meticulous cleaning procedures lies with the building management. The inability to predict an end date for the pandemic emerges the need to explore a more durable solution than routine exhaustive cleaning. As a green cleaning initiative, identifying building features that can facilitate effective cleaning while reducing surface contamination offers a long term countermeasure. Under a qualitative approach, by conducting six case studies in public facilities, the practicing GC building design features and the required building design changes to support effective cleaning was derived.

In Sri Lankan public facilities, the main cleaning challenges encountered due to design deficiencies consist of poor spatial arrangements, difficult to clean surfaces, poor access to water, lack of service elevators, staircases, poor natural ventilation and lighting, lack of automated technologies and lack of proper drainage network. The resultant effects are discouraging effective cleaning. To effectively tackle COVID 19 pandemic, identifying the existing security layers that the public facilities are equipped with is important. During the pandemic, the following GC building design features were adopted by public facilities.

- Usage of materials that requires less cleaning
- Motion sensitive lights in common places
- Automated faucets in common places
- Sink & faucets designs which reduce splashing
- Building layout that makes housekeeping more efficient
- Installation of air quality monitoring sensors in indoors
- Installation of HEPA filters

Reduction of horizontal surfaces and installation of automated faucets in common places were the subsequently adopted design features. However, the magnitude of the COVID 19 pandemic and the limitations of current requires additional supportive built environment features. Those required by Sri Lankan public buildings are

- Timely repair, renovation of old buildings
- Hybrid ventilation and increased natural lighting
- Allocated space for janitors closet
- Enclosed & separated garbage chutes and service elevators
- Staircases, wider corridors and access points
- Partitioned office spaces
- Unitary air conditioning systems
- Proper drainage systems
- Cleanable surface materials

Experiencing from the current pandemic situation, it is necessary to reflect upon future defense mechanisms against pandemics situations to support effective application of green cleaning in public facilities to reduce virus transmission.

ACKNOWLEDGEMENT

This work is supported by the Accelerating Higher Education Expansion and Development (AHEAD) - DOR Grant affiliation with Ministry of Higher Education & University Grants Commission and funded by the World Bank.

REFERENCES

Chang, A., Schnall, A., Law, R., Bronstien, A., Marraffa, J., & Spiller, H. (2020). Cleaning and Disinfectant Chemical Exposures and Temporal Associations with COVID-19 — National Poison Data System, United States, January 1, 2020–March 31, 2020. *MMWR Morb Mortal Wkly Report, 69*(16), 496-498. doi:10.15585%2Fmmwr.mm6916e1

Dietz, L., Horve, P., Coil, D., Fretz, M., Eisen, J., & Wymelenberg, K. (2020). 2019 Novel Coronavirus (COVID-19) Pandemic: Built Environment Considerations To Reduce

Transmission. *Journal of Clinical Biology, 5*(2), 1-15. doi:10.1128/mSystems.00245-20

Marnie, C., & Peters, M. (2020). *COVID-19: Cleaning and Disinfection of Hospital Surfaces and Equipment.* Australian Nursing and Midwifery Federation.

Pinheiro, M., & Luís, N. (2020). COVID-19 Could Leverage a Sustainable Built Environment. *Sustainability, 12*, 1-27. doi:10.3390/su12145863

Quinn, M., & Henneberger, P. (2015). Cleaning and disinfecting environmental surfaces in health care: Toward an integrated framework for infection and occupational illness prevention. *American Journal of Infection Control, 43*(5), 424-434. doi:10.1016/j.ajic.2015.01.029

Rastogi, P., Sobek, O., Jephson, G., & Allison, J. (2020). *A Data-driven Indoor Air Quality Framework for PostCOVID-19 Workplace Re-entry* . Glasgow, UK.

Tokazhanov, G., Tleuken, A., Guney, M., Turkyilmaz, A., & Karaca, F. (2020). How is COVID-19 Experience Transforming Sustainability Requirements of Residential Buildings? A Review. *Sustainability, 12*. doi:10.3390/su12208732

United State Green Building Council [USGBC]. (2017). *LEED v4 for Building Operations and Maintenace*. Retrieved from https://www.usgbc.org/resources/leed-v4-building-operations-and-maintenance-current-version

BIBLIOGRAPHY

Astrachan, I.-D. (2020, August 17). *Modular Construction as a Post COVID-19 Design Alternative*. Retrieved from Building Enclosure: https://www.buildingenclosureonline.com/articles/89199-modular-construction-as-a-post-covid-19-design-alternative

Awada, M., Gerber, B., Hoque, S., O'Neill, Z., Pedrielli, G., Wen, J., & Wu, T. (2020). Ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic. *Building and Environment*, 107480. doi:10.1016/j.buildenv.2020.107480

Bereitschaft, B., & Scheller, D. (2020). How Might the COVID-19 Pandemic Affect 21st Century Urban Design, Planning, and Development? *Urban Science, 4*, 1-32. doi:10.3390/urbansci4040056

Brittain, O., Wood, H., & Kumar, P. (2020). Prioritising indoor air quality in building design can mitigate future airborne viral outbreaks. *CITIES & HEALTH*. doi:10.1080/23748834.2020.1786652

Dancer, S. (2020). Covid-19 exposes the gaps in infection prevention and control. *Infection, Disease & Health, 25*(4), 223-226. doi:10.1016%2Fj.idh.2020.08.005

LI, L., & Pussella, P. (2017). Is Colombo city, Sri Lanka secured for Urban Green Space Standards? *APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH, 15*(3), 1789-1799. doi:10.15666/aeer/1503_17891799

Li, S., Xu, Y., Cai, J., Hu, D., & He, Q. (2020). Integrated environment-occupant-pathogen information modeling to assess and communicate room-level outbreak risks of infectious diseases. *Building and Environment*. doi:10.1016/j.buildenv.2020.107394

Lima, M., Almeida, R., da Fonseca, F., & Gonçalves, C. (2020). THE CHEMISTRY OF SANITIZERS IN COVID-19 TIMES:DO YOU KNOW HOW IT WORKS? *Quimica Nova*, 1-18. doi:10.21577/0100-4042.20170552

Megahed, N., & Ghoneim, E. (2020). Antivirus-built environment: lessons learned from covid-19 pandemic. *Sustainable Cities and Society*, 1-23. doi:10.1016/j.scs.2020.102350

Meguid, S., & Elzaabalawy, A. (2020). Potential of combating transmission of COVID-19 using novel self-cleaning superhydrophobic surfaces: part I— protection strategies against fomites. *International Journal of Mechanics and Materials in Design*. doi:10.1007/s10999-020-09513-x

Miller, S., Linnes, J., & Luongo, J. (2013). Ultraviolet Germicidal Irradiation: Future Directions for Air Disinfection. *Photochemistry and Photobiology, 89*, 777–781. doi:10.1111/php.12080

Quan et al. (2011). *Green Cleaning in Healthcare: Current Practices and Questions for Future Research.* The Center for Health Design. Retrieved 02 15, 2018, from www.healthdesign.org/system/files/hhigreencleaning_paper.pdf

Rawlinson, S. (2020). COVID-19 Pandemic – Let's not forget surfaces. *Journal of Hospital Infection*. doi:10.1016/j.jhin.2020.05.022

Sharifi, A., & Garmsir, A. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. *Science of The Total Environment, 749*(20), 142391. doi:10.1016/j.scitotenv.2020.142391

Suman, R., Javaid, M., Haleem, A., Vaishya, R., Bahl, S., & Nandan, D. (2020). Sustainability of Coronavirus on Different Surfaces. *Journal of Clinical and Experimental Hepatology, 10*(4), 386-390. doi:10.1016/j.jceh.2020.04.020

Vakili, S., Savardashtaki, A., Jamalnia, S., Tabrizi, R., Nematollahi, M., Jafarinia, M., & Akbari,

H. (2020). Laboratory Findings of COVID-19 Infection are Conflicting in Different Age Groups and Pregnant Women: A Literature Review. *Archives of Medical Research, 51*(7), 603-607. doi:10.1016/j.arcmed.2020.06.007

Wang, Q., Li, G., Meng, C., Xie, L., Liu, M., & Zhu, R. (2020). *The Contribution of Green Buildings in the fight against COVID-19.* China World Green Building Council.

WHO. (2020). *Infection prevention and control during health care when COVID-19 is suspected*

Significance of sustainable urban planning and development in pandemic scenario, Covid-19: Social, economic and environmental perspectives in Sri Lanka

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ABSTRACT

A pandemic is an epidemic of an infectious disease that has spread across a large region, for instance multiple continents or worldwide, affecting a substantial number of people. Understanding this, over the past few decades, numerous researches has been undertaken on the impacts of a wide range of disasters on urban areas, and necessary planning, recovery, mitigation and adaptation measures that need to be taken to deal with those disasters. Pandemics related issues are mainly focused on areas such as deficiencies, which make marginalized groups more vulnerable to pandemics. The recent pandemic COVID-19 has elevated the issue of urban vulnerability to pandemics and has revived interest in terms of urban planning for pandemic scenarios. As various forces such as climate changes and human behaviors may increase the frequency of pandemics, better knowledge of the underlying patterns and dynamics of pandemics, their effects on urban areas, and necessary preparation, response, mitigation and adaptation measures is needed. In this regard, the recent pandemic offers an unprecedented opportunity to understand how urban areas might be affected by pandemics and what actions are needed to minimize the impacts and enhance urban pandemic resilience. Against this situation, the main objective of this study was to comprehend the significance of the urban planning and development in pandemic scenarios and its impact from the social, economic and environmental perspectives. To undertake the study, qualitative research methodology was carried out in a comprehensive approach. Based on the case study findings and preliminary review, a conceptual guideline was developed with recommendations related to the socio-economic, environmental factors, urban management, transportation and urban design that can be used in post COVID-19 urban planning and development.

Key words: Sustainability, Urban planning and development, COVID-19 Pandemic, Socio-economic and environmental aspects, Conceptual guideline

1. INTRODUCTION

The urban world is changing rapidly. Whether in the west or in countries in transition, the changes taking place in cities are of revolutionary proportions. It thus becomes vitally important to look at how cities develop and how they are planned. However, the high concentration of people and activities in cities make them vulnerable to various stresses such as natural and man-made disasters. Understanding this, over the past few decades, a vast body of research has been published on the impacts of a wide range of disasters on

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cities, and necessary planning, recovery, and adaptation measures that need to be taken to deal with those disasters (Sharifi, 2020).

The disciplines of public health and urban planning were closely aligned since it is of utmost importance to have a proper urban design in order to provide a safer and healthier environment for the community inside. But with the better understanding of bacteria, infectious disease and vaccinations, however, the focus of public health shifted away from community engineering and urban design and moved towards a model based on medical principles (Duhl and Sanchez, 1999). However, as the world continues to become more complex and less linear, their emerges the challenge of how the urban design processes and systems would ensure both community health and sustainable development. This new shift calls for a framework in which people from multiple disciplines can effectively work towards creating sustainable and economically vital healthy cities. However, while this is not the first time in the human history that pandemics have affected cities, there is limited literature related to cities and pandemics before the emergence of the COVID-19 (Coronavirus) pandemic (Matthew and McDonald, 2006). Urban research related to previous pandemics was mainly focused on issues such as inequalities that make poor and marginalized groups more vulnerable to pandemics (Wade, 2020).

In fact, the COVID-19 pandemic has brought to lite the necessity of urban vulnerability to pandemics and the significance of urban planning and development in such cases to mitigate the spread of virus. Against this backdrop, the outcome of this study highlights the major lessons that can be learned for post-COVID urban planning and development.

2. OBJECTIVE AND METHODOLOGY

With the intention of identifying the significance of the urban planning and development in pandemic scenarios and its impact on the environment and socio-economic perspectives, this study adopted the qualitative research approach. The essence of which, according to Wigren (2007), consists of focusing on understanding the naturalistic setting, or everyday life, of a certain phenomenon by the investigator. Qualitative methods are essentially descriptive and inferential in character and focus primarily on the kind of evidence that will enable to understand the meaning of what is going on. Accordingly, among various approaches available in the qualitative approach, "case study" (Yin, 2003) was selected.

The case study research method provides an in-depth investigation by studying 'cases' in an uncontrollable environment. According to Yin (2003), case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events and when the focus is on contemporary phenomenon within real-life context. Considering these points, the case study method was seen as suitable for this study.

In this study, cases were selected from highly infected areas, which were isolated and locked down due to the rapid spread of COVID-19. Accordingly, five (5) cities were selected and from each city, three interviews were conducted with three random representatives. Altogether, fifteen (15) interviews were conducted and each normally lasted for 20 to 30 minutes (Table 1).

Table 1. Sampling Information

City	Interview 01	Interview 02	Interview 03
Colombo	Medical Officer	Community	Community
Kaluthara	Community	Community	Community
Gampaha	Development Officer	Community	Community
Kegalle	Medical Officer	Community	Development Officer
Mawanella	Medical Officer	Community	Development Officer

Key themes emerging from the findings were identified within each case and replication of findings were tested using 'cross-case analysis.' The research results and findings are presented and discussed.

3. FINDINGS AND DISCUSSION

The rapid spread of the COVID-19 worldwide and, in particular, within urban environments has fuelled the role of urban planning and development to contain, isolate and treat the disease within cities. But while COVID-19 may be a new pandemic and pose new challenges for cities, strategies of these kinds, formulated in response to earlier epidemics that have affected many cities at different times - such as Cholera, Tuberculosis, Typhoid, Dysentery, Ebola and the Spanish Flu (Kanniah etal., 2020) are known.

These theoretical orientations provide the foundation for a basic understanding of how public health and urban planning intersect. Specifically, they make reference to the fact that physical and socio-economic environments play major roles in the health of communities. Thus, urban planning and development serve as a form of primary prevention and contributor to health outcomes. Additionally, it sheds light on how a holistic approach to building cities become a key factor (Table 2).

Research findings from the case studies are presented here in three sections: Environmental significance of urban planning and development in COVID-19, socio-economic significance in urban planning and development in COVID-19 and integration of the health perspective in urban planning and development.

3.1. Environmental Significance of Urban Planning and Development in COVID-19

During the empirical study of Kummitha, (2020) it revealed that there is a strong association between COVID-19 transmission or mortality and high levels of air pollution. In accordance with the number of clusters in western province, most of them were detected from the congested areas and slums where air pollution is extremely high. In addition, long-term exposure to polluted air can indirectly increase vulnerability to COVID-19 by affecting the respiratory system.

Characteristics of the ambient environment can influence the transmission dynamics by affecting the survival of the virus on contaminated surfaces and or its airborne diffusion. Impacts of different environmental and meteorological parameters such as temperature, humidity, wind speed, and pollution levels have been identified as critical factors that are affecting the fast spread of COVID-19 (Sharifi *et al.,* 2020). The clusters reported from *Mattakkuliya Methsandasewana and Minijayasewana* flats were recognised as hotspots as they were the least prepared for the pandemic of COVID-19 since, basic needs such as water, toilets, sewers, drainage, waste collection, and secure and adequate spacing were already in short supply or non-existent. Further, space constraints, violence, and overcrowding in slums make physical distancing and self-quarantine impractical, and the rapid spread of an infection highly likely.

Any responses to COVID-19 that do not recognize these realities will further threaten the survival of large segments of the urban population.

Contrary to these findings, several cases identified that travel restrictions or proper planning strategies have significantly reduced NO_2 and CO_2 that are pollutants directly associated with the transportation sector in urbanized areas. Even though the air pollution levels had been low in urban areas of Sri Lanka during past few months due to relatively low vehicle movements with the COVID-19 pandemic situation in the country, suddenly the particulate matter level in the atmosphere in *Colombo, Kandy, Puttalam, Vavuniya, Jaffna* and other places has increased apart from the southern parts of the country. As per the studies of NBRO the reason behind this unexpected sudden increase of air quality level could be

Table 2. Summary of Results

Question Category	Responses
Highly reported areas of virus infectors	Slums Flats Congested areas
Issues of highly reported areas	Inadequacy of ventilation movements Air pollution Space constraints Limited access to basic needs like food and water
Self-Quarantine issues	No separate sanitary facilities Overcrowding Unawareness of hygiene practices
Effects of travel restrictions: Positive	Reduce CO_2 and NO_2 Reduce environmental pollution through air and noise pollution Increase the unity of families
Effects of travel restrictions: Negative	Supply failures of food and essential services Violence due to mental stress No space to move around
Effects of space constraints	Limited space to keep the social distance Limited space to dispose personal protective equipment (PPE) No segregation of hazardous wastes Water pollution by dropping PPE to nearest lakes Use same water outlets for handwashing Mental depression due to 'Stay Home' High population density
Issues of Employments	No opportunities for employments No PPE usage in ad-hoc jobs like porting Social tension due to unemployment Drug addiction due to isolation Hugh number of dependants
Reasons for social- tension	Economic failures Limited physical activities No entertainments Fear of virus No community gatherings Limited facilities for school children's education (Smart phones, internet connections)
Problems with urban patterns	Congested areas No space between houses No proper street arrangements to keep social distances Usage of public transportation Limited access to clean water Not having easy access to healthcare facilities like hospitals No separate areas for self-quarantine Cross-air ventilation problems
Hygienic issues	Unawareness of PPE usage and handwashing techniques Carelessness Use of public toilets and washrooms

linked with the variation of the wind pattern around the island (Hamza, 2021).

Understanding how environmental factors influence survival and diffusion of COVID-19 can help urban policymakers design more appropriate protection and response measures.

Despite the air quality improvements, there are some concerns that the used personal protective equipment like face masks, gloves and used tissues may pollute freshwater resources if they were not disposed properly with the norms of hazardous waste. This indicates the importance of taking effective

wastewater treatment measures and properly designed dispose mechanisms for those said personal protective equipment.

As coronavirus can spread through fecal-oral routes, proper management of urban water cycle is also critical for containing the spread of the virus. Also, sufficient disinfection of water plants and wastewater treatment plants and measures such as the prevention of sewage leakage into freshwater resources are essential to reduce human exposure to the virus (Xie *et al.,* 2020).

Overall, the pandemic has exposed significant anthropogenic impacts on water resources and has contributed to better identifying the sources of water pollution (Rupani *et al.,* 2020). Urban planners and policy makers should use this opportunity to take actions such as designing proper regulations to reduce harmful human impacts on water resources.

Hence, all these findings fueled the necessity of a proper urban planning and development over the country to face these types of pandemics with minimum vulnerability due to the environmental impacts.

3.2. Socio-Economic Significance of Urban Planning and Development in COVID-19

The social consequences of the pandemic have been discussed in the context of urban as well as rural cities in Sri Lanka. COVID-19 pandemic has hit minorities and people at the bottom of the socio-economic spectrum disproportionately (Sharifi and Khavarian, 2020). They often suffer more from preexisting conditions due to more exposure to risks, economic difficulties, and limited access to services. Conditions in informal developments are further exacerbated by the lack of access to medical care like hospital beds, and basic services such as clean water to comply with hand washing recommendations.

Additionally, unjustified economic conditions, and the fact that many communities depend on close social interactions for their livelihood make adherence to 'stay home' orders challenging. Accordingly, there are concerns that inequalities may not only make containment challenging, but also result in further diffusion of the virus.

Consequently, the long-term economic shutdowns due to the COVID-19 pandemic have had very negative impacts on urban economy. The consequences are complex and occur in various ways and on a wide range of scales.

The outbreak in *Bandaranayake Mawatha, Colombo* is an excellent example of how diseases spread in underserved settlements in urban areas. The cluster consisted of small living spaces, home to around 62 families on a 20 perch land. Not only do these small housing units lack basic amenities such as sanitation, water, and ventilation, but their placement also makes social distancing an impossible task. In such neighborhoods, residents tend to congregate in public spaces and visit neighbours. Tracking and controlling socializing patterns in highly congested areas adds to the challenges of making lockdowns and curfews redundant.

Furthermore, a majority of slum dwellers in urban areas are employed in self-managed, low wage jobs in the informal sector and earning daily wages. The informal nature of their employment, with no protective measures, makes them vulnerable to sudden earning losses, access to food and other basic needs. This in turn exposes them to higher risks, when they are compelled to ignore precautionary measures in desperate attempts for survival.

Residents of informal settlements like *Keselwatta* are also economically vulnerable during any COVID-19 responses, since most urban poor living in slums are informal workers, meaning they must show up to earn daily wages, and this daily income is used for subsistence.

Increase the occurrence rate of social tensions is another issue that has been identified from the interview series. Cases reported from *Gunasinhapura, Colombo,* is a very good example for this social tension as the drugs addicted people were infected easily by the virus. Naturally by the behavior these drug addicted people are more aggressive and out of control. Therefore, when a set of people get caught to the virus other over-react towards the situation and caused conflict at the point. Thus, through this unwise reaction, a very critical situation is created in the area, resulting in the police officers being infected by the virus too.

Therefore, to overcome these complexities in terms of socio-economic background, proper urban planning and developing strategies will significantly affect.

4. INTEGRATION OF THE HEALTH PERSPECTIVE IN URBAN PLANNING AND DEVELOPMENT

As rates of infection and death rose, cities needed to identify health management and urban design problems. Historically, some infectious disease outbreaks have inspired new urban planning actions. For example, the cholera epidemic in the 19th century led to improvements in urban sanitation systems (Sharifi., 2020). Today, urban planning has failed to incorporate the prevailing socio-economic conditions and health crises. Thus, COVID-19 pandemic may be a chance to optimize urban areas by integrating the socio-economic and environment behaviour at a pandemic time through health perspectives in planning and development (Figure 1).

With the integration of both comprehensive literature review and the case study findings, it was identified that for a successful integration, there must be a proper involvement and improvement in some critical features like; urban density, street design, public transport, building uses, parks and green areas, building design, core services, technologies and smart cities and uninterrupted internet service in urban planning and designing to facilitate a healthy city.

4.1. Urban Density

The greater the population density, the greater the risk of infection (Bhadra *et al.,* 2020). Therefore, cities and urban designs may need to be revised from a population density point of view, which is one of the most basic factors affecting the spread of an epidemic like COVID-19. Accordingly, cities need to review appropriate planning not only to achieve social justice but also to face epidemics in a sustained way.

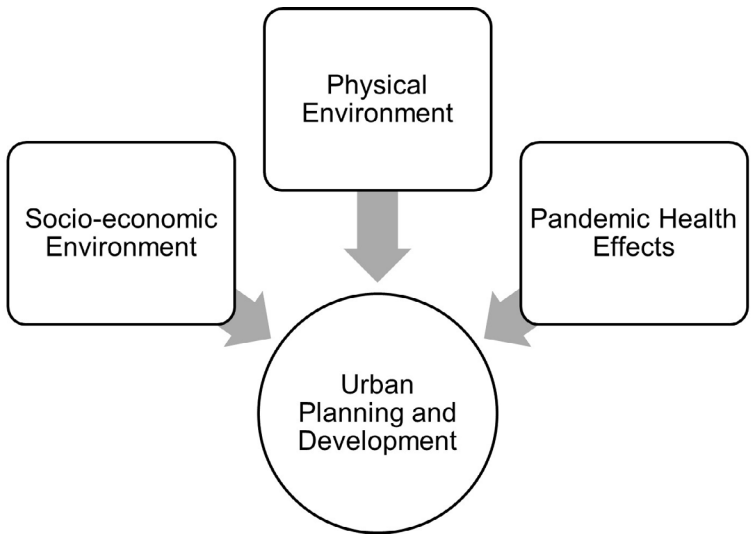

Figure 1. Integration of the Health Perspective in Urban Planning and Development

In urban planning and development, city's decentralizing and deconstructing policy can reduce extreme density, and promote the concept of walkability in each neighborhood, in which containing homes, jobs, facilities, stores, *etc*. If neighborhoods are changed to be more walkable, with services and jobs in those communities; cities may be able to mitigate the intense congestion and crowding. Anthropologically, walking is not only a kind of human movement, but also a culture and social practice that can promote physical activity and affect the residents' health besides increasing the value of urban spaces.

4.2. Streets Design

A proper street designing aims to create healthier and more social-sustainable cities that affect citizens' behaviour in the time of pandemics like COVID 19. Also, to achieve the principle of social distancing and allow wider spaces among users, the rethink of the designing of the streets by barring cars from some streets and providing more spaces for pedestrians and cyclists thus turning the city into green and low carbon.

It is worth mentioning when referring to the point of redesigning streets during an epidemic; the new standards of using sidewalks should be considered. Such as social distancing while queuing that requires providing wider sidewalks and paths and leaving a safe distance between passengers.

4.3. Decentralization of core services

Every city's accessibility to core services will be prioritized moving forward. During the interview process it was identified that some residents in Sri Lankan cities do not have access to essential services such as water, health care and housing, and can have trouble attending to the problem. Since people should travel to the nearest town or city to make their essentials like healthcare facilities, the virus can spread faster through the transportation modes such as buses or taxis and the places they are occupying. Thus, it is necessary to decentralize the core services in every city to fulfil their essentials within the city without traveling as a virus carrier directly or silently.

4.4. Public Transport

Public transportation is often a gateway to COVID-19. Great restrictions on public transportation were imposed in past few months in the country to reduce the spread of COVID-19 because, public transportation such as buses and trains increase Coronavirus outbreak and present numerous risks when transmitting infection by touching handles, armrests, and seats etc. The health effects of social distancing on transport can be reduced by differentiating between entering and leaving the transportation stations. Further, it needs a frequent sanitization. Transit risks can be minimized by restricting crowding, proper cleaning and sanitising hygiene of employees and passengers, and safety of operators.

4.5. Building Uses

At the time of pandemics, the use of public spaces such as stadiums and conference centers can be repurposed for emergency hospitals and quarantine centers. The most rapid practical approach is to adapt existing buildings. Countries like Sri Lanka can adhere to this solution, as the number of buildings cannot be increased suddenly with regards to all social and economic aspects. Buildings like, *School of Agriculture - Kundasale*, *National Collage of Education – Pasdunrata and number of star hotels like, Citrus, Club Palm Bay etc.* were taken as quarantine centers during the pandemic. So, these buildings were used for different purposes before the pandemic and the government got the most practical approach to adopt the existing building as per the pandemic scenario.

4.6. Parks and Green Areas

Designers may need to create more spaces for individual use in planning green areas such as expanding running tracks and paying attention to small neighborhood parks (Liu, 2020). As one of the new solutions that allow individuals to enjoy public parks with social distance. A great suggestion of green

infrastructure, which improves public health benefits, is having a connected system of green areas. This system is more useful than scattered parks, and it means to have a network of different scales and uses parks through which residents can move easily and connect to nature. Therefore, parks and green areas can encourage more people to safely get outside their homes and maintain safety at the same time.

4.7. Building Design

From the public health view, building can cause diseases, which is known as the sick building syndrome, and it indicates the effect of the building design on human health and the diseases that the building can cause to humans. For example, a lack of interest in the good design of yards and the ventilation of residential buildings leads to the possibility of spreading respiratory diseases. This indicates the importance of buildings orientation aspect in urban spaces according to pandemic spread behavior.

4.8. Technology and Smart Cities

With the use of new technologies, smart cities can be used in these types of pandemic scenarios as the decisions can be taken by relying on digital data sources like mobile devices and remote sensors to track people infected with COVID-19. With the increasing numbers of residents and cities, it is logical to change the way of thinking in designing cities to make them healthier and more stable to face any future challenges. While most of the world's population practice social distancing to reduce the spread of disease, it is important to focus on the functional cities strategy which has good technological and sustainable features; that help in monitoring and collecting infection database (Wesdani *et al.,* 2020).

4.9. Uninterrupted Internet Access

During the pandemics, all the workers, students and other business dealers got isolated within their houses as they were not considered as the essential servers or front liners. But still, they should continue their processes without any interruption and the only solution is the online communication. In Sri Lanka due to the geographical situation, many parts of the country cannot be connected with the internet facility. In some areas, though the internet facility is available it is not continuous. Residents of these parts of the country are the worst victims for the online employment, education and communication during the period of COVID-19. Thus, in the urban planning, this factor must be considered to facilitate an uninterrupted internet service to all in all parts of the country.

5. CONCLUSION AND RECOMMENDATIONS

Many cities in Sri Lanka are still on the front lines battling the COVID-19 pandemic, and highly urbanized areas have felt the most concentrated effects of the virus. As rates of infection and death rose, cities needed to identify health management and urban design problems. History tells us that airborne illnesses such as COVID-19 are hard to combat and only physical distancing, wearing masks, lockdowns and travel bans can halt the spread of airborne viruses. Hence, there should be a proper design in urban planning and development to face the virus without spreading it among the people of the city. In that sense, with all the findings of the study, a conceptual guideline was developed as presented in Figure 2 to enhance the significance of a proper urban design.

As many areas of Sri Lanka was locked down due to the outbreak, people started working from home while students got the opportunity of e-learning. Consequently, demand for internet facility became more imperative. Therefore, the smart city solution would be a great support to provide uninterrupted internet access and all the related digital data for easy recognition of infected people and the places where there exist. Easy access to data is utmost important in dealing with the pandemic. Granular, local data should be available digitally to aid in faster decision-making, local mapping and community information.

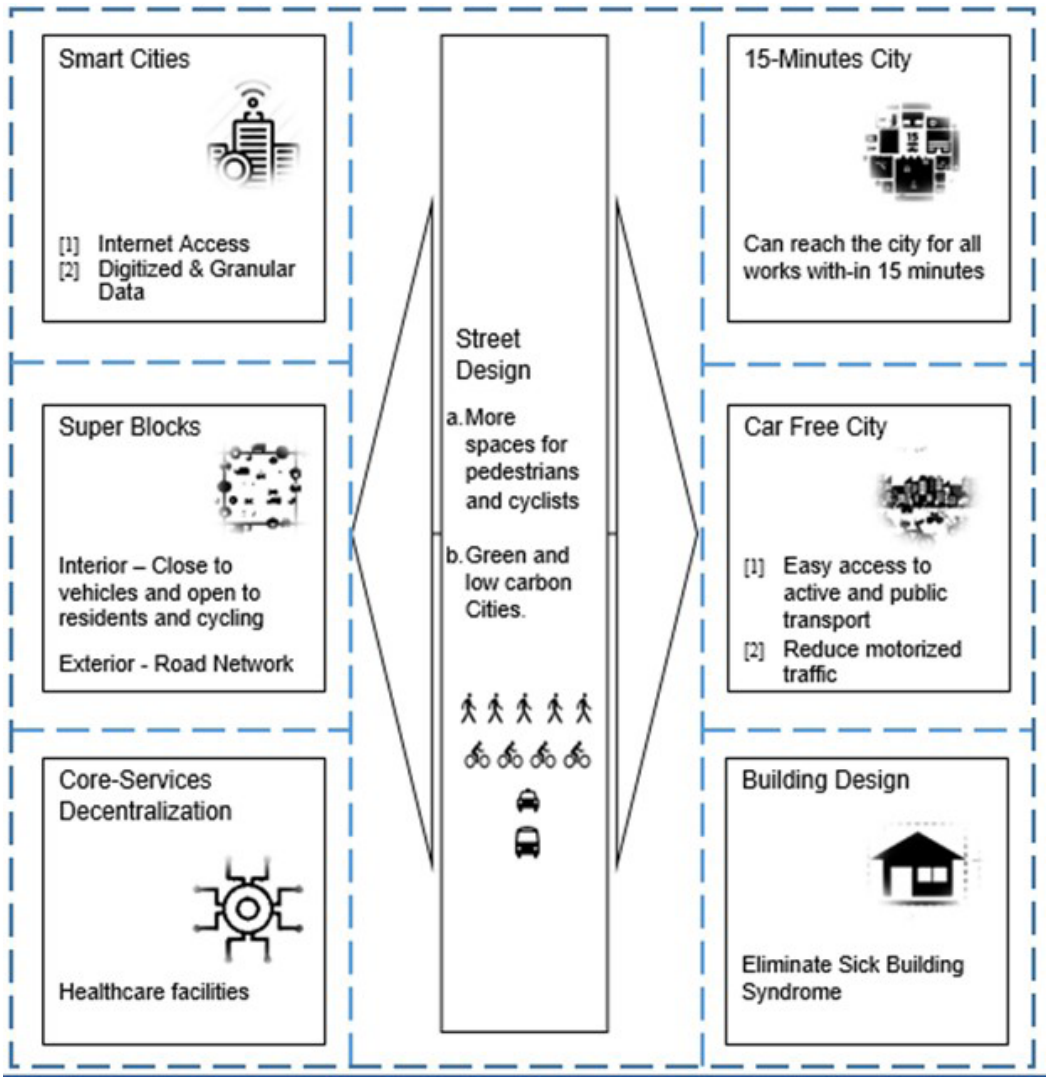

Figure 2. Conceptual Guideline

"15-minutes" city is a novel concept that placed all the essentials in 15 minutes distance and people can reach their service providers within 15 minutes to get them done. Considering the superblocks, it is a city block that is much larger than a traditional city block. They occur incidentally in areas with extremely large buildings. They can also be pursued as an urban design strategy to reduce the impact of cars on cities. A superblock can be created by disallowing cars on small roads in a neighborhood. The roads instantly become broad sidewalks. This provide opportunity to use land for bicycle paths, community projects and appealing commercial ventures.

Car-free cities reduce unnecessary private motorized traffic and provide easy access to active and public transportation. They reduce air pollution and noise levels, increase physical activity and create space for green areas.

Every city's accessibility to core services will be prioritized moving forward. Some residents lack access to essential services like water, health care and housing, and can have trouble amending the problem. While

designing the buildings, a significant attention much be directed towards the comfort of the building as diseases like sick building syndrome can affect to the occupants in a negative way. By controlling risk factors, such as odour, biological, chemical and sound pollution, it can play an important role in preventing the symptoms of the syndrome that encourage the occupants to wear personal protective equipment against COVID-19.

Accordingly, all these aforementioned recommendations can be implemented with the aid of a perfect street design. For that purpose, it is recommended to provide more space for pedestrians and cyclists while providing less space for cars and public transportation like buses, which ultimately create green and low carbon cities.

REFERENCES

Barton, H., & Grant, M. (2012, June). Urban Planning for Healthy Cities. Journal of Urban Health, 129–141. https://doi.org/10.1007/s11524-011-9649-3

Bhadra, A., Mukherjee, A. and Sarkar, K. (2020). Impact of population density on Covid-19 infected and mortality rate in India. *Modeling Earth Systems and Environment*,

Duhl, L.J and Sanchez, A.K. (1999). Healthy city and the city planning process. *World Health Organization*

HAMZA, M., 2021. Abnormal Increase in Air Pollution Levels In Sri Lanka: NBRO | Economynext. [online] EconomyNext. Available at: <https://economynext.com/abnormal-increase-in-air-pollution-levels-in-sri-lanka-nbro-75390/> [Accessed 5 January 2021].

Kanniah, K.D., Kamarul Zaman, N.A.F., Kaskaoutis, D.G., Latif, M.T. (2020). COVID-19's impact on the atmospheric environment in the Southeast Asia region. *Science Total Environment*. 736.

Kummitha, R.K.R. (2020). Smart technologies for fighting pandemics: the techno- and human-driven approaches in controlling the virus transmission. Gov. Inf. Q. 37 (3), 101481.

Liu, L. (2020). Emerging study on the transmission of the Novel Coronavirus (COVID-19) from urban perspective: Evidence from China. *Cities*, 103, p.102759.

Matthew, R.A., McDonald, B. (2006). Cities under siege: urban planning and the threat of infectious disease. J. Am. Plan. Assoc. 72 (1), 109–117.

Rupani, P., Nilashi, M., Abumalloh, R., Asadi, S., Samad, S. and Wang, S. (2020). Coronavirus pandemic (COVID-19) and its natural environmental impacts. *International Journal of Environmental Science and Technology*, 17(11), pp.4655-4666.

Shammi, M., Bodrud-Doza, M., Towfiqul Islam, A.R.M., Rahman, M.M. (2020). COVID-19 pandemic, socioeconomic crisis and human stress in resource-limited settings: a case from Bangladesh. *Heliyon* 6 (5).

Sharifi, A. and Khavarian-Garmsir, A. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. *Science of The Total Environment*, 749, p.142391.

Sharifi, A. (2020). Urban resilience assessment: mapping knowledge structure and trends. *Sustainability 12* (15), 5918.

Wade, L. (2020). An unequal blow. *Science 368* (6492), 700–703.

Wasdani, K.P., Prasad, A. (2020). The impossibility of social distancing among the urban poor: the case of an Indian slum in the times of COVID-19. *Local Environment.* 25 (5), 414–418.

Wigren, C. (2007). Assessing the quality of qualitative research in entrepreneurship. In: H. Neergaard, J.P. Ulhoi, eds. *Handbook of qualitative research methods in entrepreneurship*. Cheltenham: Edward Elgar publishing Ltd. 383-405.

Xie, J., Zhu, Y. (2020). Association between ambient temperature and COVID-19 infection in 122 cities from China. *Science Total Environment*. 724.

Yin, R.K. (2003). *Case study research: design and methods.* 3rd ed. California: Sage publications Inc.

Zangari, S., Hill, D.T., Charette, A.T., Mirowsky, J.E. (2020). Air quality changes in New York City during the COVID-19 pandemic. *Science Total Environment*. 742.

COVID-19 and Environment: Lessons learned

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ABSTRACT

The effects of the novel coronavirus 2019 (COVID – 19) caused by Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2) are widespread and have extended to most parts of the world. Attempts by governments to restrict the spread of infection and mitigate the effects of the pandemic with minimal loss of life include the enforcement of lockdown measures. In Sri Lanka, a 24-hour curfew was enforced on the 16th of March and was continuously enforced for a two-month period, after which, even still a phased return to normalcy is being attempted. Worldwide, lockdowns have allowed for many lessons to be learned. Against a backdrop of continuing activism for climate action and greener economic policies, the effects of lockdowns on the environment have not gone unnoticed. The decrease in vehicular traffic, cessation of industrial activities and declined economic activity has resulted in a noticeable decline in carbon emissions, improvement of ambient air quality and an overall improvement of the environment. Unfortunately, the lack of sustainability in the achieved environmental relief must be highlighted. The above-mentioned events, which occurred along with a decline in economic security could result in adverse effects on the progress made by nations towards climate security and sustainable development. Events related to the pandemic can provide Sri Lanka with many lessons that can be incorporated into its environmental framework. Providing an opportunity to re-evaluate and redirect the approach to building a more concise and timelier environmental framework to ensure the conservation of its natural wealth while mitigating and adapting to climate change.

Key words: COVID - 19, Environment, Climate change, Lessons, Clean energy, Sri Lanka

1. INTRODUCTION: COVID − 19 AND THE ENVIRONMENT

The start of the new decade was universally acknowledged as a time for rejuvenation and realignment of goals and more or less a starting line to brighter prospects. Never before had humanity been more wrong. The rapid and uncontrolled spread of a deadly hitherto unknown disease caused by a novel coronavirus, SARS-CoV-2, named COVID – 19 has resulted in the deaths of over 3.49 million people and infection of over 168 million persons worldwide; statistics that continually keep rising (WHO, 2021). Globally, the impacts of the novel coronavirus SARS-CoV-2, have surpassed any predictable and expected models and have resulted in the drastic slowdown of global economies.

Within a short period, beginning from December 2019, when the first COVID – 19 case was identified in Wuhan, China; tremendous changes to varied aspects of human life have taken place. The earliest measures taken to contain the spread of the infection included lockdowns that aimed at restricting human movement. Imposed lockdowns minimised the spread of the disease, but more importantly

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provided health care services and governments time to adapt and re-evaluate the approach to combatting the virus.

Despite the dire repercussions of the pandemic and the efforts taken to mitigate the spread of the infection, some unforeseen but yet highly desirable changes to the environment have been noted (Henriques, 2020). Beneficial environmental aspects of the lockdown have been continually brought to attention; clearer skylines over cities, greatly reduced air pollution (Watts & Kommenda, 2020) and a 17% reduction in CO_2 emissions compared to the same time the previous year (Le Quéré et al., 2020). However, an expectation that these changes will have a lasting effect on curtailing global pollution is unlikely (Basso, 2020).

The means of achieving this unexpected silver-lining, which is bringing economies to a sudden standstill, is not one that can be expected to be maintained over a long period without dire consequences on global GDP and the stability of economies (Gopinath, 2020). Furthermore, it is also irrational to conclude that the reduction in pollutants and greenhouse gases during this small period will have a long-lasting effect on the ongoing Climate Crisis which is a cumulative outcome of human activity from the advent of industrialism (English, 2020). On the flip side, these unexpected consequences of the sudden shut down of economies could generate even greater environmental implications causing greater harm (Gardiner, 2020).

The following review has been penned with the intention of bringing to attention the need to better adapt to the new normal brought about by the COVID – 19 pandemic. Scientists, policymakers and environmental activists have been calling for more radical approaches to resolving global environmental problems to no avail. Seemingly the present scenario may provide a pedestal to enact just this. Improvements in global climatic conditions provide us a chance to recalibrate humanities' outlook on the environment and would ideally provide incentive and motivation to work towards a cleaner future.

2. OUTLOOK OF POSITIVITY AMIDST A GLOBAL PANDEMIC?

Beginning from the lockdown of Wuhan on the 23rd of January 2020, major global economies have been enforcing indefinite lockdowns intending to limit the spread of infections and ensure that medical systems are not overburdened. Enforced lockdowns have resulted in the closure of public transport, drastic reduction of air traffic, shut down of industries and limited movement of citizens from their homes. Unexpectedly, these efforts to contain the spread of SARS-CoV-2 have resulted in some positive outcomes with respect to the environment.

A pronounced decline in levels of pollutants has been identified in many regions of the world, particularly associated with major metropolises within which levels of pollutants are generally elevated. Reduction in levels of smog, fine particulate matter which includes droplets and tiny particles that are two and a half microns or less in width; $PM_{2.5}$ and other pollutants have been evident, and heightened visibility has been observed in cities such as New Delhi, Colombo and Bergamo (Hernandez, 2020). Real-time satellite images published by NASA show a dramatic reduction in pollution levels over major economies in the world (such as China, Italy and India) indicating a vast improvement in global atmospheric conditions and a reduction in air pollution (NASA, 2020 .

NO_2 in particular is a major concern to human health, as it is particularly harmful to humans and can cause irritation, damage to lung tissue and aggravation of respiratory issues (Schlesinger & Lip_{pm}ann, 2020). Studies carried out in Northern Italy by the Copernicus Atmosphere Monitoring Service (2020), have put forward data indicating a gradual 10% reduction in levels of NO_2 each week in major cities such as Venice, Milan and Bologna during the early periods of lockdown. Daily analysis of hourly concentrations of regulatory air pollutants has been used as means to quantitatively show the ground truth in relation to the changes observed through satellite imaging.

Likewise, in Spain, levels of NO_2 in major cities such as Madrid and Barcelona declined by 75% and 45% respectively (Planelles, 2020). Improvement in air quality in the United Kingdom has been seen to be tied to a decline in daily human activity, in particular reduced vehicular traffic (Speare-Cole, 2020). In New York, early results indicated a 50% drop in levels of CO (emitted from vehicular traffic) in comparison to the previous year's indicating an improvement in overall levels of air pollution in the city (McGrath, 2020).

In China, around half a billion people, equivalent to 7% of the world population were forced to remain at home (Hernandez, 2020 . Thus, the lockdown measures have resulted in an estimated 25% drop in carbon emissions, equivalent to about 200m tonnes of CO_2, within a four-week period (Carbon Brief, 2020). This reduction in emissions has been definitively linked to the decrease in motor traffic and industrial activity. Apart from motor traffic, large-scale coal consumption in China is responsible for a large number of harmful emissions which contain oxides of carbon, nitrogen and sulphur, PM and ash (Munawer, 2018).

A study carried out in China concerning the effects of the pandemic lockdown on the environment by Wang & Min (2020), draws data from several sources and shows how the quarantine period, coupled with economic decline, has resulted in a reduction in overall air pollution, global carbon emissions, emission of nitrogen oxides and other harmful air pollutants.

Studies in Colombia (Arregoces et al. 2020) too indicate a reduction in levels of PM by an average of 35%. Levels of NO_2 were found to reduce by around 60%. Weekly and monthly comparisons of $PM_{2.5}$ levels before and after lockdown periods between the week of 6th January and June 22nd 2020 were obtained and compared with daily values obtained from Terra/MODIS satellite during the period of January to June in the years 2018 – 2020. Reduction in vehicular flow tied to imposed lockdowns was found to be a major factor that contributed to the observed improvements in the environment mentioned in the above study.

In Sri Lanka, beginning from the 16th of March 2020, an indefinite curfew period was imposed. As with other regions of the world, these lockdown measures resulted in cleaner ambient air quality and reduced emissions (Planelles, 2020; remasiri, 2020). Numerous reports indicate that the main source of emissions within the country arises from vehicular traffic and makeup about 45% to 48% of CO_2 emissions of the island (CEB, 2020; USAID, 2015).

Ambient air quality monitoring carried out by the National Building Research Organisation (Premasiri, 2020), showed a reduction in PM and an overall improvement in air quality in Colombo 07 and urban areas in the North and North-western areas of the island (including Anuradhapura, Vavuniya and Jaffna) throughout the mandatory lockdown period in correlation to reduced vehicular traffic. A 75% reduction in $PM_{2.5}$ levels (11 μg/m^3) and a 60% reduction in PM_{10} (22 μg/m^3) levels between the period of March 15th and April 7th were recorded in the above-mentioned cities, indicating the lowest levels of particulate matter in the past 20 years.

Reduced motor traffic, aviation traffic and industrial activity indicate a reduction in the demand for fossil fuels. Oil, gas and coal firms have been some of the badly affected industries (50% below start-of-the-year prices) because of the sudden shut down of industry and travel, among other consumers. Predictions are made that the novel coronavirus 2019 will lead to the largest contraction in sales of oil in history (Blas, 2020).

The reduced demand implies a reduced consumption of fossil fuels and accordingly reduced emissions which correlates to the improvements in air quality. Secondly, reduced fuel costs represent an ideal opportunity for the removal of subsidies from fossil fuel consumption, thus, saving economies money that could be redirected into investments such as education and clean energy (Crist, 2020).

3. ALL THAT SHINES ISN'T GOLD: IS THE ENVIRONMENT TRULY MENDING?

Despite the unexpected positive effects on the environment brought into the limelight by mainstream media, the long-term environmental impacts of the global pandemic of COVID 19 could head in the opposite direction. With global economies rapidly reopening and aiming to achieve pre-COVID economic stimulation, the focus is now shifting to ensuring economic stability, with little concern for the environment. This could easily set back decades of progress made towards climate security, which in any case, is yet to be achieved. Expectations that the generated effects of environmental improvements will have any long-standing effects on air pollution or climate change are unrealistic (English, 2020). The reopening of industries and public transport has already shown to cause an increase in the levels of carbon emissions (Harvey, 2020). Levels of carbon emissions that were once 17% less than the mean level in 2019 have now risen to 5% less than the global mean of emissions in 2019 (Le Quéré et al., 2020).

A recent article by the World Economic Forum (2020) based on findings by the Centre for Research on Clean Energy and Air indicates an overshoot of levels of harmful pollutants from China to levels much higher than pre-lockdown. Such overshoots in levels of pollutants following periods of economic decline, more commonly known as "revenge pollution" or "dirty recovery", represent efforts by economies to establish stability following periods of turmoil through the fastest route feasible. Dr. Thani Al Zeyoudi, the UAE Minister for Climate Change and Environment warns of the possibility of the occurrence of "revenge pollution" by governments worldwide post COVID – 19 (Zeyoudi & Al-Zu'bi, 2020). He notes that actions to be taken by governments, post COVID-19, to boost their economies and recover from their losses, if left unchecked, could have a disastrous effect on the global environment.

Previous accounts of "revenge pollution" stem from the $586 billion stimulus package launched by the Chinese government in 2009 in order to recover from the 2008 Financial Crisis (Cao, 2018). The drastic efforts backed by the Chinese Government called for rapid infrastructure development that resulted in a far-spread public outcry owing to the rising levels of pollution leading to what was referred to as an '*airpocalypse*' characterized by extremely hazardous levels of PM in the atmosphere, haze that blocked out the sun for several days and other harmful forms of air pollution (FlorCruz, 2013). The outcome of this resulted in the rapid adoption of emergency measures against hazardous pollution and the development of China's first national air pollution action plan in September 2013 (Jiang & Karimi, 2013).

The novel coronavirus will not only set back economies but has also affect efforts to curb climate change as well (Crist, 2020; Elkerbout et al., 2020). The manner in which economic recovery by governments and day to day human activity return to pre-COVID levels could potentially unravel efforts taken to curb global warming and climate security over the years.

The postponement of COP26, the 2021 United Nations Climate Change Conference, is one such major setback. COP26 aimed at discussing the efforts taken to achieve climate security and curb climate change following discussions at the 2015 Paris Agreement. This conference would have provided an ideal platform for policymakers and governments to re-evaluate, redirect and rebuild actions and plans to achieve climate security based on previous discussions and achievements made up to now. The postponement of this conference is effectively depriving the world of an important opportunity to benchmark mitigating and mobilizing climate action. Along with COP26, several other pivotal international negotiations and major platforms for the environment, such as the World Conservation Congress, the Convention on Biological Diversity, the 2020 UN Oceans Conference and the High Seas Treaty, have been postponed (Cho, 2020).

Furthermore, governments may attempt to sidestep climate action with the intention of prioritizing economic development causing critical delays in efforts to achieve climate stability. A prime example for this is the opinion voiced by the Prime Minister of the Czech Republic, Mr. Andrej Babis, who called for the European Green Deal, a policy package which commits EU members to zero emissions by 2050 (Harvey & Rankin, 2020), to be set aside for the time being, while countries focus on combating the effects of the pandemic (Nicolás, 2020). A similar proposal has been made by the Polish Deputy Minister for State Assets and the first Vice President of the Romanian ruling party (Nicolás, 2020). Fortunately, these suggestions have been refuted by the European Commission indicating that the climate laws have been designed in a manner in which they will not burden economies and be overlooked in situations requiring pressing concern or immediate action (Nicolás, 2020).

While the European Green Deal sets an exceptional role model for other nations, including Sri Lanka to follow, it has been predicted that the enforcement of the new green deal will require more than 200 billion pounds to achieve goals set for 2030 (The European Commission, 2019). The manner in which European Nations endorse this deal and formulate monetary and fiscal policies amidst the prevailing pandemic will provide many lessons for other nations.

The cost of combatting climate change and mitigating the effects of environmental degradation is large (Nordhaus, 2013). Against the backdrop of the COVID-19 pandemic and recovery from it, governments will have to redirect funds for the purpose of reinforcing healthcare systems, generating stimulus packages to combat economic burdens and ensure the general welfare of civilian activity. Thus, it is most likely that there will be a loss in funds allocated to combatting climate change.

The present status of the economy and reduced prices of fossil fuel owing to the effects of the COVID – 19 pandemic may further impede the achievement of climate security. While reduced costs and thus, removal of subsidies does provide the doorway for more funds to be redirected to other avenues (Le Quéré, 2020), it could also lead to heightened consumption. Reduced prices in fossil fuels over a long-time frame could mean that governments may turn to quick, emission-heavy means to run industries and achieve economic stability. With the availability of such options and an absence of suitable policies and direction, a paradigm shift among nations from being environmentally conscious to opting for the quickest way out of forthcoming economic plight at the expense of the environment may become evident.

Despite this, it is pivotal that mitigation of the growing climate crisis is averted in a timely manner. The Stern Review is a decisive piece of work that showcases the need for early, effective and sustainable approaches to mitigate climate change and pollution. Such a timely approach has never been more vital than in the present millennium (Stern et al., 2006) and the prevailing situation will only further consolidate this need. The impending global economic crisis is estimated to push 420 million people or more, mostly from developing or underdeveloped nations, below the absolute poverty line[1] (Sumner et al., 2020). Exacerbation of poverty and poor living standards would be catastrophic to the well-being of the future as environmental degradation, deforestation, climate change and a variety of concerns associated with the environment are directly linked to poverty and poor living standards (Bucknall et al., 2020). Owing to the development of such a critical outlook in the future regarding socio-economic and environmental standards, it is imperative that adequate measures and policies are adopted by governments and industries. These adopted strategies must ensure that steps taken in the past towards mitigation of poverty and thus; climate change and environmental degradation are not undone. Revival of the economy by whatsoever means feasible without paying attention to the needs of climate action and sustainable development would be short

1 Living on < $ 1.90/day.

sighted. In retrospect, such strategies by governments will be responsible for repeating the narrative that has lead us to where we stand today.

4. COVID-19 AND SRI LANKA

The outcry for the environment has been taking the centre stage in the social and political spheres of Sri Lanka presently. Improper and unplanned development, political agenda, misinformation and misinterpretation overlapping one and another leave environmentalists and policymakers faced with an arduous task at hand. The present situation regarding COVID-19 further exacerbates this concern. The projected cost of the European Green Deal (200 billion pounds to achieve 2030 targets) provides insight into the general difficulty in adopting such climate mitigation efforts and combatting climate change especially among developing and underdeveloped countries. Given the current global economic crisis driven by the pandemic, it is vital to adapt these measures in ways that are both effective and successful in meeting the current needs and situation of the country. Investments and funds should be streamlined in ways that ensure climate-proofing instead of postponing climate resilience for a later time. However, within Sri Lanka, there has been a commendable shift towards better adaptation to combat climate change (Hewawasam & Matsui, 2019).

The National Adaptation Plan for Climate Change Impacts in Sri Lanka (NAPSL, 2016) compiled by the Climate Change Secretariat, Ministry of Mahaweli Development and Environment, has provided a framework to achieve climate resilience and meet the adverse effects of climate change. This is proposed to be achieved by adapting the needs of key vulnerable sectors, of which nine have been identified, and cross-cutting national needs of adaptation. Furthermore, The Ministry of Mahaweli Development and Environment has also been identified as the focal point to the United Nations Framework Convention on Climate Change and was instrumental in the generation of the Intended Nationally Determined Contributions - 2015 (INDC) to drive Sri Lanka to reach the goals of the COP21. Four areas have been addressed by the INDC and include mitigation, adaptation, loss and damage and means dealing with the existing climate crisis.

According to the INDC, within the energy sector, Sri Lanka intends to cap its emissions through unconditional emission reduction by 4% against the 2010 baseline to 4,88 million tCO_2 by 2030. Through conditional emission reduction, emissions are predicted to be reduced to 3.33 million tCO_2 by 2030. Other forms of emission reduction have been planned by the reduction of greenhouse gas (GHG) emissions from the transport sector, industrial sector, waste management sector and the forestry sector.

Energy production within the island contributes to 41% of CO_2 emissions. The Ceylon Electricity Board (CEB) is the largest utility in Sri Lanka, and holds the monopoly over a major portion of power generation and owns all coal power plants in the island (CEB, 2017). The CEB provides up to 12.96 GWh of power to the national electrical grid through coal power (CEB, 2017). Up until the '90s, the majority of energy on the island was met through hydropower (CEB, 2020). The use of coal to meet the country's energy demands began in 2011 with the commencement of operations in the 1st unit of the Lakvijaya Power Plant which has a 900MW capacity (CEB, 2020). While the 'Long-Term Generation Expansion Report 2020-2039' (LTGER: 20/39) drafted by the CEB attempts to push for alternative energy, most renewable energy sources are undervalued. The report only indicates a yearly energy generation capacity addition of 100MW from solar energy throughout the period from 2020 to 2039 (CEB, 2020).

Further plans to increase the capacity of the Lakvijaya power plant to include the 4th unit and to develop two 300MW high efficient coal power plants by 2023 in Foul Point Trincomalee imply a continual reliance and predictable increase in coal usage within the country. Against a background where the

president of Sri Lanka is pushing to fulfilling 80% of the country's power demand through renewable energy by 2030 (Gotabaya, 2020) and, where scientists and policy makers in the majority of the world are laying down a road maps for 100% energy or zero net carbon emissions in the near future, (BloombergNEF, 2020b; Jacobson et al., 2017; Bradner & Saenz, 2019) the long-term plans of the CEB seem to fall short.

The predictions made by the CEB in the above report concerning the emission of CO_2 indicate a continuous increase in local emissions. An almost 150% increase in CO_2 emissions from 9.4 million tons per year to 24.4 million tons per year is predicted between 2020 and 2039. A similar increase in other forms of hazardous gases and PM is expected.

Despite the stance taken by the CEB indicating that Sri Lanka has a low effect on GHG emissions (0.05% of global GHG emissions), the reality stands that; as a global citizen, Sri Lanka is and will continue to be an active contributor to impending climate crisis. The need to ensure climate security is the responsibility of every country. Further, the 'right to utilise available resources in order to continue in the development path with the least economic effect on its people' stated in the CEB report on the basis that Sri Lanka achieved a level of economic development of 4000 USD per capita income in 2017 is not a good enough reason to deter from development which prioritises environmental well-being (CEB, 2020).

The expectations of the CEB to continue in the path indicated by the LTGER: 20/39 is quite out of line with the present global perspective and trajectory regarding clean energy and capping global emissions.

The short-sighted nature of the CEB expansion report is further heightened due to concerns of an impending coal shortages, rising coal prices, public opposition to coal and an instability of the global coal market which is more or less diminishing in most parts of the world (Froggatt, 2013; IEA, 2019).

Despite these shortcomings, many attempts are also being mobilized by the CEB to shift toward cleaner energy (CEB, 2020; Hewawasam & Matsui, 2019). Sunlight and wind have been identified as major sources through which renewable energy may be harnessed in Sri Lanka. The CEB has been active in promoting solar power as an alluring form of electricity generation through schemes such as the "Net Energy Metering Facility" which was introduced in 2010. This scheme created to promote solar energy usage in Sri Lanka, encouraging consumers to invest in solar energy to provide excess electricity back to the national grid. Electricity consumers that participate in this scheme are not provided monetary relief but are given credit in kWh for the consumption of the same amount in the subsequent billing period. Fourteen thousand seven hundred installations that generate solar power have been established under this scheme providing 106MW of solar power (CEB, 2020).

Along with this the "Net Accounting" and the "Net Plus" scheme have been instrumental in the growth in solar power achieved on the island today. "Net Accounting" is an extension to the existing new metering scheme, which compensates consumers through a two-tier tariff for a 20-year period while the "Net Plus" scheme allows the consumer to establish a solar PV generation unit and transfer all generated energy to the national grid.

Utilization of wind energy has been fast-growing on the island over the past years. The Asian Development Bank (ADB) in the 2019 assessment of the energy sector of Sri Lanka identified that Sri Lanka has an estimated wind power potential of 5600 MW (ADB, 2019). Based on the predictions by the Long-Term plan of the CEB, the demand for electricity is expected to increase to 9709 MW by 2044. This indicates that were the full potential of wind energy in the island to be accessed, wind energy alone would be able to fulfil up to 65% of the energy requirement in Sri Lanka. Yet the expansion plan of the CEB continuously indicates only a 100MW generation of power from the Mannar wind farm (CEB, 2020). Brighter prospects such as the proposed

construction of the Pooneryn Renewable Energy Park, the success of the Accelerated Solar Development Plan initiated in 2016 and the projected increase in renewable energy capacity should not go under-appreciated as they are indicative of the capacity for change towards a county powered by cleaner energy.

"*Development of variable renewable energy policy in developing countries: a case study of Sri Lanka*", a study by Shi et al. (2018) provides vital information that can be incorporated into policymaking to help achieve renewable energy goals. The recommendations made by this study include: better coordination among governing agencies (especially towards developing aims at working toward a common goal of sustainability and economic growth); generating policy instruments to match the technical characteristics of variable renewable energy; adaptation of policies that account for the potential rapid decline in renewable energy costs; and generating policies that aid the development of variable renewable energy without significantly altering the electricity market. The authors are not hesitant to highlight the need for better policy frameworks and better coordination. They are indicative of the ability to achieve more ambitious goals in relation to clean energy within the country.

Along with aims towards cleaner energy, Sri Lanka also intends to expand into Clean Development Mechanisms (CDMs). The highest potential for which has been identified in the Energy sector. CDM will allow emission reduction projects to earn Certified Emission Reduction (CER) credits, which in turn can be traded and used by industrialised countries to meet their emission reduction targets under the Kyoto Protocol. Carbon Partnership Facilities (CPF) and Partnership for Market Readiness (PMRs) are two schemes to which Sri Lanka has committed to with the intention of aiming for a cleaner future.

CPF which is a Carbon crediting program in partnership with the World Bank will allow the CEB to act as a trustee and any private producer in the energy sector will be allowed to join the scheme by transfer of carbon credits through the CEB. This would then provide Carbon revenue which may be utilized to overcome financial barriers to renewable energy development.

PMR on the other hand will act as a grant-based, capacity-building trust fund that will provide funding and assistance for 'collective innovation and piloting of carbon-pricing instruments (CPIs) that reduce GHG (CEB, 2020).

Other means proposed by the CEB to mitigate environmental degradation ties to the energy sector include;

1. Fuel quality road maps that aim for better quality low sulphur diesel, alternative transport fuel (such as biofuel), promotion of electric vehicles, development of fuel quality standards and introduction of LNG as cleaner energy sources.

2. Loss Reduction.

3. Demand for Side Management and Energy Conservation.

4. Tree Planting Programs.

5. LESSONS TO BE LEARNT FROM COVID – 19 PANDEMIC

"*I consider this painful global pandemic to be a complex, adaptive challenge. In a connected and interdependent world, a complex and adaptive challenge cannot be solved by individual countries alone*." Ethiopian Prime Minister Hon. Abiy Ahmed, (10th June 2020)

The lessons that can be learned from the events that are unfolding, driven by the COVID - 19 global pandemic, will be pivotal in shedding a new perspective to the numerous environmental concerns faced in the modern world. As a developing country, Sri Lanka can benefit vastly by identifying such lessons and aptly incorporating them into the policy framework of the country to better meet sustainable development and environmental goals.

5.1. Understanding that global issues have no national borders is vital

Effects of climate change and environmental degradation will ultimately affect all nations in the world and undermine the efforts made by nations towards sustainable economic development. The prevailing pandemic and the effects of imposed lockdowns will only further dampen efforts to meet these goals. However, these effects will be felt largely disproportionately. Under-developed nations and developing nations, in particular, will face the largest difficulties in adapting to the new normal, shifting climate patterns and other effects of climate change, while developed, richer nations which are responsible for most emissions and prevailing climate scenarios will be able to rebound economies with comparative ease.

The novel coronavirus pandemic has shown that solidarity and unity in the face of global challenges are essential to successfully overcome them. Towards this end, the World Economic Forum recently held a forum, named "The Great Reset", which was centred on building a collective approach to re-initiating of global economic activity in the wake of the COVID – 19 pandemic. It is noteworthy to state that, in line with the need for global solidarity, the Ethiopian Prime Minister Hon. Abiy Ahmed called for all G20 nations to use all available policy tools to aid low-income countries that are facing the consequences of the COVID – 19 pandemic (Alessi, 2020).

5.2. Achieved reduction in emissions during lockdown periods is not sustainable

Despite a pronounced reduction in global emissions of pollutants and greenhouse gases due to the slowing down of economic activity, it is imperative to understand that these seemingly positive outcomes we see today have not been achieved sustainably and thus will not be long lasting. The possibility that levels of emissions will rise back to pre-lockdown levels or even much higher, resulting in a scenario of *revenge pollution* must not be overlooked. Achievement of economic stability, while being extremely important, must not overlook environmental well-being. Through sound policy formation and adoption, it is possible to generate a foundation that ensures sustainable development and economic growth without sidestepping environmental actions. The decline of emissions in relation to the decline in economic activity is understandable, but it is in no way a permanent solution to the prevailing climate crisis or any other environmental concern at hand.

Apart from the prevailing scenario there have been three scenarios in the past where the increase of global emissions of CO_2 have been zero or less in comparison to previous years. Three such instances, the early 1980s, 1992 and 2009, were similar to the present-day events, where reduced emissions were coupled with a decline in economic activity. This trend does not however represent a norm. Policymakers and governments alike must not be clouded in their judgments to think that the only means of achieving lower emissions is by depreciating economic activity. This misconception can be put to rest when taking into consideration the period between 2009 and 2015 when the economy of the United States grew by more than 10% while CO_2 emissions from the energy sector fell by 9.5% (Council of Economic Advisers, 2017). Numerous other studies carried out in India (Ghosh, 2010), China (Zhang & Ya-Bin, 2015; Alam et al., 2016), Pakistan (Mehmood & Kanwal, 2017), Brazil (Alam et al., 2016) and Saudi Arabia (Alshehry & Belloumi, 2015) indicate that a reduction in CO_2 emissions or the amalgamation of climate-conscious policies will not hinder or impede economic growth.

5.3. The present status of the World has brought to light the need to rapidly embrace Greener Policies

Growing concerns of highly unsustainable human activity and development that is pressing hard against the planetary boundaries implies that policymakers and politicians are now at crossroads regarding actions to be taken

in the future. Failure to adopt environmentally conscious policies would result in major losses and additional financial burdens to governments.

William Nordhaus in his book '*The climate casino: Risk, uncertainty, and economics for a warming world*' making use of Integrated Assessment Models and the Dynamic Integrated model of Climate and the Economy developed at Yale University shows that a 4°C rise in global temperature from preindustrial times could result in losses amounting to 1% - 5% of global GDP each year by 2100. In the Stern Review, the *minimal* loss owing to the failure to take mitigation action against climate change is predicted to be at least 5% of the global GDP (Stern, 2006).

Many other concerns will arise owing to elevating global temperatures and deteriorating environmental conditions. These include progressively declining opportunities for a high quality of life in developing and underdeveloped countries, development of new diseases (Fox-Shelly, 2017), various catastrophic weather events such as floods, accelerated meltdowns of Arctic and Greenland ice sheets, positive feedback effect on rapid acceleration of global warming with the release of greenhouse gases from previously frozen soils (Obama, 2017) and elevating sea levels.

Ignoring or side-lining climate action will eventually result in nations needing to redirect more investment for mitigating and adapting to impacts of climate change. For example, funds will have to be allocated to contain the effects of rising sea levels, conservation of biodiversity, water management and even tourism. Additional funds to ensure management of crops and agriculture in the backdrop of changing climate conditions will be needed to ensure that global food security is achieved. The lack of proper policies with association to climate change and food security is predicted to thrust around 160 million people towards the risk of hunger in 2050 and avoiding such scenarios would cost around 0.18% of global GDP (Fujimori et al., 2019). These numbers are likely to grow given the effect of the COVID - 19 pandemic.

5.4. Policies formulated in the past have to be modified to suit the '*New Normal*'

Governmental frameworks proposed to curb climate change, achieve sustainable development and economic growth must now undergo revaluation and be modified to suit a world that is markedly different to that within which these policies were initially created (IMF, 2020). Attention must be paid to ensure that the environment is not at the losing end in these newly modified policy frameworks. Steps to ensure that funds are aptly streamlined towards achieving climate conscious, sustainable development may include; making proactive efforts to move away from a coal-based economy, further investing in clean energy achieved through solar power, wind power and hydropower and developing the public transport sector.

Formulated policies must guide the economy through what may be one of the worst impending global recessions of the modern world while prioritizing the environment as well. With such motive the capacity to achieve long term climate security and environmental growth alongside with economic development will be plausible.

The information gathered during this period could be used as strong evidence for organisations such as the Central Environmental Authority to push for developing policies and measures. Such facets when strategically planned and implemented, could help to raise awareness among communities on the importance of developing consciousness on the reduction of one's carbon footprint and highlight the small ways in which every person in the community could work towards a greener future. These may include development of public transport and encouraging companies to endorse work from home options to help reduce the density of motor traffic.

However, it is important to remember that the individual efforts of people even throughout the globe will be irrelevant, if the action taken by economies throughout the world in line with mitigating climate change. Thus, in this regard what is imperative here is a synergetic approach between both the society and the government (Pralle, 2009).

5.5. Informed decision making based on scientific evidence must become the focal point of new policies and decisions adopted by the government

Along with the intensification of the pandemic and the growing health crisis, the spread of false information and conspiracy theories surrounding the pandemic were rampant. Beliefs that the disease was caused by 5G telephone towers and shifts in magnetic fields of the earth were few of the laughable conspiracies that were circulating. Other forms of misinformation, however, were not as humorous.

The severity of misinformation and the absence of science backed decision making regarding the COVID – 19 pandemic has had deadly effects. Former American President Donald Trump was notorious for downplaying the severity of the pandemic, disregarding it as a mere flu and even fuelling rumours that the virus was a bioweapon created by China. Consequently, America has been one of the worst effected countries due to the pandemic. Along with the increase in the number of 'Anti-mask' protests in USA, so did the number of active cases. Daily infections were found to exceed 100,000 cases during the height of the pandemic and presently the death toll lies at above 592,000 deaths, the highest among the developed nations, with numbers continually rising daily. Apart from this, social implications such as growing acts of violence and racism toward Asian communities in America are also being recorded (BBC News, 2021).

Even now, with the development of the vaccine and active vaccination programs being carried out in many parts of the world, Anti-vaccine groups claim that the vaccine is harmful and is merely a mechanism for private firms to obtain profits. Perhaps more so disturbing is when such misinformation is endorsed by political figures and enters into the governing framework of countries. The lack of proper informed decision making can result in dire situations that could reverse the progress achieved in numerous fronts.

Growing trends and concerns in Emerging Infectious Diseases had been previously voiced in many studies (Jones et al., 2008; Nii-Trebi, 2017) despite which most governments in the world, including that of Sri Lanka, failed to adopt early resilience strategies in facing these threats. Climate and environmental concerns too have been continually identified as impending global concerns since the early 19th century. The 2019 Global Risks Report by the World Economic Forum identifies extreme weather events, failure to adapt to climate change and natural disasters as three of the top five global risks in terms of likelihood and impact. In short; plenty of early warnings regarding the climate crisis have been given well ahead of time. Yet, despite the early warnings given to policymakers and governments, many, if not all governments of the world have failed to adopt early strategies to face the challenges of the pandemic. In view of climate security and global warming, a lapse in preparedness to face forthcoming challenges is inexcusable. A plethora of science evidence and information is readily available to stakeholders and governments regarding the forthcoming climate crisis. Failing to develop strategies to mitigate the impending crisis and to make use of a *Science-backed* approaches will result in far worse consequences than the prevailing pandemic.

5.6. The approach to cleaner energy must not be compromised

The manner in which governments and policy makers approach clean energy in the coming years will be another factor that will influence the direction to achieving climate security. The present dependence of Sri Lanka and the rest of the world on non-renewable energy sources cannot be denied. We have

relied on numerous forms of energy sources primarily centred around fossil fuel to fulfil energy demands. However, in this day and age, with the pressing concerns of firstly global warming and secondly an impending short supply of fossil fuels, which are expected to exhaust by 2060 (Dudley, 2015), alternative and cleaner energy which is carbon negative is now highly appealing as a major solution to these problems (Abbasi & Abbasi, 2011). Of notable mention apart from the previously mentioned sources of green energy, Bio-gas, presents itself as a highly desirable fuel source. The ability to generate fuel while simultaneously providing a source of fertilizer for crops, makes Bio-gas an attractive energy source for agricultural communities.

It is estimated that up to 80% of current coal reserves, a third of oil reserves and half of the gas reserves in the world should remain unused between 2010 to 2050 in order to ensure that the globally agreed 2° C rise in global temperatures, agreed upon by policy makers is not exceeded (McGlade & Ekins, 2015), implying that the need for clean energy with minimal emissions has never been more important.

5.7. Education is vital in combating climate change and the promotion of sustainability, as it is the only tool that can allow for the spread of self-sustaining change to be achieved.

Education allows for the inculcation of knowledge, skills and behavioural changes that are essential in combating climate change and the assurance of lasting effects of such efforts (Anderson, 2010). The lessons learnt through the rapid spread of the infection has transgressed all fields of life and has resulted in a shift in the framework which has been considered the norm up to now (Gudi & Tiwari, 2020). The spread of the COVID-19 pandemic will result in the shift of normality in the years to come. In a backdrop of the extensive changes that the global economy will face, Sri Lanka must introduce and adapt policies based on scientific evidence, failing which the repercussions will set back years of economic growth. However, when considering economic stability and environmental security, neither can take priority over the other. Synergy is essential and there can be no compromise with regard to it. Failing to understand the importance of ensuring the well-being of the environment as a whole will only result in future burdens on sustainable development.

6. CONCLUSION

In conclusion, the prevailing pandemic has brought about an array of undesirable outcomes. Attempts made by governments throughout the world to combat rising number of infections resulted in the enforcement of lockdowns that unknowingly resulted in the cessation of economic and industrial activity. Consequent improvements in global climatic conditions were identified in many regions of the world, especially associated with major cities. While these improvements are not expected to last long, the lessons that we could learn from this period are valuable and it is vital to make amends accordingly. A key requirement in developing strategies to address environmental concerns following this tumultuous period is to first develop a sound understanding of the issue at hand. The information which would be collected from such a standpoint will allow scientists and policymakers to effectively and efficiently allocate resources and streamline efforts in order to bring about the most desirable outcome (Pullin & Knight, 2009). The understanding that the existence of humanity is tied to the existence of the environment in which we live is indubitable and has never been more vital to our understating of the dynamics of environmental management than in the present day. Since the beginning of the modern environmental movement, scientists have been grappling with data and information that has been obtained in a backdrop of continually rising levels of emissions, ongoing pollution and degradation of the environment. In this sense, the COVID – 19 pandemic has provided us with a once in a lifetime opportunity where there is a reduction in the levels of pollution, locally and globally, thus, providing an unprecedented opportunity with many

lessons that will help mould future policies and decisions.

The author declares that there is no conflict of interest regarding the publication of this paper and no funding was provided for this work.

ACKNOWLEDGMENTS

The author would like to thank all those who helped make this venture a success. Dr. S. Miththapala and Dr. Tamara Weerasinghe, in particular, provided guidance and knowledge stemming from decades of experience in the field of Environmental Science. Further, S. Amarasinghe and T.K.Tennakoon for guidance and support with editing and for all who have put countless hours into research and innovation to achieve a greener future for the Blue Planet.

REFERENCES

Abbasi, T. and Abbasi, S.A. (2011). *Renewable energy sources: Their impact on global warming and pollution.* PHI Learning Pvt. Ltd. India, 332 Pp.

Alam, M.M., Murad, M.W., Noman, A.H.M. and Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators* 70: 466-479.

Alessi, C. (2020). *'Collective action' - restarting the global economy amid a Great Reset* (Online). World Economic Forum. Available from : https://www.weforum.org/agenda/2020/06/covid-great-reset-gillian-tett-abiy-ahmed (Accessed: 12 July 2020).

Alshehry, A.S. and Belloumi, M. (2015). Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. *Renewable and Sustainable Energy Reviews* 41: 237-247.

Anderson, A. (2010). *Combating climate change through quality education*. Brookings Global Economy and Development, Washington. Available from : https://www.brookings.edu/research/combating-climate-change-through-quality-education/ (Accessed: 13 December 2020).

ADB (2019). Sri Lanka Energy Sector Assessment, Strategy, and Road Map. Available from: https://www.adb.org/sites/default/files/institutional-document/547381/sri-lanka-energy-assessment-strategy-road-map.pdf (Accessed: 27 May 2021).

Basso, L. (2020). *Why a 17% emissions drop does not mean we are addressing climate change*, The Conversation, Australia. Available from: https://theconversation.com/why-a-17-emissions-drop-does-not-mean-we-are-addressing-climate-change-138984 (Accessed: 27 May 2021).

Blas, J. (2020). *The World's Oil Demand is Shrinking by the Most in History.* Bloomberg, New York. Available from: https://www.bloomberg.com/news/articles/2020-03-13/trafigura-sees-oil-demand-contracting-by-the-most-in-history?sref=ZCCexVBt (Accessed: 18 June 2020).

Bloomberg New Energy Finance (2020a). *Electric Vehicle Outlook 2020*, BloombergNEF, London. Available from: https://bnef.turtl.co/story/evo-2020/page/1?teaser=yes (Accessed: 18 June 2020)

Bloomberg New Energy Finance (2020b). *Solar demand could fall for the first time in 30 years due to Coronavirus,* BloombergNEF, London. Available from: https://www.edie.net/news/10/Solar-demand-could-fall-for-first-time-in-30-years-due-to-Coronavirus/ (Accessed: 18 June 2020).

Bradner, E. & Saenz, A. (2019). *Joe Biden's climate plan targets net-zero emissions by 2050*. CNN. Available from: https://edition.cnn.com/2019/06/04/politics/joe-biden-2020-climate-plan/index.html (Accessed: 14 July 2020).

Bucknall, J., Kraus, C. and Pillai, P. (2000). *Poverty and Environment. Environment Strategy Background Paper.* World Bank, Environment Department, Washington, DC.

Cabral, S. (2021). *Covid 'hate crimes' against Asian Americans on rise*. BBC. Available from https://www.bbc.com/news/world-us-canada-56218684 (Accessed 29 March 2021)..

Cao, M. (2018). *China's Response to the 2008 Global Financial Crisis and its Legacy.* Cathay Review.

Myllyvirta, L. (2020). *Analysis: Coronavirus temporarily reduced China's CO2 emissions by a quarter*, Carbon Brief. Available from: https://www.carbonbrief.org/analysis-coronavirus-has-temporarily-reduced-chinas-co2-emissions-by-a-quarter (Accessed 28 May 2021).

CEB (2017), accessed 27th May 2021, Available from: https://ceb.lk/.

CEB (2020) *Long Term Generation Expansion Plan 2020 – 2039 (Draft)*, Ceylon Electricity Board, Colombo, Pp 280. Available from: https://www.ceb.lk/front_img/img_reports/1591174971Revised_LTGEP_2020-2039.pdf (Accessed: 18 June 2020).

Cho, R. (2020). *COVID-19's Long-Term Effects on Climate Change—For Better or Worse*. State of the Plante, Columbia University. Available from: https://blogs.ei.columbia.edu/2020/06/25/covid-19-impacts-climate-change/ (Accessed: 12 July 2020).

Climate Change Secretariat (2016). *National Adaptation Plan for Climate Change Impacts in Sri Lanka 2016 – 2025*, Ministry of Mahaweli Development and Environment, Colombo, Pp. 178. Available from: https://www4.unfccc.int/sites/NAPC/Documents%20NAP/National%20Reports/National%20Adaptation%20Plan%20of%20Sri%20Lanka.pdf (Accessed: 18 June 2020).

Council of Economic Advisers (2017) *Economic report of the President*. Council of Economic Advisers, White House, Washington, DC, Pp. 423-484.

Crist, M. (2020). *What the Coronavirus Means for Climate Change*, The New York Times, New York. Available from: https://www.nytimes.com/2020/03/27/opinion/sunday/coronavirus-climate-change.html (Accessed: 18 June 2020).

Di Marco, M., Baker, M.L., Daszak, P., De Barro, P., Eskew, E.A., Godde, C.M., Harwood, T.D., Herrero, M., Hoskins, A.J., Johnson, E. and Karesh, W.B. (2020). Opinion: Sustainable development must account for pandemic risk. *Proceedings of the National Academy of Sciences*, 117(8): 3888-3892. Available from: https://www.pnas.org/content/117/8/3888 (Accessed: 18 June 2020).

Dudley, B. (2015). *BP statistical review of world energy 2016*. BP p.l.c. London, Pp: 48. Available from http://oilproduction.net/files/especial-BP/bp-statistical-review-of-world-energy-2016-full-report.pdf (Accessed: 18 June 2020).

Elkerbout, M., Egenhofer, C., Ferrer, J.N., Catuti, M., Kustova, I. and Rizos, V. (2020). *The European Green Deal after Corona: Implications for EU climate policy*. Centre for European Policy Studies, Pp: 12. Available from: https://www.ceps.eu/ceps-publications/the-european-green-deal-after-corona/ (Accessed: 18 June 2020).

English, J. (2020). *Why your reduced carbon footprint from lockdown won't slow climate change*, CBC News, Toronto. Available from: https://www.cbc.ca/news/technology/pandemic-climate-change-covid-emissions-1.5579232 (Accessed: 14 July 2020).

Finance & Development (2020). *Six prominent thinkers reflect on how the pandemic has changed the world*. International Monetary Fund. Available from: https://www.imf.org/external/pubs/ft/fandd/2020/06/how-will-the-world-be-different-after-COVID-19.htm (Accessed: 15 July 2020).

Flor Cruz, J.A. (2013). *Living with Beijing's "air-pocalypse."*. CNN. Available from: https://edition.cnn.com/2013/01/19/world/asia/china-florcruz-pollution/index.html (Accessed: 5 July 2020).

Fox-Skelly, J. (2017). *There are diseases hidden in ice, and they are waking up*. BBC Earth, London. Available from: http://www.bbc.com/earth/story/20170504-there-are-diseases-hidden-in-ice-and-they-are-waking-up (Accessed: 18 June 2020).

Froggatt, A. (2013). The climate and energy security implications of coal demand and supply in Asia and Europe. *Asia Europe Journal*, 11(3): 285-303.

Fujimori, S., Hasegawa, T., Krey, V., Riahi, K., Bertram, C., Bodirsky, B.L., Bosetti, V., Callen, J., Després, J., Doelman, J. and Drouet, L. (2019). A multi-model assessment of food security implications of climate change mitigation. *Nature Sustainability* 2(5): 386-396.

Gardiner, B. (2020). *Why COVID - 19 will end up Harming the Environment*. National Geographic, Washington. Available from: https://www.nationalgeographic.com/science/2020/06/why-covid-19-will-end-up-harming-the-environment/ (Accessed: 11 July 2020).

Ghosh, S. (2010). Examining carbon emissions economic growth nexus for India: a multivariate cointegration approach. *Energy Policy* 38(6): 3008-3014.

Gopinath, G. (2020). The great lockdown: Worst economic downturn since the Great Depression. *IMFBlog–Insights & analysis on economics & finance*. Available from : https://blogs.imf.org/2020/04/14/the-great-lockdown-worst-economic-downturn-since-the-great-depression/ (Accessed: 11 July 2020).

Gotabaya, R. (2020) 18 January. Available from: https://twitter.com/gotabayar/status/1218542522215124993?lang=en (Accessed: 15 July 2020).

Gudi, S.K. and Tiwari, K.K. (2020). Preparedness and lessons learned from the novel coronavirus disease. *International Journal of Occupational and Environmental Medicine* 11: 108-112.

Harvey, F. (2020). *'Surprisingly rapid' rebound in carbon emissions post-lockdown*. The Guardian, London. Available from: https://www.theguardian.com/environment/2020/jun/11/carbon-emissions-in-surprisingly-rapid-surge-post-lockdown (Accessed: 12 July 2020).

Harvey, F. and Rankin, J. (2020). What is the European Green Deal and will it really cost €1tn?, The Guardian, London. Available from: https://www.theguardian.com/world/2020/mar/09/what-is-the-european-green-deal-and-will-it-really-cost-1tn (Accessed: 18 June 2020).

Henriques, M. (2020). Will Covid-19 have a lasting impact on the environment?, BBC News, London. Available from: https://www.bbc.com/future/article/20200326-covid-19-the-impact-of-coronavirus-on-the-environment (Accessed: 11 July 2020).

Hernandez, M. (2020). *This is the effect coronavirus has had on air pollution all across the world*, World Economic Forum. Available from: https://www.weforum.org/agenda/2020/04/coronavirus-covid19-air-pollution-enviroment-nature-lockdown (Accessed: 18 June 2020).

Hewawasam, V. and Matsui, K. (2019). Historical development of climate change policies and the Climate Change Secretariat in Sri Lanka. *Environmental Science & Policy*, 101: 255-261.

IEA (2019). *Press Release: Asia is set to support global coal demand for the next five years,* International Energy Agency, Paris. Available from: https://www.iea.org/news/asia-is-set-to-support-global-coal-demand-for-the-next-five-years (Accessed: 5 July 2020).

Jacobson, M.Z., Delucchi, M.A., Bauer, Z.A., Goodman, S.C., Chapman, W.E., Cameron, M.A., Bozonnat, C., Chobadi, L., Clonts, H.A., Enevoldsen, P. and Erwin, J.R. (2017). 100% Clean and Renewable Wind, Water, and Sunlight all-sector Energy Roadmaps for 139 countries of the World. *Joule*, 1(1):108-121.

Jiang, S. and Karimi, F. (2013). *Beijing adopts emergency measures for 'hazardous' pollution,* CNN. Available from: https://edition.cnn.com/2013/01/14/world/asia/china-smog-blanket/index.html (Accessed: 5 July 2020).

Jones, K.E., Patel, N.G., Levy, M.A., Storeygard, A., Balk, D., Gittleman, J.L. and Daszak, P., (2008). Global trends in emerging infectious diseases. *Nature*, 451(7181): 990-993.

Le Quéré, C., Jackson, R., Jones, M., Smith, A., Abernethy, S., Andrew, R., De-Gol, A., Shan, Y., Canadell, J., Friedlingstein, P., Creutzig, F., and Peters, G. (2020). Supplementary data to: Le Quéré et al (2020), *Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement (Version 1.0),* Global Carbon Project. https://doi.org/10.18160/RQDW-BTJU. (Accessed: 18 June 2020).

Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernethy, S., Andrew, R.M., De -Gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G., Friedlingstein, P., Creutzig, F. and Peters, G.P. (2020). Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. *Nature Climate Change*: 10: 647-653. DOI https://doi.org/10.1038/s41558-020-0797-x.

McGlade, C. and Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2°C. *Nature* 517(7533): 187-190. DOI https://doi.org/10.1038/nature14016.

McGrath, M., (2020). *Coronavirus: Air pollution and CO2 fall rapidly as virus spreads*. BBC News, London. Available from: https://www.bbc.com/news/science-environment-51944780 (Accessed 12 July 2020).

Mehmood, M.F. and Kanwal, A. (2017). Energy consumption, carbon emissions and economic growth in Pakistan: Dynamic causality analysis. *Renewable and Sustainable Energy Reviews* 72: 1233-1240.

Ministry of Mahaweli Development and Environment, (2015). *Intended Nationally Determined Contributions*, The Ministry of Mahaweli Development and Environment, Colombo. Available from: http://www.cansouthasia.net/pdf_files/INDC%20of%20Sri%20Lanka.pdf (Accessed: 19 June 2020).

Munawer, M.E. (2018). Human health and environmental impacts of coal combustion and post-combustion wastes. *Journal of Sustainable Mining*, 17(2):87-96.

NASA (2020). *Air-born Nitrogen Dioxide Plummets Over China*, NASA, Washington D.C. Available from: https://earthobservatory.nasa.gov/images/146362/airborne-nitrogen-dioxide-plummets-over-china (Accessed: 20 July 2020).

Nicolás, E.S. (2020). *Will coronavirus torpedo the Green Deal?*, EUobserver, Brussels. Available from: https://euobserver.com/coronavirus/147815 (Accessed: 18 June 2020).

Nii-Trebi, N.I., (2017). Emerging and neglected infectious diseases: insights, advances, and challenges. *BioMed research*

international 2017: 1-15. DOI https://doi.org/10.1155/2017/5245021.

Nordhaus, W.D. (2013*). The climate casino: Risk, uncertainty, and economics for a warming world.* Yale University Press, Connecticut, 392 Pp.

Obama, B. (2017). The irreversible momentum of clean energy. *Science* 355(6321): 126-129.

Planelles, M. (2020). *Pollution in Spain falls to record lows amid coronavirus lockdown*, El Pais, Madrid. Available from: https://english.elpais.com/society/2020-03-24/pollution-in-spain-falls-to-record-lows-under-coronavirus-lockdown.html (Accessed: 12 July 2020).

Pralle, S.B. (2009). Agenda-setting and climate change. *Environmental Politics* 18(5): 781-799.

Premasiri, H.D.S. (2020). *Absence of Vehicles on Road with Island Wide Curfew Has Improved the Air Quality in Urban Arears of Sri Lanka,* National Building Research Organisation, Colombo.

Pullin, A.S. and Knight, T.M. (2009). Doing more good than harm–Building an evidence-base for conservation and environmental management. *Biological Conservation* 142(5): 931-934.

Schlesinger, R.B. and Lippmann, M. (2020). Nitrogen oxides, In: M. Lippmann and G.D. Leikauf (Eds.), *Environmental toxicants: Human exposures and their health effects*. 4th edition. Jhon Wiley & Sons, New Jersey Pp. 721-781.

Shi, X., Chen, H., Yu, Y. and Wen, F., (2018). Development of variable renewable energy policy in developing countries: a case study of Sri Lanka. *International Journal of Public Policy*, 14(1/2): 10 – 29.

Speare-Cole, R. (2020). *Air pollution falls as UK goes into coronavirus lockdown*, The Evening Standard, London. Available from: https://www.standard.co.uk/news/uk/pollution-falling-uk-coronavirus-lockdown-a4396051.html (Accessed 12 July 2020).

Stern, N.H., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., Crane, D., Cruickshank, S., Dietz, S., Edmonson, N. and Garbett, S.L. (2006). *Stern Review: The economics of climate change*. Cambridge University Press.

Sumner, A., Hoy, C. & Ortiz-Juarez, E. (2020). *Estimates of the impact of COVID-19 on global poverty*: *WIDER Working Paper 2020/43*. UNU-WIDER: Helsinki. Available from: https://doi.org/10.35188/UNU-WIDER/2020/800-9 (Accessed: 18 June 2020).

The Copernicus Atmosphere Monitoring Program (2020). *Air quality information confirms reduced activity levels due to lockdown in Italy*. Available from: https://atmosphere.copernicus.eu/air-quality-information-confirms-reduced-activity-levels-due-lockdown-italy (Accessed: 12 July 2020).

The European Commission (2019), *The European Green Deal,* The European Commission, Brussels. Available from: https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf (Accessed: 18 June 2020).

United Nations Environment Programme and Bloomberg New Energy Finance (2011). *Global trends in renewable energy investment 2011*, Bloomberg New Energy Finance, p64. Available from: https://www.fs-unep-centre.org/wp-content/uploads/2019/11/Global_Trends_Report_2011.pdf (Accessed: 18 June 2020).

United States Agency for International Development (2015). *Greenhouse Gas Emissions in Sri Lanka,* USAID. Available from: https://www.climatelinks.org/sites/default/files/asset/document/Sri%20Lanka%20Fact%20Sheet%20-%20rev%2010%2012%2016_Final_0.pdf (Accessed: 18 June 2020).

Wang, Q. and Min, S. (2020). A preliminary assessment of the impact of COVID-19 on environment–A case study of China. *Science of the Total Environment*, 728 DOI 10.1016/j.scitotenv.2020.138915.

Watts, J. and Kommenda, N. (2020) *Coronavirus pandemic leading to huge drop in air pollution*, The Guardian, London. Available from: https://www.theguardian.com/environment/2020/mar/23/coronavirus-pandemic-leading-to-huge-drop-in-air-pollution (Accessed: 18 June 2020).

Edmond, C. (2020). *China's air pollution has overshot pre-pandemic levels as life begins to return to normal*, World Economic Forum. Available from: https://www.weforum.org/agenda/2020/07/pollution-co2-economy-china/ (Accessed: 12 July 2020).

World Economic Forum (2020). *The Global Risks Report: Ed. 14*, World Economic Forum. Available from: http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf (Accessed: 15 July 2020).

World Health Organisation (2020). *WHO Coronavirus Disease (COVID-19) Dashboard*. Available from: https://covid19.who.int/?gclid=Cj0KCQjwoaz3BRDnARIsAF1RfLfFjGa8yCzwHc2T-5pk1xHLjXDqlaanwhix01IfIojA0s7Qoyeftd0aAgcOEALw_wcB (Accessed: June 18 2020).

Zeyoudi, T., Bin A.A. and Al-Zu'bi, I. (2020). *A New Baseline for Greater Collective Action: The*

Impact of Covid-19 on our Environment and Climate Change, Ministry of Climate Change & Environment, United Arab Emirates. Available from: https://www.moccae.gov.ae/assets/download/61f813eb/A%20New%20Baseline%20for%20a%20Greater%20Collective%20Action%20-%20enhanced(7).pdf.aspx (Accessed 5 July 2020).

Zhang, Yue-Jun, and Ya-Bin Da. (2015). The decomposition of energy-related carbon emission and its decoupling with economic growth in China. *Renewable and Sustainable Energy Reviews* 41: 1255-1266.

NATIONAL SCIENCE FOUNDATION

Section 6

Society and Education

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Society and Education: Introduction

Siri Hettige and Kalinga Tudor Silva

Covid 19 pandemic that began in China at the beginning of 2020 by now has spread across the world affecting almost all countries to varying degrees. Its health and economic impacts have varied across countries, and some countries have been devastated by it. In the absence of vaccines against the virus at the beginning, public health and social distancing measures were expected to contain the pandemic and minimize its diverse impacts on societies. Effectiveness of such measures to contain the virus has been uneven and this is due to diverse circumstances within societies. As a result, some countries have shown greater resilience against the pandemic but many other countries have been far more vulnerable. There is no simple explanation for the above variations across societies. In fact, many economic, social, cultural, political and environmental factors have contributed to societal vulnerability or resilience in the face of the pandemic. In other words, societal resilience or vulnerability has been product of the cumulative effects of the above factors. As a result, a country can have a high level of societal resilience or a low level depending on the overall economic, social, cultural, political and environmental conditions that have emerged over decades. Some of the key ingredients that have led to the emergence of a high level of societal resilience are inclusive, balanced and sustainable development, developed social infrastructure, widely available, well developed social protection systems, social harmony and tolerance and even celebration of cultural and ethnic diversity, good governance and rule of law, national unity, environmental quality and protection and sustainable use of natural resources. Societies that have these conditions in general have been able to overcome the challenges posed by the pandemic more effectively.

Public health and other medical interventions have undeniably played a vital role in dealing with the pandemic. Yet, as indicated above, economic, social, cultural and political conditions under which people live have become equally important as the capabilities of countries and people to cope with the pandemic has been largely determined by these conditions. In fact, the level of vulnerability or resilience has varied across the world as the health, economic and other data has shown.

It is highly significant that several developed countries have been able to develop vaccines against the virus within a relatively short period of time. The countries concerned have had the scientific and research capabilities to do so. It is clear that these countries are among the ten countries that have the highest levels of Research & Development investment as a proportion of the GDP. As we all know, these countries have been able to vaccinate a large proportion of the local population by now. Today vaccination is considered the most effective way to prevent the people getting infected.

On the other hand, many poorer countries outside the developed world have not yet been able to secure enough vaccines to immunize a significant part of their populations. This situation makes these countries more vulnerable in terms of not only its impact on morbidity and mortality but also its adverse effects on the economy, society, inter-community relations and the well-being of diverse segments of society such as school children, the poor, the unemployed, the elderly and other marginalized groups.

As is well known, the impact of the pandemic on society has been wide ranging. It has disrupted normal human activities. Strict public health restrictions imposed on people by health and law enforcement authorities have not only disrupted or even impeded economic, social and cultural processes that facilitate collective life of people of all walks at all levels ranging from neighborhoods through diverse institutions to social and political movements.

Disruption of economic activities has a differential impact on diverse strata and segments of society. This is particularly so in less developed countries that are characterized by widespread income and other inequalities. The lack of adequate social security arrangements such as

unemployment insurance, pensions and income transfer programs make the lives of the members of the marginalized groups affected by the adverse economic and social effects of the pandemic. This situation is clearly evident in Sri Lanka today. Thousands of people who lost their jobs and income sources, particularly in urban areas seek income support and food aid from government and other sources.

Economic and social issues make vulnerable people less sensitive to public health guidelines that demand the public to comply with them. This makes it necessary for health authorities to make their public health messages to be more convincing, consistent and forceful in order to ensure public compliance. Meanwhile, law enforcement authorities continue to complain that many people do not strictly follow health guidelines.

In the pages that follow this brief introduction, we have included a number of papers dealing with several important aspects of the effects of the pandemic and how Sri Lanka has responded. The list of papers is not exhaustive, yet covers considerable ground in terms of persisting and emerging issues. These include problems and prospects of sustainable development and Human Development, the effects of the pandemic on intercommunity relations, the impact of the digital divide on equitable access to education at all levels, from primary to university.

As is the case with the rest of the world affected by the pandemic, Sri Lanka had no choice but adopt virtual mode of teaching and learning in all educational institutions. But the persisting digital divide in the country has been a major obstacle to provide universal access to internet based, virtually provided educational services to students scattered across the country. Many efforts have been made by authorities to ensure equitable access to all but a significant section of the children and youth from underprivileged backgrounds and remote rural and estate areas has remained marginalized. This is understandable. While the children and youth from more affluent socio-economic backgrounds have easy access to the internet and the necessary electronic devices necessary to participate in virtual education programs, children and youth from disadvantaged backgrounds, the experience of marginalized groups has been very different. This situation cannot be easily changed as its origins are structural, and it persuades the authorities to explore alternative, more easily accessible means of providing educational services to all.

Closing down of universities for an indefinite period during the pandemic initially disrupted the educational calendar leading to various problems for undergraduates. When the universities began on-line educational programmes in place of face to face teaching and other activities, students have come under considerable pressure due to increased workload, language issues, poor access to internet facilities, etc. A minority of university students who cannot access virtually provided instruction and assessment services has been left out but no easy solution can be found to address their problems.

However much virtual means of providing educational services reached the wider student population in the country, what should not be forgotten is that education is not just class room teaching and dissemination of educational content to students but a much wider social and cultural process that enable children and youth to interact with peers and engage in many extra-curricular activities outside formal class room teaching and learning that includes secondary socialization outside their homes. So, the ideal situation is to have a covid19 free environment where children and youth can once again take part in their normal educational activities in their respective institutional settings.

In this section entitled 'Impact of Covid19 Pandemic on Society and the Education Process, we have a number of empirically based research papers dealing with different aspects of the overall theme but, for want of space, no attempt is made to introduce them individually in the context of this brief introduction. These papers are written by experienced and competent researchers and academics who are well versed with their respective areas of research. I am sure that the readers will find their work presented here are informative and enlightening.

I. Society

COVID-19 pandemic and its impact on the sustainable development goals driven development agenda: The case of Sri Lanka

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ABSTRACT

Covid19 pandemic that unexpectedly emerged in China in early 2020 rapidly engulfed the whole within a short period of time, disrupting the global economic order and affecting the personal, social and cultural lives of the people almost everywhere. This happened at a time when the global leaders and multilateral institutions were focused on the need to mobilize the countries across the world to address the pressing issues of Sustainable Development, climate change and considerable deficits in human development in many developing countries. The newly emerged, urgent need to address and contain the pandemic compelled the countries and their leaders to concentrate on the new challenge. Yet, the achievement of SDG's and addressing the issue of climate change remain as important and urgent as ever, particularly because the pandemic has made it more difficult to achieve these targets for many countries including Sri Lanka. In this paper, we examine this issue in the light of Sri Lanka's experience in regard to SDG's and Human Development and highlight the need to simultaneously concentrate on these areas because this is necessary to prepare the country to face and overcome future economic, health, social, cultural and environmental challenges. In other words, sustainable development has become even more important today as a policy framework for economic and social planning in the country.

Key words: COVID-19, Pandemic, Sustainable development goals, Sri Lanka, Poverty

1. INTRODUCTION

Covid-19 pandemic within a space of less than two years has reached all parts of the world causing major disruption to social life and breakdown of economies. The exponential growth of the infection seen worldwide initially is beginning to level in some countries in the Global North the situation in the Global South either remains unchanged or becoming worse. While the pandemic as a public health emergency is the immediate concern its far reaching and destructive impact on the economy is proving to be a major worry for politicians and policy makers in the long-term. Unlike a typical disaster where there is a clearly identifiable end COVID-19 is expected to remain for a longer period of time compelling countries to adopt measures that will fundamentally change social life which in turn will have transformative impact on economic activities and livelihoods.

According to the International Monetary Fund (IMF) COVID-19 caused the worst recession since the Great Depression. The global economy contracted sharply in 2020, by 3.5% according to the latest estimates by IMF (World bank, B021). Though IMF initially

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projected that the global economic growth would return to annual average of 5.8 in 2021 there will be variations between regions and countries with some countries, especially those in Sub Saharan Africa, Latin America and Emerging and Developing Asia, performing below the global average. Similarly, the impact of the pandemic on social life is also not expected to be uniform with the poor, women and other disadvantaged groups taking the brunt of the adverse impact of the pandemic. These developments raise many issues with regard to Sustainable Development Goals in countries in the Global South are the worst affected by the pandemic in economic terms.

As a result of its adverse impact on economic activities and general disruption in the social life the pandemic is expected to have far reaching negative impacts on many areas that are covered by UN Sustainable Development Goals Agenda. According to estimates of the United Nations Development Programme (UNDP) the number of people living in extreme poverty is projected to increase by 40-60 million and the number of undernourished people by 14–80 million by 2021 (UNDP, 2020). Another study by Frederick Pardee Centre for International Futures makes a similar yet higher prediction claiming that 50 to 100 million people will be in acute poverty in the same year[1]. ILO on the other hand estimates that up to 400 million full-time jobs lost and another 340 million at risk of being lost by the end of 2020 (ILO-ACTRAV, 2021). The expected fall of the Human Development Index this year, the first such fall since the measurements began in 1990, (UNDP, 2020) is another indicator of the impact of pandemic on society. The emerging scenario therefore indicates to a rough road for the SDG Decade of Action and will act as a major stumbling block on the road to realization of SDGs by 2030 as planned. It is in this context that we need to understand Sri Lanka's drive to achieve the Goals set out in Agenda 2030 the SGD Decade of Action.

The attempt of the authors is to understand the impact of COVID-19 pandemic on Sri Lanka's progress towards Sustainable Development Goals (SDG) 2030. Data for the study come primarily from records of UNDP, ILO and other official sources both local and national and from the Sustainable Development Report[2].

1.1. The Impact of COVID-19 Pandemic on Sustainable Development Goals

COVID-19 pandemic not only triggered an economic crisis of unprecedented proportions in the recent history but also forced countries to adjust to new realities and accept ways that have far reaching consequences on every aspects of social life. These range from restrictions on travel and changes in work patterns to flow of goods and services, especially delivery of such essential services like education[3] and healthcare among others. Lockdowns and travel restrictions required to contain the spread of the virus, have far reaching impact on range of economic activities, from industrial production to tourism and delivery of services such as education and health to mention a few. The worst affected by these developments are the poor and other vulnerable groups, especially women, youth, low-wage workers (Shulla et al., 2021). While no country is spared from the above negative economic and social impact of the pandemic developing countries are the most affected for their built-in vulnerabilities of which two are arguably the most crucial. They on the one hand depend heavily on external support in the form of favourable trade terms, credit facilities and direct donations from the rich nations who themselves are affected. On the other due to the worsening crisis in their home countries they today need above external support more than ever.

1 https://www.du.edu/news/pardee-center-analyzes-impact-covid-19-global-development

2 A joint annual publication by Bertelsmann Stiftung, Sustainable Development Network and the Cambridge University Press

3 According to UNESCO digitalized education is impacting over 1.2 billion learners in over 170 countries (72% of all learners) during the initial lockdown

The economic crises caused by COVID-19 pandemic is expected have a long-term on the realization of SDGs through increasing levels of poverty in all countries. According to analysts the pandemic has reversed the downward trend in global poverty for the first time in a generation and is projected to push more than 100 million people into extreme poverty (Lackner et al., 2021) the impact of which will be heavily felt in Sub Saharan Africa and South Asia (World Bank, 2021). The increase in poverty is closely linked to the economic downturn driven by COVID-19 mobility restrictions that have direct and immediate negative consequences on economic activities that lead to lay-offs, pay cuts and other outcomes that affect livelihood activities and household income. That in turn has far reaching impact on general well-being of individuals and their right to have access to life needs realized, the call on which the Sustainable Goals Agenda 2030 is founded. The inevitable link between COVID-19 with poverty therefore makes it logical to analyse changes in poverty and related areas to assess the impact of COVID-19 pandemic on Sustainable Development Goals.

1.2. The Current Situation of Sustainable Development Goals and the Impact of COVID-19 Pandemic

According to the Annual Assessment of Sustainable Development Goals Agenda no country is on track towards achieving all SDGs even prior to the onset of COVID-19 pandemic (Bertelsmann Stiftung, 2020). A large majority of countries in the Global South, especially those in Sub Saharan Africa and low-income countries in Asia, Latina America and Oceania, experience a range of problems in realizing them by 2030. Even the regions that are economically better off and politically stable such as OECD Bloc and the Western Europe, still have some distance to go if they are to achieve full success by 2030. According to UNDP the United States has seven goals with major challenges and the United Kingdom five major challenges to overcome, meaning that neither of these two countries will be able to reach the required levels of success to realize SDGs by 2030.

Many high-income countries are not making progress on issues related to responsible consumption and production (SDG 12) and with regard to Goal 14 (Life Below Water). On the other hand, low-income countries tend to have lower SDG Index scores overall in all areas for which lack of resources, i.e., adequate funding, are contributory among others like political culture, governance issues and even cultural constraints[4]. SDGs that concern with basic survival needs like elimination of extreme poverty (SDG 1) and zero hunger (SDG 2) and life needs like education (SDG 4) and water and sanitation, Gender Equality (SDG 6) are major challenges in low-income countries. In spite of these challenges, they have made notable progress towards ending extreme poverty, undernourishment, access to health and education services, and access to basic infrastructure (Bertelsmann Stiftung, 2020, Bertelsmann Stiftung, 2021). Still there are achievement gaps in many areas in these countries, for example, in achieving SDG 1 No Poverty and SDG 2 No Hunger. Among the countries that have experienced sharpest reversals are the ones that are experiencing conflicts and political instability (Bertelsmann Stiftung, 2021).

COVID-19 pandemic has impacted Sustainable Development Goals in all countries though the level and the degree of impact varies from country to country. In some countries it has slowed the progress while in some others progresses have been reversed. The worst negative impact is in Sub Saharan Africa region that shows a downward trend. In Western Europe, Eastern Europe and Central Asia, and Middle East and North African region growth has slowed. In East and South Asia and in Latina America and the Caribbean the results are mixed (Bertelsmann Stiftung, 2020; Bertelsmann Stiftung, 2021).

Impact of the pandemic is not only global in geographical extent but also comprehensive

4 For example, traditions, cultural values and religious beliefs are constraints to progress of Gender Equality, in general and in Education (opposition to participation of girls in education) in particular, in many countries in the Arab World and in Asia.

with all key focus areas, namely, economic, social and environmental getting affected. Poverty is one of the biggest impact areas and the projected decline of extreme poverty to 6% by 2030 from 8.6% in pre-pandemic 2019 is not expected to happen now (Bertelsmann Stiftung, 2021). Decline in physical health, caused by the virus itself has direct impact on the health situation and deaths unprecedented in modern times is resulted in lowering life expectancy. Further, analysts are worried about psychological impact of the pandemic with social and psychological issues increasing as a result of lockdowns and other forms of controls of human mobility restricting social interaction. These all are expected to slow down the progress of SDG 3 good health and well-being. Though the impact on agriculture is not as big as in other sectors, due to the nature of agricultural activities, as they are low density population areas that do not require strict controls restricting production activities, the sector is also experience disruption in production and that will lead to increased food security affecting SDG 2 zero hunger in poor countries (Bertelsmann Stiftung, 2021).

Quality Education (SDG 4) is another Goal that has felt the brunt of COVID-19. School closures are depriving children's right to education but also opportunity for social interaction. The short-term impact of school Socio-psychological impact on children who are forced to remain indoors isolated from their peers is a major concern. Online education is not an alternative, at least as yet, because access to online education mode is still a problem for the poor, especially those from low-income countries. Further, social life of children, i.e., peer interaction which is an essential ingredient of education is not part of the online mode. School disruption and the loss of school days negatively impacting on quality of education will have negative impact on productivity.

The tightly interlinked nature of Sustainable Development Goals means that any impact on one Goal invariably will have impact on one or more other Goals. For example, an adverse impact on Zero Poverty SDG 1 will have impact on several other connected Goals such as Zero Hunger (Goal 2) and Good Health and Well-Being (SDG 4) among others. Therefore, the impact needs to be understood in terms of this integrated nature of the Goals too.

1.3. Progress of Sustainable Development Goals in Sri Lanka

Sri Lanka with an SDG Index score of 64.6 is in 87th position in 2021 which is a substantial improvement compared to the previous year and also the best country rank for four years. In the East Asia and South region, the country is ranked 8th and first in South Asia with Nepal a distance second with 62.8 score. Sri Lanka has done reasonably well in reaching some SDGs, for instance those connected with poverty, hunger, education and gender equality. Sri Lanka's public investments in health, particularly in primary healthcare and universal free education, as well as progressive social legislation in such areas like education, land rights and social protection, has led to steady improvements in its human development. The country is on target to reach two SDGs, name, No Poverty (SDG 1) and Climate Action (SDG 13) and faces major challenges in seven Goals and in one Goal the country is regressing (SDG 15).

Sri Lanka though a Middle-Income Country the above success on par with counties of higher income categories is not surprising. It also has a better HDI Index compared to other countries in the South Asian region and done well in all other measures of development. The country has not only maintained a good Human Development Index throughout but also has improved it further in recent years. Though no one can dispute that recent policies and programmes have also been instrumental in the positive picture of the country both in HDI and SDGs the main causes for the successes are rooted in the welfare policies adopted by successive Sri Lankan governments since the 1940s in areas such as education, health, land rights, social protection for formally employed persons in the State and private sectors, etc. Therefore, it can be argued that Sri Lanka has had a head start with respect

to both Millennium Development Goals and its successor Sustainable Development Goals.

According to Sustainable Report of 2021 the overall outlook of Sustainable Goals in Sri Lanka is mixed. Three Goals, namely, No Poverty (SDG 1) Quality of Education (SDG 4) and Climate Action (SDG 13) on target to achieve goals by 2030. Of them Quality Education (SDG 4) and Climate Action (SDG 13) have achieved the level required for 2021. However, the country is facing challenges in fully realizing the Goals by 2030 with 10 of the 17 Goals facing major challenges and 4 facing significant challenges (Bertelsmann Stiftung 2021).

In comparison the overall situation prior to COVID-19 pandemic, in 2019 there were only 7 major challenges. Most importantly in 2019 there were five Goals on target to achieve SDG to three 2021. I addition in 2021 one goal was decreasing. These clearly shows that pandemic has had significant impact on Sri Lanka's Sustainable Development Goals.

1.4. COVID-19 Pandemic and its Impact on Sri Lanka

Sri Lanka responded swiftly and quite successfully to the first wave of the COVID-19 outbreak. By mid-May the government declared that the virus was fully under control and lifted the control measures allowing the country to return to normal operations but under strict guidelines. The postponed General Elections to the Parliament was held in early August and there was air of confidence among the public and the feeling in general was that the worst was over. However, things began to change in early October with the discovery pf several cases at a garment factory close to Colombo. New cases started to appear regularly but slowly in other part of the country first in the Colombo District but by early January of 2021 it became common for new cases to come from all parts of the country. However, things appear to be under control until there was a sudden spike in numbers after the country's New Year celebrations. In no time cases reported jumped over 1000 a day and deaths crossed double digits. When daily cases reported started to rise and reached the 2000 mark and deaths reaching double digits the government had no other alternative and imposed strict controls again in mid-May. However, controls are not as strong/strict as during the first wave. Currently daily cases are around 3000 and deaths over 100.

The government's economic response to COVID-19 in 2020 focused primarily on addressing macro-economic issues which relied on monetary easing and credit creation to support the economy (ADB 2021). It expected to extend a temporary lifeline to economy that it assumed will also address some social issues created by the pandemic, mainly, large scale lay-offs that would lead to unemployment and increase of poverty. In addition, there were also measures to support the vulnerable segments of society, namely the poor who were already on social welfare by offering a temporary allowance of LKR 5,000 which to those who are registered under Samurdhi Programme and welfare support programmes (ADB 2021). Other than this temporary measure there are no other long-term policy and programme of action to address the human dimension of the pandemic. While these addresses the challenges faced by SDGs under pandemic indirectly there are no concerted action on the part of Sri Lanka government, neither at policy level nor at programme level.

Post COVID-19 South Asian economies experienced declines in their growth with an average decline of -6.7 (Bertelsmann stiftung 2021) except for Bangladesh and Nepal that posted marginal growths of 2% and 0.2% respectively. Maldives was the biggest loser. Sri Lanka too experienced a negative growth (-3.6) behind India (-9.6) and Maldives (-21.5) the biggest losers in the region.

Sri Lanka Gross Domestic Product recorded a negative growth in 2020 but is expected to recover modestly in 2021 and continue into 2022 with even slower rate (Bertelsmann Stiftung, 2021). The decline in sectoral GDP varies with the industry sector the most affected. The decline could

be attributed to export contraction, factory closures, constrained mobility and reduced tourist arrivals due to the pandemic (ADB 2021). Contraction was highest at 6.9%, in industry with construction falling by 13.2% and manufacturing by 3.9% (ADB 2021). In services decline in accommodation and restaurants was staggering 39.4% but the effect overall was mitigated by growth in other services, especially telecommunication which rose by 15.4%. Agriculture also contracted but only by 2.4% as the decline of growth in fisheries and commercial crops, namely, tea, coconut and rubber were compensated by rise in the production of cereals, rice, spices, and other minor crops (ADB 2021).

Analysts agree that tourism and apparel sectors to be the most affected by COVID-19 pandemic followed by transportation and construction (KMPG, 2020; Hada-Zevros, 2020). Even though it was expected that overseas remittance to be affected considering the large number of contract workers in the Middle East and Gulf Countries it appears that impact will be less severe than the early estimates, but the situation is not clear (EconomyNext, 2020). However, the travel and tourism sector, the third largest foreign exchange earner behind foreign remittances and apparel industry for the country, that contributed 11.0% of employment in 2019 and 10.6% of GDP[5], came to a complete standstill in 2020 and continues even today in spite of several attempts by the government to revive it[6].

Compared to the industry and service sectors, Sri Lanka's agriculture has so far been the least affected by COVID-19 outbreak, as the sector is only loosely integrated with global supply chains according to market observers. This is only partly true as international supply chains affect only export agriculture, tea and rubber mainly. Tea being a major export item of the country any impact on its international supply chain will be detrimental to the economy. It has not happened. The effect of the pandemic on the agricultural sector in the domestic market is still comparable to that in other countries in the region. The restrictions of travel and transport are affecting local supply chains and wholesale market operations are near collapse. The ultimate victims of the situation is the farmers who depend both small-time collectors and big market operators, both wholesale markets and big-time collectors like supermarket chains to sell their produce. An estimated 2.1 million agricultural households are at a risk of losing their livelihoods despite various measures taken by the government to safeguard agricultural supply chains. Though the lockdown exempted farming operations and food supply chains from the beginning, implementation problems caused severe labour shortages and price collapse in wholesale markets[7].

Pandemic has caused redefining of norms of social interaction, for example social distancing, has far reaching consequences on labour intensive industries that are a feature of the production process in low-income countries in the Global South. They are also one of their main sources of foreign exchange. One example is Sri Lanka's apparel industry where production facilities and living arrangements are challenging to social distancing norms and tea plantations where living arrangements compel workers' families to disregard the same. The cost of social distancing is very high on the economy not only because of its negative impact on production but also adverse impact on household income and livelihood. Similarly, restrictions on movement of people within and across countries both as labour migration and tourism has far reaching repercussions not only on foreign exchange earnings but

5 The World Travel and Tourism Council (WTTC), estimates the direct contribution of travel and tourism to the country's GDP to grow by 5.7% per year between 2018 and 2028 to LKR1.26trn ($7.9bn), 5.7% of GDP in 2028 (Oxford Business Group 2019).

6 Sri Lanka received 1, 913,702 tourists in 2019 but only 507,704 in 2020. That is also except 393 in December were the arrivals in the first three months of 2020. Travel bubble was a failure and the continual closure of the Airport, compelled by the steep increase of infections after October 2020 means that the government has few options in this regard.

7 https://www.netherlandsandyou.nl/latest-news/news/2020/06/02/impact-of-covid19-on-food-supply-chains-in-sri-lanka

also on unemployment levels and livelihoods. Their human consequences, namely, loss of jobs and livelihood opportunities and resulting disruption of education of children, therefore have long-term impact on well-being of citizens. Rising levels of unemployment, deteriorating living standards and declining household income resulting from weakening economy in turn invariably become a major cause of social unrest.

In Sri Lanka, as in other countries, the loss of jobs and incomes incurred by the pandemic has been severe. Negative impact of the pandemic on economic activities resulted in cost cutting measures that included lay-offs and other measures to cut down losses in the formal sector adding to both unemployment and underemployment. According to a Labour Department survey done in May 2020 64% of employees in the surveyed establishments were not in work with manufacturing and service sector the most affected with over 50% of establishments in these sectors having to close shop and the majority of the rest operating under capacity (Wimalaweera, 2020). In informal sector too there were similar losses as many operations were depend on the formal sector, for example tourist industry that supported large number of people who depended on indirect employment it created. The inevitable result of these were increasing poverty. It not only added to the traditional poor, i.e., low-income groups who are semi-skilled or unskilled but also created a new poor, namely, middle class skilled workers and, even professionals. However, while workers in almost every sector have been affected, informal workers who make up about 70 percent of the workforce, and especially those in the industries and low-end services such as trade, have been the most affected. The apparel industry, which employs about half a million workers, has been forced to cut a significant number of jobs. So is the situation of the tourism sector (Hadad-Zevros, 2020) that contributes over 10% to the GDP of the country and a source of indirect employment a large number of people in the informal sector indirectly.

2. CONCLUSION

COVID-19 pandemic has made significant impact not only on the economy of the country but also on social life of its people. There should not be any doubt that these would in turn to have the above negative impacts translate into slow down in the economy and the resultant negative impact on employment and the job market directly affect poverty levels of the country. That in turn has spill-over effects on several other areas of service provisions and access to services resulting them having making an impact on Sustainable Development Goals.

Still Sri Lanka was not on the way to realize Sustainable Development Goals even before COVID-19 pandemic. Except in Quality Education (SDG 4) in all other Goals the country was facing challenges of which majority were major challenges (Bertelsmann Stifftung, 2020). COVID-19 only aggravated the situation further by slowing the progress. The economic downturn prompted by the pandemic has resulted in a financial crisis at the macro level impacting upon the government to stand by its commitment to Sustainable Development Goals. It also has made impact on the household level by reducing the household's ability to afford services that will in turn affect the progress of the Goals. But on the questions how much impact there will be and how long the impact will last there is no agreement among analysts though there is expectation that Sri Lanka will recover in the long-term (Bertelsmann Stiftung, 2020).

Sri Lanka economy was on a slow growth phase even before the onset of COVID-19 pandemic. After a relatively high rate of growth in the 2010 to 2012 period economy started slow down to below 6 percent growth and remain fluctuating between 4% and 2% with a low -3.6 % in 2020 (pandemic effect). Even with the slowing rate of growth progress of Sustainable Development Goals of the country has been not only steady but was at a relatively better rate than some countries with better growth rates, for example India. Of the countries in the South Asian region only Bangladesh which

was enjoying a much better growth rate than Sri Lanka was doing better. The fact that the country was doing better than countries whose economies growing faster means that Sri Lanka's progress in Sustainable development goals is helped by factor other than economic growth of the economy.

Sri Lanka has been constantly performing in the Human Development Index on par with countries that are economically advanced. Country's scores are high in many indicators, especially, life expectancy and average years of schooling. The common denominator for Sri Lanka's success in both Human Development Index and Sustainable Development Goals arguably is the welfare state Sri Lanka has been since the independence. Not only education and healthcare are completely free but also there are other welfare measures built into them. Free education also includes free textbooks and free uniforms. School students are given concessionary travel facilities on the public transport system and the Ministry of Education has a school nutrition programme supported by state funds and donor support. Health service, in addition to free hospital care also includes nutritional support for pregnant women and mothers with babies. Free education and free healthcare are supported by all political parties. Free education guarantees that students complete their 14 years of mandatory schooling (SDG 4) and free health service help maintain healthy citizenry as demonstrated by high life expectancy on par with advanced economies and health indicators (malnutrition, mortality etc.) far above countries with similar income levels. The priority given to welfare services by successive governments is demonstrated by the fact that even during the civil war welfare expenditure growing even more than defence expenditure[8].

Social welfare is the sacred cow of Sri Lankan politics and no political party dares to touch it. What is important is that social welfare works as a cushion during periods economy is doing badly by preventing economic hardships hitting the people. Sri Lanka's long tradition of social support system, especially, free education and free health service has helped the country to achieve high levels of human development which is reflected in its Sustainable Development Goals too. will work to cushion out the negative impact of the pandemic in many areas. They have had direct and positive impact on the Goals dealing with poverty, hunger, education, health and well-being and sustainable cities and communities. The future progress of Sustainable Development Goals in the country needs to be seen in the context of the welfare system that almost entirely depends on state funds.

The impact of the COVID-19 pandemic on the economy of the country is hard and extensive and adds to the financial crisis the country is already in. Even before the onset of the pandemic Sri Lanka's foreign reserves were at critical levels and the country was in a brink of a debt crisis and its credit ratings were continuously being downgraded by international credit agencies. Impact of the pandemic on countries foreign earnings which depends on a very limited number of sources, namely, apparel industry, workers remittance, tourism and tea are expected to go down further aggravating the situation. Slowing down of the economy also will mean less tax revenues for the state[9]. The drying out of funds, both external and internal, will have serious repercussions on Sustainable Development Goals from two directions. First, it will mean that the government will have limited funds to invest directly on Sustainable Development Goals. Second, it will also mean that the government will not be able to maintain the welfare state at the levels needed to maintain Sri Lanka's progress towards Sustainable Development Goals as it has done in the past. Both will have far reaching adverse impact on the future.

8 Even during the height of the civil war government's allocations for education and healthcare and other welfare expenditure grew even at a higher rate than defence expenditure according to Treasury Reports

9 Sri Lanka's tax revenue as a percentage of GDP is low around 11% at present (2019 data from Trading Economics). https://tradingeconomics.com/sri-lanka/tax-revenue-percent-of-gdp-wb-data.html

REFERENCES

ADB. (2021), Asian Development Outlook: Financing a Green and Inclusive Recovery, Maila: Asian Development Bank, https://www.adb.org/sites/default/files/publication/692111/ado2021.pdf, Accessed June 04, 2021

Bertelsmann Stiftung (2020). *Sustainable Development Report 2020, Sustainable Development Goals and COVID-19,* Cambridge: Bertelsmann Stiftung and Sustainable Development Solutions Network,

Bertelsmann Stiftung. (2021). *Sustainable Development Report 2021, The Decade of Action for the Sustainable Development Goals*, Cambridge: Bertelsmann Stiftung and Sustainable Development Solutions Network,

EconomyNext. (2020). *Sri Lanka worker remittances up 25-pct in July 2020,* https://economynext.com/sri-lanka-worker-remittances-up-25-pct-in-july-2020-74052/

Hadad-Zervos, F. (2020). Three *ways Sri Lanka can deal with COVID-19 induced poverty* https://blogs.worldbank.org/endpovertyinsouthasia/three-ways-sri-lanka-can-deal-covid-19-induced-poverty, October 21, 2020, Accessed 20-06-2021

ILO. (2021). the likely impact of COVID-19 on the achievement of SDG 8: a trade union opinion survey, Publication of ILO Bureau of Workers Activities (ILO-ACTRAV), https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---actrav/documents/publication/wcms_770036.pdf , Accessed May 18, 2021

Lakner, C., N. Yonzan, D. G. Mahler, R. A. Aguilar, and H. Wu. (2021). "Updated Estimates of the Impact of COVID-19 on Global Poverty: Looking Back at 2020 and the Outlook for 2021." *Data Blog*, January 5, 2021. https://blogs.worldbank.org/opendata.

KPMG. (2020). Impact *of COVID-19 on the Sri Lankan Economy. KPMG Deal Advisory,* Colombo: KPMG

Oxford Business Group. (2019). *Sri Lanka tourism named a top travel destination for 2019*, https://oxfordbusinessgroup.com/overview/time-shine-all-eyes-are-sri-lanka-world%E2%80%99s-top-destination-2019

Shulla, K. et. el. (2021). Effects of COVID-19 on the Sustainable Development Goals (SDGs), *Discover Sustainability,* 2:15, https://doi.org/10.1007/s43621-021-00026-x, Accessed June 10, 2021

UNDP. (2020). *COVID-19 and Human Development Perspectives: Assessing Crisis and Envisioning the Recovery, 2020, Human Development Perspectives,* New York: UNDP

Wimalaweera, A. (2020). *Covid 19 & Beyond- The impact on the Labour Market of Sri Lanka, Survey Report of the e-survey conducted on Private Sector Establishments* –May 2020, Colombo: Department of Labour, Sri Lanka

World Bank. (2021). *Global Economic Prospects, A World Bank Group Flagship Report,* Washington: World Bank

Risk communication and building trust: Lessons from COVID-19

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ABSTRACT

Pandemic control requires behavioural change. Voluntary participation in society-wide preventative mechanisms depends on trust in the state, which can be built via good public communication. In this paper, we map out some of the Sri Lankan government's communication efforts during COVID-19. We analyse televised dissemination of information through two major television channels. We focus primarily on television because it has extensive reach in Sri Lanka and address the time period from 1 February – 31 March 2020. We assess these televised communications through selected guidelines recommended by the World Health Organization in 2017. We surmise how effective the reach and inclusiveness of different communications methods might be. Finally, we discuss recommendations for dealing with future pandemics and similar emergencies.

Key words: COVID-19, Emergency communication, Epidemics, Risk communication, Trust

1. INTRODUCTION

Effective pandemic control requires the general public to change their behaviours to mitigate disease spread. COVID-19 control has necessitated preventative measures such as mask wearing, quarantines, and lockdowns. It is impractical to monitor every citizen to ensure that measures are being followed. To ensure effective adoption of these behaviours, citizens need to trust the government's recommendations so that they participate voluntarily, or at least do not sabotage them. The vitality of public trust in healthcare systems to effective pandemic response has long been noted (Siegrist & Zingg, 2014). An important mechanism for building trust is good risk communication with the public.

This paper studies some aspects of the risk communications of Sri Lanka's government during COVID-19. We review some existing literature on risk communication and trust building and outline several risk communications of the government. We then analyse televised communications through two most viewed television channels in Sri Lanka. We focus especially on television because of its broad reach within Sri Lanka. We focus on the time period from 1 February 2020 - 31 March 2020, which included the first significant increase in COVID-19 cases in Sri Lanka and the beginning of the first curfew period as declared by the government. We analyse these televised disseminations through a selection of guidelines from "Communicating risk in public health emergencies: A WHO guideline for emergency risk communication (ERC) policy and practice" (World Health Organization, 2017). Finally, we consider lessons for the next pandemic. It should be noted that this paper focuses on the "first wave" of COVID-19 in Sri

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Lanka, which may be considered roughly from January - May 2020. We do not touch on events since October 2020, which may be termed the "second wave" of the pandemic in Sri Lanka.

1.1. Background and Brief Literature Review

Trust involves 'a leap of faith,' in that it is not guaranteed that the trustee will deliver (McLeod, 2020). This is certainly the case during a novel epidemic, which is a situation that the trustee has never faced before, so there is always the possibility of failure. *Confidence* in the trustee's ability to deliver may be built however, through past demonstrated competence (Earle & Siegrist, 2006). In a pandemic, governments need to persuade citizens to take 'a leap of faith' in their ability to handle a new, dangerous situation and have confidence in the government's existing abilities. Otherwise, it may be harder to persuade citizens to cooperate with government recommendations.

People react to risk depending on how they perceive it and seek to verify their perceptions including through their own observations and prior experiences (Glik, 2007). People are more likely to act to mitigate risk if they believe that they are vulnerable to the risk, can take actions that will lower their vulnerability, and that the advantages of these actions exceed possible disadvantages (Glik, 2007). Several facets of risk communication can be identified. They include the actors (responsible persons or organizations), the purpose of communication (to prepare for, prevent, or mitigate risk), modes and channels of communication, messaging (including honestly acknowledging knowns and unknowns about the risk and tailoring the message to target groups) and good governance principles (including transparency and basing communications on scientific evidence) (OECD, 2016). The previously mentioned WHO guidelines are one of the key guidelines on risk communication in public health emergencies. They are based on a systematic review, directed by an expert group, of both published literature and grey literature by multiple organizations, including five languages and both quantitative and qualitative studies. We will return to the relevant guidelines later. Good risk communication, therefore, has many aspects, including selecting the relevant actors to deliver messages, dispatching messages through appropriate channels, and tailoring the message to achieve effectiveness. People also need to feel empowered to take actionable measures that can reduce risk.

1.2. Risk communication in Sri Lanka: Overview

The Health Promotion Bureau (HPB) of Sri Lanka has released a Risk Communication and Community Engagement (RCCE) Plan (HPB, 2020). This plan outlines some of the key personnel and institutions, such as the Epidemiology Unit and the Director General of Health Services, among others, and how these actors could coordinate with each other. Other actors within the framework were relevant stakeholders, local and district health authorities, and trusted influences. The plan also includes the kinds of messages to be disseminated (e.g. preventative measures, what a person should do if they have COVID-19 symptoms), and the kinds of communication channels that could be used (e.g. press conferences, social media). Rumour management was also addressed. The risk communication activities were also divided into phases. Phase 1 (no cases reported) and Phase 2 (sporadic cases reported) plans was completed on 25 January 2020, and the Phase 3 plan (cluster of cases and exit strategy) was completed on 25 February 2020.

Some risk communication activities undertaken in Sri Lanka include:

Websites: The website of the National Operations Centre for the Prevention of COVID-19 has news updates and YouTube links to press conferences (https://alt.army.lk/covid19/#). The HPB website has a COVID-19 dashboard with updated statistics (total case counts, daily case counts, etc.) (https://hpb.health.gov.lk/covid19-dashboard/).

Social Media: The HPB and Department of Government Information use Viber channels to provide COVID-19 updates[1].

Department of Government Information: Regular press releases on COVID-19, including information such as daily case counts, deaths, and curfew updates (https://www.dgi.gov.lk/news/press-releases-sri-lanka/covid-19-documents).

We now move on to the analysis of televised dissemination of information.

2. METHODOLOGY

Television has extensive reach in Sri Lanka and is consumed both offline (Verité Research, n.d.) and online (e.g., YouTube and Facebook).[2] The period chosen for the study is 1 February - 31 March 2020. This was the period where the number of reported COVID-19 patients in Sri Lanka began to increase noticeably, and marked the beginning of the first curfew period as declared by the government (the first COVID-19 positive case was reported in Sri Lanka on 27 January, a tourist from China ("First patient with coronavirus", 2020)). TV Derana and Independent Television Network (ITN) were chosen based on ownership and viewership. TV Derana has the largest audience share among Sri Lanka's privately-owned channels (Verité Research, n.d.). ITN has the largest audience share among the state-owned channels (Verité Research, n.d.). Accordingly, the TV Derana news telecast at 6.55PM and ITN news at 6.30PM were monitored daily on weekdays. These are the prime-time evening news segments of the two channels. These telecasts were in Sinhala language.[3]

2.1. Categories of government actors monitored

1. Politicians in the government (e.g., the President, Minister of Health).
2. Health officials (e.g., then Director General of Health Services (DGHS) Dr. Anil Jasinghe, Chief Epidemiologist Dr. Sudath Samaraweera, and Public Health Inspectors)
3. Police personnel (e.g., Deputy Inspector General (DIG) of Police Ajith Rohana)
4. Military officials (e.g., Commander of the Sri Lanka Army Lt. General Shavendra Silva, Director Media at Army Headquarters Brigadier Chandana Wickramasinghe)
5. Other (Any government official that speaks on COVID-19 not captured in categories 1-4. Eg. Secretary to the President)

The above were selected based on the frequency of their appearances assessed during a trial period (1-5 June 2020). The data reflects actors who, as per the title listed in the newsclip, are speaking in their capacity as an official working in a government institution.

2.2. Types of Government Messaging Monitored

Categories were chosen based on the aforementioned WHO guidelines. News entries that fell into these categories were selected. It is beyond the scope of this paper to study all the WHO recommendations. Therefore, we excerpted selected guidelines falling under the "Trust" and "Communicating Uncertainty" categories. The guidelines we chose are below:

1 See https://invite.viber.com/?g2=AQBfgwZSTjnrf0s%2BLxOWSueYJuni13CXJ0Kp5eiTKupc%2B%2FBsPTjjwqf3HHz6ZTgW&lang=en; https://invite.viber.com/?g2=AQAr73SDEIkx4kvUu991sclyDaHbh08ji%2F1M84l%2B%2Fi1Vjyozrj HtFMmwX%2FUOxmFZ&lang=en

2 For example, see ITN YouTube channel - https://www.youtube.com/channel/UCV66ictLH2DZehG1tH0G5KA and TV Derana Facebook page - https://www.facebook.com/adaderana

3 Quotes and paraphrasing of news items have been translated into English in this paper.

2.2.1. A1: Trust

To build trust, risk communication interventions should:

- link to functioning and accessible services
- be easy-to-understand
- acknowledge uncertainty
- link to self-efficacy

2.2.2. A2: Communicating Uncertainty

Communication by authorities to the public should

- indicate what is known and not known at a given time.

From this, we derived the following five categories, based on which entries were selected.

Category 1 – Captures Self-Efficacy, which is part of A1: Trust.

Objective of news - to encourage or instruct members of the public on what they can do to help prevent disease spread. Some of the instructions we looked for under this category included:

- Instructions on wearing masks
- Advice on washing hands regularly, and on maintaining 1 metre distance
- Instructions on safety measures when visiting a store
- Advice on what to do if someone displays symptoms or if they think they have contracted COVID-19
- Requesting people to limit movements and avoid gathering in groups
- Instructions to pregnant mothers on avoiding contracting the disease
- Instructions issued by the Department of Ayurveda
- Instructions on how weddings and private functions could be held in alignment with health guidelines
- Requesting people to avoid visiting clothing shops during the April festive season
- Details on who should be quarantined
- The importance of respecting curfew and health guidelines

Category 2 – Captures links to functioning and accessible services, which are part of A1: Trust.

Objective of news - to inform the public of the facilities and services that are available, unavailable or limited during the pandemic. Some of the instructions we looked for under this category included:

- Access to food and medicine
- Facilities available during quarantine
- Helpful contact numbers and websites
- Government/business services operating during curfew
- Availability of public transport
- Repatriation services
- Facilities to treat patients
- Relief given in the case of regulations that must be followed (e.g., expiration of vehicle revenue licenses, loan repayments)
- Access to curfew permits
- Access to government employees' salaries and the salaries, allowances and New Year overtime payments for plantation sector employees
- Transportation for people stranded in Colombo when curfew was imposed

Category 3 – Captures A2: Communicating Uncertainty

Objective of news - information the government knows with certainty that was communicated about the nature of the virus and its spread. The following topics of discussion were considered to belong to this category when selecting entries:

- How dangerous/not dangerous the virus or the pandemic situation is
- The characteristics of the virus and how it spreads

- What symptoms patients display
- The number of people who have contracted COVID-19
- The number of people entering the country from COVID-19 positive nations
- The number of people who have evaded quarantine

Category 4 – Captures A2: Communicating Uncertainty

Objective of news - what information the government communicated that it did not know with certainty about the nature of the virus and the nature of its spread. The following topics of discussion were considered to belong to this category when selecting entries:

- If the government is unsure of the number of people who might have COVID-19
- If the government is unsure about anything else related to the nature/spread of the virus.

Category 5 – Captures Easy to Understand, which is part of A1: Trust.

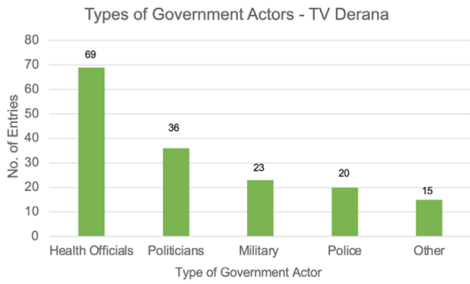
The information under this category is captured in Categories 1 and 3. This includes if the communicators provided easy to understand explanations when speaking about prevention methods or when explaining the nature of the virus, the spread, or on testing methods. Therefore, we chose to capture this in the summaries for the entries selected in Categories 1 and 3 whether the information was easy to understand or not.

2.3. Limitations

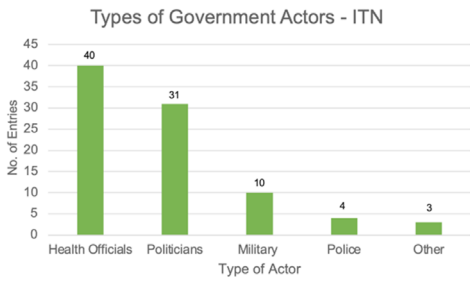
1. TV news: when analysing the messages telecast on news, we assumed that the message telecast on the news was how the actor actually stated it. We have not considered how different TV channels may have edited content and how it may affect the message given.
2. Categorisation: the categorisation of the message also at times depended on how a TV channel had edited the actual message. This meant that while some entries could be included in the database when viewed on one channel, they had to be rejected when viewed on another channel as it did not include the segment which made it possible to categorise it as a certain type. On some occasions, a message would have more than one topic. When categorising such entries, we either looked at which topic was focused on for a longer duration, or else, at what the underlying purpose of the communication was.
3. The choice of channels and telecasts meant that the study focused on Sinhala language communications and does not include Tamil language communications. This is a limitation of the scope of the study.

3. RESULTS

On many occasions both channels featured the same message delivered by a specific actor on a certain occasion. To avoid considering duplicate messages, we analysed message entries separately for each channel. Out of a total of 251 entries in our database that



(a)



(b)

Figure 1. Types of actors featured

fitted the selection criteria, 163 were from TV Derana while 88 were from ITN (Figure 1).

Health officials were the most featured group, followed by politicians, the military, and then the police.

The TV coverage on both channels predominantly featured then DGHS Dr. Anil Jasinghe amongst the health officials. His messages consisted of situational updates, outlining preventive measures, addressing misinformation, explaining the importance of the quarantine measures taken by the government, listing the facilities being made available for patient treatment and explaining how medications could be accessed during curfew.

Out of the government politicians, Minister of Health Pavithra Wanniarachchi was the most featured politician on both ITN and TV Derana. Communication from Minister Wanniarachchi included situational updates and urging the public to follow health guidelines. Minister of Trade Bandula Gunawardena was the most featured politician. All his messages were of the "links to accessible services" category, where he explained the availability of essential goods required by the public.

Of the military personnel, Army Commander Lieutenant General Shavendra Silva got the highest coverage in the two channels. Messages were related to quarantine centre facilities, the number of people at the facilities, and requesting the public to adhere to quarantine and health guidelines. For example, on 15.03.2020 he explained the facilities available at quarantine centres, stating also that those in quarantine undergo health checks thrice a day (Ada Derana, 2020a).

DIG Ajith Rohana's messages included informing the public on what they can and cannot do under curfew, availability of certain services during the curfew and urging the public to respect the curfew. He also briefed the public on the flexibility being provided regarding certain regulations. For example, on 18.03.2020, he stated that all police stations were instructed to grant relief for expired vehicle revenue licenses until the COVID-19 outbreak had been brought under control (Ada Derana, 2020b).

3.1. Types of Messages

Most of the messages fell into the "self-efficacy" category, followed by "links to functioning and accessible services." To motivate adherence, it was observed that some messages promoting self-efficacy were framed as appealing to self-interest or performing a service to the country. For example, on 18.03.2020: Dr. Seetha Arambepola (speaking as a member of the Presidential task force appointed for the prevention of COVID-19) stated that "at no other time will history present them such an opportunity as this to be of service than to self-quarantine right now," regarding Sri Lankans arriving from COVID affected countries (Ada Derana, 2020c).

Regarding Category 5, we observed that the messages generally did not contain technical jargon, and were therefore easier to understand.

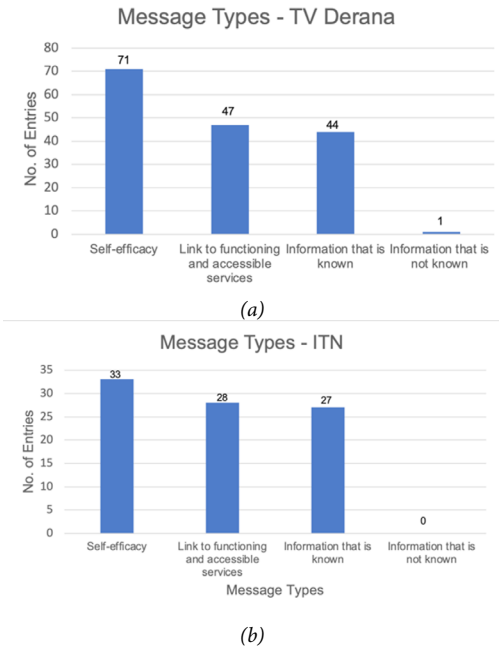


Figure 2. Message Types

4. DISCUSSION

A nation-wide telephone survey conducted 29-31 March 2020 by Vanguard Survey Pvt. Ltd. and Verité Research found that 95.7% of the respondents were "very satisfied" or "somewhat satisfied" regarding "how the government is trying to control the Covid-19 pandemic in Sri Lanka." 73.11% of the respondents were "very satisfied" (Verité Research, 2020). This provides some evidence that the Sri Lankan public had high trust in the government's ability to control COVID-19 in this period.

As seen above, health officials were among the most featured category of officials. There is some evidence in the literature that health officials are rated as trustworthy authorities regarding matters such as infectious disease (Sopory et al., 2017). In terms of message types, there was a high emphasis on communicating actions that the public could take as individuals to assist with pandemic control, and how they could access both health services as well as services to assist with accessing essentials during curfew. This is in keeping with observations in the literature that risk communication should make people feel empowered to act. If they have specific guidance on actionable recommendations that they feel are implementable, they are more likely to follow through.

However, based on the entries we studied, less emphasis appears to have been placed on communicating uncertainty. When communicating information that is known, this appears to have consisted mostly of situation updates. Some updates were given on the nature and spread of the virus (for example, on 05.02.2020, Minister Wanniarachchi stated there was no evidence that the virus can spread through contaminated surfaces of commercially prepared food items and other commercial goods (Ada Derana, 2020d)). The one entry we found for the category of communicating unknowns was on 23.03.2020, when Lt. Gen. Shavendra Silva noted that there may be some COVID-19 cases that were not known to the government, and therefore the curfew was necessary to prevent the virus being spread by possibly unknown cases (Ada Derana, 2020e). The HPB RCCE plan mentioned beforehand, while detailed in many respects, also does not include a specific strategy for how to communicate in an inherently uncertain situation.

During an outbreak of a novel pathogen, there are likely to be many unknowns since knowledge of the pathogen's characteristics and how it spreads are in the process of being discovered. As a result, that knowledge is likely to change and evolve over time. It has been noted that openly acknowledging uncertainty can increase public trust (Cairns et al., 2013). Acknowledging uncertainty is also noted to be better than communicating certainty and then being found to be mistaken, which risks damaging trust (Holmes et al., 2009).

For example, Singapore (which has reported just 29 COVID-19 deaths at the time of writing (Johns Hopkins University, 2021)), made communicating uncertainty a key part of their COVID-19 risk communications. Singaporean officials continually stressed that there were many uncertainties, in particular the means and extent of virus transmission. This messaging was kept up even in early March, when it appeared that new infection numbers were under control (Wong and Jensen, 2020). This is in keeping with the Singaporean government's communication philosophy of "defensive pessimism," which stressed the severity of the risk, it's probable persistence, and the role of the government in getting ready for potentially bad outcomes in a highly uncertain situation (Wong & Jensen, 2020). Acknowledging uncertainty, therefore, can not only help build trust but can also alert the public to the need to be continuously vigilant, since knowledge about the disease is still emerging.

It should be noted, of course, that these observations from the televised communications are based on our sample, and the mode of communication we chose to study. We do not rule out the possibility that

unknowns may have been communicated elsewhere or through another channel.

5. CONCLUSIONS

It appears that television will be the most effective risk communication channel for the time being due to its broad reach. The effectiveness of other modes such as social media will depend on if social media reach increases in the future. As of 10 January 2021, the HPB Viber channel had 454,000 members, and the Government Information Viber channel had 368,000 members. Social media may possibly become a more dominant channel in future pandemics, at which point the government could look further to digital media communications strategies.

In terms of messaging, the strongest points were that the public was given actionable recommendations about measures they could take to prevent the spread of the virus. The public was also made aware of services that they could access both to protect their health and how to obtain other essential services during curfew. In future pandemics, messaging strategies to communicate uncertainties around emerging pathogens could be developed. A major challenge of COVID-19 control has been preventing cases from rising again after lockdowns are lifted. If uncertainty is emphasized, this can encourage the public to continue to exercise precautions and may help contain spread.

ACKNOWLEDGEMENTS

This work was supported by grant from the International Development Research Centre (IDRC), Canada. Stephanie Nicholle, Rathika Fernando (Verité Research) assisted in writing and data analysis. Madushen Paramanathan and Shantha Kirindagodagamage (Verité Research) assisted in data collection and verification.

REFERENCES

Ada Derana. (2020a, Feb 1). *අද දෙරණ 6.55 ප්‍රධාන පුවත් විකාශය - 2020.02.01.* [Video]. YouTube. https://www.youtube.com/watch?t=410&v=GaMdktO10ps&feature=youtu.be

Ada Derana. (2020b, 18 Mar). *අද දෙරණ 6.55 ප්‍රධාන පුවත් විකාශය -2020.03.18.* [Video] YouTube.https://www.youtube.com/watch?t=648&v=R6ks-lRyFVY&feature=youtu.be

Ada Derana. (2020c, Mar 22). *අද දෙරණ 6.55 ප්‍රධාන පුවත් විකාශය - 2020.03.22.* [Video].ube. https://www.youtube.c=1464&v=t5qsWS7ADzM&feature=youtu.be

Ada Derana. (2020d, Feb 5). *අද දෙරණ 6.55 ප්‍රධාන පුවත් විකාශය - 2020.02.05.* [Video]. uTube. https://www.youtube.com/watch?t=836&v=GwVeEP651XA&feature=youtu.be

Ada Derana. (2020e, Mar 23). *අද දෙරණ 6.55 ප්‍රධාන පුවත් විකාශය - 2020.03.23.* [Video]. YouTube. https://www.youtube.com/tch?t=898&v=dq22fn7SRS0&feature=youtu.be

Ada Derana. (n.d.). *Home* [Facebook Page]. Facebook. Retrieved June 5, 2021 from https://www.facebook.com/adaderana

Cairns, G., de Andrade, M., & MacDonald, L. (2013). Reputation, Relationships, Risk Communication, and the Role of Trust in the Prevention and Control of Communicable Disease: A Review. *Journal of Health Communication, 18*(12), 1550-1565. DOI: 10.1080/10810730.2013.840696

Earle, T.C., & Siegrist, M. (2006). Morality Information, Performance Information, and the Distinction Between Trust and Confidence. *Journal of Applied Social Psychology, 36*(2), 383-416. https://doi.org/10.1111/j.0021-9029.2006.00012.x

Glik, D.C. (2007). Risk Communication for Public Health Emergencies. *Annual Review of Public Health, 28*, 33-54. https://doi.org/10.1146/annurev.publhealth.28.021406.144123

Health Promotion Bureau. (n.d.). *COVID-19 : Live Situational Analysis Dashboard of Sri Lanka.* Health Promotion Bureau. https://hpb.health.gov.lk/covid19-dashboard/. Retrieved June 5, 2021.

Health Promotion Bureau. (2020). *COVID-19: Risk Communication and Community Engagement (RCCE).* Health Promotion Bureau, Sri Lanka. https://hpb.health.gov.lk/media/pdf/community-engagement.pdf

Health Promotion Bureau. (n.d.). *HPB SL COVID-19: Official COVID-19 updates by HPB, Ministry of Health.* Viber. https://invite.viber.com/?g2=AQBfgwZSTjnrf0s%2BLxOWSueYJuni13CXJ0Kp5eiTKupc%2B%2FBsPTjjwqf3HHz6ZTgW&lang=en. Retrieved June 5, 2021.

Holmes, B. J., Henrich, N., Hancock, S., & Lestou, V. (2009). Communicating with the public during health crises: experts' experiences and opinions. *Journal of Risk Research, 12*(6), 793-807. DOI: 10.1080/13669870802648486.

Johns Hopkins University. (2021). *COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU).* Johns Hopkins University. https://coronavirus.jhu.edu/map.html. Retrieved January 15, 2021.

McLeod, Carolyn. Trust. *The Stanford Encyclopedia of Philosophy* (Fall 2020 Edition), Edward N. Zalta(ed.), URL = <https://plato.stanford.edu/archives/fall2020/entries/trust/>.

Siegrist, M. & Zingg, A. (2014). The Role of Public Trust During Pandemics: Implications for Crisis Communication. *European Psychologist, 19*(1), 23-32. doi:10,1027/1016-9040/a000169

Sopory, P., Day, A., Novak, J., Eckert, K., Wilkins, L., Padgett, D., Noyes, J., Allen, T., Alexander N., Vanderford, M., & Gamhewage. G. (2017). *Evidence Syntheses to Support the Guideline on Emergency Risk Communication: Q5.* World Health Organization Department of Communications. https://www.who.int/risk-communication/guidance/process/Report.pdf

Verité Research. (2020). *Covid19 Sri Lanka: Citizen's Pulse 29-30 March 2020.* Verité Research. https://www.veriteresearch.org/insight/covid19-sri-lanka-citizens-pulse-29-30-march-2020/

Verité Research. (n.d.). *Media Ownership Monitor Sri Lanka: Television.* Verité Research. https://sri-lanka.mom-rsf.org/en/media/tv/

Wong, C. M. L. & Jensen, O. (2020). The paradox of trust: perceived risk and public compliance during the COVID-19 pandemic in Singapore. *Journal of Risk Research. DOI: 10.1080/13669877.2020.1756386.*

World Health Organization. (2017). *Communicating risk in public health emergencies: A WHO guideline for emergency risk communication (ERC) policy and practice.* World Health Organization. https://www.who.int/risk-communication/guidance/download/en/

BIBLIOGRAPHY

Department of Government Information. (n.d.). https://www.dgi.gov.lk/news/press-releases-sri-lanka/covid-19-documents. Retrieved June 5, 2021.

Department of Government Information. (n.d.). Government Information: Official media releases of the Government of Sri Lanka. Viber https://invite.viber.com/?g2=AQAr73SDEIkx4kvUu991sclyDaHbh08ji%2F1M84l%2B%2Fi1Vjyozrj HtFMmwX%2FUOxmFZ&lang=en Retrieved June 5, 2021.

First patient with coronavirus reported in Sri Lanka. (2020, Jan 27.). Colombo Page. http://www.colombopage.com/archive_20A/Jan27_1580144354CH.php

ITN News Online. (n.d.). Home [YouTube Channel]. Retrieved from https://www.youtube.com/channel/UCV66ictLH2DZehG1tH0G5KA

National Operation Centre for Prevention of COVID - 19 Outbreak. (n.d.). Sri Lanka Army. https://alt.army.lk/covid19/#. Retrieved June 5, 2021.

Organization for Economic Co-operation and Development. (2016). *Trends in Risk Communication Policies and Practices.* OECD. https://dx.doi.org/10.1787/9789264260467-en

State response to the COVID-19 pandemic in Sri Lanka and uncovering social distancing experience in socio-cultural context

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ABSTRACT

The present paper explores culture competency of social distancing, science communication and behaviour modification strategies implemented by the state in Sri Lanka to control the COVID-19 pandemic, adopting a top-down approach. Purposive sample of the study included 60 respondents, 30 Social Science undergraduate/ postgraduate students and 30 respondents from diverse socio-economic backgrounds contacted through social network of investigator. A mixed method approach was used in data collection that included systematic observation of the phenomenon from its beginning up-to-date, in-depth interviews and focus group discussions. Interviews were conducted to elicit data on lay perceptions and meaning attached to social distancing and lived experience of social distancing. The study examined the nature of the state-led public health interventions in terms of their socio-cultural sensitivity, communication strategies used, public compliance and behavioural change that followed. The exploratory study analyzed how public health is conceptualized in local socio-cultural context and identified strengths and gaps in state response to pandemic control. Findings highlight the significance of considering local socio-cultural context in implementing universal public health measures that determine the specific outcomes. The paper concludes that priority should be given to strengthening the free healthcare delivery system of country while enhancing the capacity of healthcare providers to collaborate with communities and multidisciplinary groups to achieve better public health outcomes. Pandemic situation requires innovative interventions to support marginalized social sections where social scientists have a unique competency to facilitate and contribute. Epidemic control at local socio-cultural context requires a bio-psychosocial approach with a holistic perspective.

Key words: Social distancing, Socio-cultural context, Lay-perception, Bio-psychosocial approach

1. INTRODUCTION

In responding to the global COVID-19 pandemic, long standing public health measures such as social distancing, isolation and quarantine have been implemented all over the world to control the fast spreading new corona virus (Wilder-Smith et al., 2020). However, each country adopts quite specific strategies to implement those universally designed interventions depending on specific socio-cultural context, level of threat perception, existing mechanisms for science communication, capacity of healthcare delivery system, and the leadership qualities of a particular country (Bavel et al., 2020). Empirical evidence suggests that informal social distancing interventions in epidemics have minimized exposure to the virus would help control the pandemic until a vaccine becomes widely available (Greer, 2013). However, in applying the health belief model

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Beaker argues that the compliance behaviour is determined by the ways in which how lay-people conceptualize the illness, modifying and enabling relevant factors (Becker et al., 1977).

In responding towards the global pandemic, the government of Sri Lanka has taken immediate actions to implement social distancing strategies as public health measures by strengthening health sector capacity to manage ill-health, contact tracing and arrangements for quarantining the individuals who are suspected as having a risk of carrying the virus (Ministry of Health, 2020). During first wave of the pandemic, the whole country was locked down for quite long time to control the pandemic while providing limited assistance for the people. However, the strategies have been changed from the second wave of the pandemic onwards while taking necessary action to isolate/lockdown only the localities/ clusters identified as high risk for transmission of the virus. The whole process of designing appropriate interventions and implementation has been operated by the state as a collaborative effort by healthcare providers, the tri-forces, the police and intelligence services with the guidance of the political leadership of the country. Present paper explores culture competency of social distancing, science communication and behaviour modification strategies implemented by the Sri Lankan state to control the COVID-19 pandemic by adopting a top-down approach. Thus, the paper critically reviews the nature of state-led, top-down public health interventions in terms of their socio-cultural sensitivity, communication strategies used, public compliance and behavioral change that followed. It also identifies best practices and limitations of state interventions and future challenge in moving towards a new normal situation.

2. METHODOLOGY

This paper is based on an ongoing exploratory study on "social determinants of COVID-19 pandemic, lived experience of social distancing and associated socio-cultural implications". A purposive sample was selected for the study, consisting of 60 respondents who were selected based on accessibility criteria in order to contact them during pandemic situation while adhering to given health guidance. The sample included 30 undergraduate/postgraduate students in social science degree programmes and 30 respondents from diverse socio-economic backgrounds who were contacted through social network of the investigator. This category included housewives, teachers, healthcare providers, private sector employees, farmers and other categories of workers.

A mixed method approach was used in data collection. It included a systematic observation of the phenomenon from its beginning to the end; qualitative interviews and Focus Group Discussions (FGDs). In-depth interviews were conducted with 42 respondents and three FGDs were carried out with 19 undergraduate/postgraduate students. Both individual interviews and FGDs were expected to elicit data on lay perception of social distancing measures, lived experience of pandemic and compliance behavior with regard to state interventions. The observation process has been systematically documented incidents which are reported in diverse media sources including TV channels, social media, webinar discussions and web-sources. Content analysis is used in analyzing the data. Perception and behavioural patterns of respondents are summarized in identified themes under the results and discussion section.

3. RESULTS AND DISCUSSION

Sri Lankan experience reveal that threat perception with regard to pandemic by the state was quite high and urgent actions were taken to implement social distancing strategies as public health measures employing a top-down approach. A special task force has been established by the state to manage all activities related to containment of COVID-19 pandemic. "Quarantine and Prevention of Disease Ordinance of 1897 introduced during British colonial period has been used by the state in implementing social distancing strategies. Though the state adopts a collaborative approach in interventions, those strategies have

been transferred directly from top-to-bottom, assuming that the general public would rely on recommended behavior as passive recipients. This empirical study predominantly focused on analyzing compliance behavior and summarizes the findings under sub-themes related to lay perception of social distancing measures; lived experience of respondents with regard to compliance behavior and strengths and gaps in state interventions.

3.1. Lay perception of social distancing measures

As mentioned earlier, the study sample included respondents from diverse socio-economic and educational backgrounds. A majority of the university students in the study sample (90%) is from rural areas and most other respondents are from urban areas. One respondent in the study sample reported that he was positive for COVID and three respondents mentioned that at least one of their family members were affected by the virus by the time of conducting interviews with them. In qualitative interviews and FGDs with respondents, they were requested to share their individual/family experience with regard to social distancing measures as well as their observations on compliance behavior of relevant neighborhoods/communities where they are living.

The study discovered that a majority of respondents is well aware of the importance of using a face mask in public space, maintaining hand sanitization and physical distance in order to prevent from the infection. However, respondents were quite confused with regard to key terms such as social distancing, isolation and quarantine which were used quite often in media sources by healthcare providers for the purpose of science communication. These are not very familiar terms for the lay people in Sri Lanka until they experienced the pandemic. Most of the respondents pointed out that 'physical distance' would be the most appropriate term instead of using 'social distancing' in this context to maintain the recommended behavior in interacting with others to prevent the transmission of COVID virus. The expected meaning of using social distancing in pandemic situation was not adequately explained by experts though they have strongly communicated the importance of keeping physical distance in relationships. Interpretations of respondents point to certain misconceptions regarding social distancing and isolation resulting in negative consequences for social relationships that reduce the access to social capital crucial for enhancing resilience during a crisis situation.

The epidemic is perceived by the lay people as a life-threatening condition and displayed a fear of being infected by the virus. Distress towards COVID 19 is emerging not only due to the severity of the illness but also due to stigma and discrimination associated with the entire process of testing for COVID-19, directing patients to treatments centers, contact tracing, isolation and quarantine arrangements for those who are suspected as carrying the virus. Many respondents had not received sufficient knowledge in responding each of the above steps in the process though they have some information gathered through media sources. The respondents pointed out that certain procedures were quite clear during first wave of the pandemic but most of them became complicated since from the beginning of the second wave of the pandemic. Thus, certain situations are unclear for lay people as the state continuously keep on changing procedures with regard to treatment and quarantine arrangements while making people confused.

The respondents who have close experience with regard to isolation and quarantine process were critical about the approach used by PHIs to isolate sick family or individuals who are suspected to have the risk of carrying the virus. After identifying a sick family, the relevant PHI takes immediate action to display a formal notice in front of relevant household as "quarantine household" and the label resulted negative consequences for the concerned family though the notification helps in preventing transmission of virus to others. Narratives of respondents reveal that they faced a lot of difficulties during quarantine

period to fulfill survival needs as there were no prior arrangements and also not receiving any support from their neighborhoods.

As one of the respondents further pointed out during qualitative interviews "this was one of the best opportunities in my life to understand the real nature of our people. Some people still not even look at our face, seems like we did something wrong to them" (a member of a COVID-affected family).

Participants in our FGDs clearly explained that the ways in which how lay people used to manage viral diseases in a humanistic manner by using local knowledge and cultural practices. As such, if a family recognizes as its member/s get affected from a viral disease immediately they communicate the massage to others by symbolically displaying branches of *Kohomba* (neem leaves) at the entry of the house to prevent the entrance of others into the vulnerable premises. The sick family was never socially isolated by the concerned community, rather voluntarily supporting them to fulfill daily needs of sick family while maintaining physical distance to prevent the transmission of virus until they come back to normal. Thus, the family itself takes necessary action to maintain a physical distance between the patient/s and healthy members within a household. In comparing those experiences with the present scenario, respondents were critical about some of the state interventions with regard to social distancing and provided several incidents where people were compelled to hide the illness, delaying treatment and fear to visit healthcare institutions even seeking treatment for other ailments particularly cough, common cold and fever. A respondent provided a concrete example where one of his friends who was working in Colombo identified as COVID positive and he kept the incident as secret even from his immediate family who live in the village assuming negative consequences that the family would face due to stigma and discrimination associated with the infection. However, he acknowledged the support extended by his friends to recover from difficult situation. Number of similar incidents were found in different media sources where patients, family members and healthcare providers have faced a lot of difficulties due to fear of disease and also due to negative consequences of stigma and discrimination associated with COVID-19 pandemic.

3.2. Lived experience of social distancing strategies and the compliance behavior

This section summarizes lived experience of social distancing strategies and compliance bahaviour of respondents who come from diverse socio-economic and cultural backgrounds. The respondents who had direct experience regarding quarantine and isolation mentioned that they had to undergo a lot of difficulties during this period in order to fulfil their survival needs, hardly received any support from relevant communities and avoiding their presence even after completion of recommended quarantine period. A small businessman in our sample pointed out that he was suddenly instructed by the PHI to close down the boutique and entire family was asked to self-quarantine for two weeks due to a COVID positive person who had visited his shop. After re-opening the boutique after quarantine period he noticed that most of his regular customers avoided the boutique due to this incident. A nurse who works at a COVID management hospital was sharing her experience and noted that her family members underwent difficulties as the neighborhood responded negatively due to her professional engagement with the disease. She worries about this situation and fears about the safety of her family members though she strictly adhered to preventive measures. A respondent from law enforcement authorities working in Colombo mentioned that when he go home for leave, people in his community treated him as a COVID positive person and the family encountered negative consequences. Another respondent pointed out that an individual from his workplace was identified as COVID positive and he had to self-quarantine at home. His neighbors came to know about it and complained to the PHI when his family member went out for buying food and medicine. These empirical

examples show that stigma and discrimination associated with COVID pandemic continue even after completion of quarantine period or after completely recovered from the infection.

The respondents also complained about the violation of privacy while taking individuals to quarantine centers where they cited a number of incidents related to unethical media practices in pandemic situation. Respondents' observations with regard to compliance behavior of their neighborhoods/communities referred to people in remote areas who hardly use face-masks in a proper manner assuming that the village is a safe place for them as they know each other very well. Some villagers are reluctant to use face-masks due to their habits of betel chewing, smoking etc. They are compelled to use a face-mask when they come to the nearest town. Moreover, some villagers do not use face-mask while traveling by bus and wear it after getting off from the bus because law enforcement authorities monitor their compliance behavior. The respondents in urban areas noted that most of the people nowadays are compelled to use a mask though the quality of the masks depend on social background of the individual. One of the respondents pointed out that "the poor are using cloth-mask or a piece of cloth; the middle class uses surgical masks and KN95 masks are used by the upper strata". They also identified some issues related to using face-masks such as not using them properly, re-using it for longer period and using low quality masks just for the formalities due to both affordability issues and inadequate knowledge to understand the advantages of using them properly.

Narratives of respondents and evidence gathered from media suggest that non-compliance behavior is quite visible in diverse social gatherings though appropriate guidelines were given by the state to follow in each event. Everyday lives of people strongly associated with diverse religious, ritual, and social gatherings. The empirical evidence clearly shows that direct transferring of health regulations from top to bottom has number of gaps and fail to adopt culture sensitive behavior change communication strategies required to minimize non-compliance.

The respondents highlighted some of the behavioral changes happening in their everyday lives during pandemic situation. Most of the respondents pointed out that they have started drinking herbal medicine as preventive measures which are based on commonsense knowledge and also prepared medicine available at the market from different brands. Some traditional medicines available in the market claim to improve immunity of people against the virus. The evidence reveal that there is an emerging discourse on efficacy of indigenous medicine and recognizing traditional food practices. Most of the respondents claimed that they started home gardening during lockdown period. The respondents highlighted number of positive and negative consequences of work from home and study from home due to pandemic situation. An empirical study conducted by Ruhuna University shows diverse social and economic impacts of COVID pandemic (Faculty of Social Sciences and Humanities at Ruhuna University, 2020).

3.3. Strengths and gaps in state interventions

The state interventions with regard to pandemic containment have both strengths and limitations. Country's leading healthcare delivery system has strong capacity to reach up to grass root levels through Medical Officer of Health (MOH) system (Adikari et al., 2020). Social distancing strategies have been implemented as public health measures through MOH system by adopting a top-down approach. It is important to note that though the country has well-established public-private mixed healthcare delivery system, the state has decided to manage the pandemic predominantly relying on public healthcare delivery system while strictly regulating private sector involvement in pandemic control. Achievements in pandemic control in Sri Lanka during the second wave were comparatively better than many other countries, including those with a well-developed healthcare delivery

systems. The recovery rate of COVID patients in Sri Lanka is very high while maintaining a low mortality rate mainly due the strengths of healthcare delivery system in the country. The vertical structure of healthcare delivery system in Sri Lanka was well-established during British colonial period as it was considered as one of their model colonies (Jones, 2004). As mentioned earlier, the state adopted an ordinance of disease prevention introduced in 1897 in order to implement social distancing strategies as public health measures where the law enforcement authorities were given necessary power to monitor the interventions.

The state interventions show that despite some achievements in top-down approach adopted in implementing social distancing strategies there are number of deficiencies due to insufficient attention given for empowering people to be self-reliant. As Amartya Sen (2020) pointed out tackling a social calamity requires cooperative efforts, participatory governance and alert public discussions. Pandemic prevention interventions in Sri Lanka predominantly focused on direct transferring of an array of interventions from top to bottom assuming that the general public would comply with the interventions. Using appropriate behavior change communication strategies that recognizes lay perspective would be a more effective strategy to popularize the safety measures introduced. The state has taken necessary action to develop health guidelines for people targeting each specific event with social gatherings. However, the state lacks collaborative strategies in implementing those interventions rather forcing people to adhere with the behavioural change introduced. Empirical evidence clearly shows that there are many occasions where people violate those guidelines, increasing the risk of spreading the virus among large number of people though the law enforcement authorities are continuously taking necessary action to punish them. The top-down approach worked during first wave of the pandemic as the entire country was locked down and the law enforcement authorities were able to closely monitor the process. However, gaps in this approach becoming visible since from the beginning of second wave of the pandemic where the state started using cluster-focused localized approach that requires more collaborative and active participation from the general public.

Internal structure of local healthcare delivery system has three overlapping and interconnected sectors as shown in the Figure 1.

Local health care structure comprised of three sectors, the popular, folk and professional sectors where the state interventions predominantly focused under professional sector-the biomedical system rather neglecting the other two sectors. Pandemic prevention interventions demand an integrated and a collaborative approach among these three sectors. Each sector has its own ways of explaining and treating ill health in their therapeutic encounter. The popular sector is the largest part of health care system where the illness is first defines and health care activities initiated. However, both popular and folk sectors of healthcare have been neglected greatly. Lay people have paid more attention on complementary medicine during pandemic situation and emerging a discourse on efficacy of traditional medicine. A number of gaps prevail in vertical structure of public healthcare system at delivery point and number of shortcoming as those strategies failed to incorporate knowledge about local social structures, behavioral patterns and the mentality of lay people. Lived experience of respondents point to a number of socio-cultural and psychological issues have been emerging in the local context which are not merely due to adverse effects of the pandemic but also due to drawbacks in intervention process itself by the state.

Threat perception of respondents was fairly high and they have a strong sense of fear with regard to illness due to its severity as well as the stressful situation created through intervention process itself. In this process, the patient and his/her family members, and concerned communities labeled as high prevalent localities had many difficulties as COVID-19 pandemic is characterized by stigma and

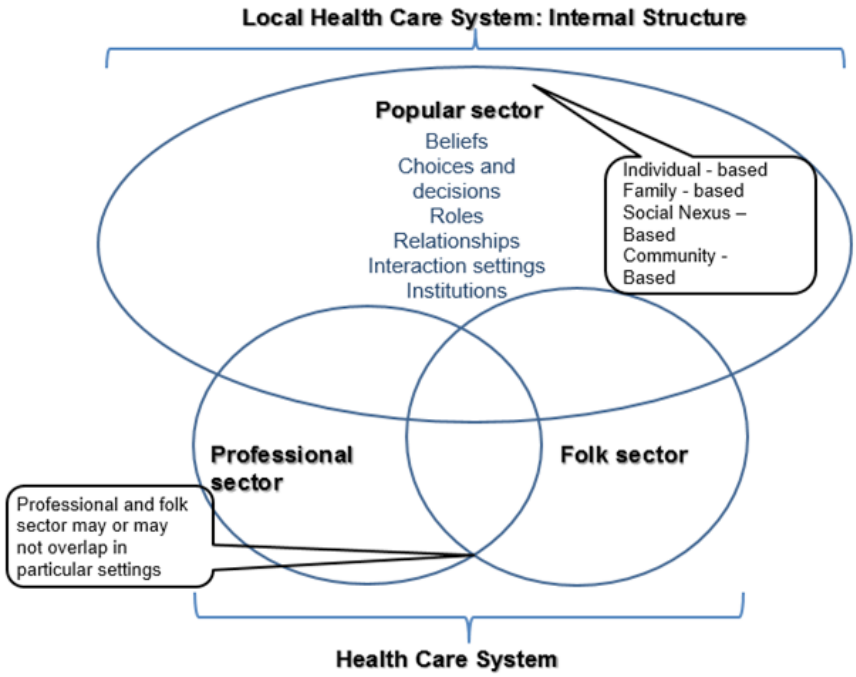

Figure 1. Internal structure of local health care delivery system

Source: Kleinman, A (1980)

discrimination. The negative consequences are enhanced due to unethical media operations. The awareness raising campaign focused only on formal media sources which hardly touch the marginalized social groups who have no access to those media coverage. Thus, the process hardly incorporated culture sensitive and informal communications strategies to educate marginalized and most vulnerable sections of the society leading to non-compliance behavior. The evidence clearly shows that emerging economic, psycho-social and cultural issues were not taken in to account in programme implementation and monitoring and follow up work. Evidence also suggest that the existing social protection policies in Sri Lanka is inadequate to address newly emerging issues connected with the pandemic. Marginalized social groups, those who involved in informal economy and peculiar work face various types of socio-economic issues and there are gaps in existing social protection policies in responding those newly emerging issues. Social determinants of COVID-19 pandemic have not been adequately addressed in interventions and the evidence reveal that the pandemic has contributed in reinforcing social inequalities based on social class, ethnicity, gender etc. (Silva, 2020; Faculty of Social Sciences and Humanities at Ruhuna University, 2020).

4. CONCLUSIONS

This exploratory study has analyzed how public health interventions are conceptualized within a given socio-culture context and identified strengths and gaps in state response to COVID 19 in Sri Lanka. Public health care delivery system in Sri Lanka has a great potential to manage global pandemics in a satisfactory manner. However, the vertical system that operates from top-to-bottom lacks culturally competent strategies to collaborate with popular and folk sectors of local healthcare structure. The paper concludes that priority should be given to strengthening free healthcare delivery system of the country while enhancing the capacity of healthcare providers to collaborate with communities and multiple stakeholders to achieve better public health outcomes. The pandemic situation requires innovative interventions to support the marginalized social sections and to address

behavioural issues where social scientists have a greater competency to contribute. It is recommended to adopt a "bio-psycho-social approach" for epidemics control where social and behavioural scientists could collaborate with healthcare providers to address the gaps highlighted from the findings of present study. Community empowerment approach is significant to move forward in the direction of new normal society. Priority should be given to strengthening family support services while revisiting social protection policies in Sri Lanka.

ACKNOWLEDGEMENTS

I acknowledge with thanks the contribution of all the respondents who shared their lived experience with me to develop this paper. I thank Professor S. T. Hettige for his comments to modify the abstract and Thiran Liyanage for technical assistance.

REFERENCES

Adikari, P. S., Pathirathna, K., Kumarawansa, W., & Koggalage, P. (2020). Role of MOH as a grassroots public health manager in preparedness and response for COVID-19 pandemic in Sri Lanka. *AIMS Public Health*, *7*(3), 606-619.

Bavel, J., Baicker, K., Boggio, P., Capraro, V., Cichocka, A., & Cikara, M. (2020). Using social and behavioural science to support COVID-19 pandemic response. *Nature Human Behaviour*, *4*(5), 460-471.

Becker, M., Maiman, L., Kirscht, J., Haefner, D., & Drachman, R. (1977). The Health Belief Model and Prediction of Dietary Compliance: A Field Experiment. *Journal of Health and Social Behavior*, *18*(4), 348.

Faculty of Humanities and Social Sciences. (2020). COVID-19: The Socio-Economic Impact on Sri Lanka. Part-1: The Economic Impact of the COVID-19 Pandemic in Sri Lanka. University of Ruhuna, Matara

Greer, A. (2013). Can informal social distancing interventions minimize demand for antiviral treatment during a severe pandemic? *BMC Public Health*, *13*(1).

Jones, M. (2004). *Health policy in Britain's model colony*. Hyderabad, India: Orient Longman, in association with the Welcome Trust Centre for the History of Medicine.

Kleinman, A. (1980). Patients and Healers in the Context of Culture: An Exploration of the Borderland between Anthropology, Medicine and Psychiatry. University of California Press.

Ministry of Health. (2020). Sri Lanka Preparedness & Response Plan for COVID-19, Ministry of Health and Indigenous Medical Services, Sri Lanka.

Silva, K.T. (2020). Identity, infection and fear: A Preliminary analysis of COVID-19 Drivers and Responses in Sri Lanka, International Centre for Ethnic Studies, Sri Lanka.

Wilder-Smith, A., & Freedman, D. (2020). Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. *Journal Of Travel Medicine*, *27*(2).

COVID-19 and the pandemic of hate in Sri Lanka

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ABSTRACT

This paper argues that side by side with the COVID-19 pandemic, a pandemic of hate broke out in Sri Lanka through print and electronic media as well as social media. This situation has already been noted for several other countries. Even though Sri Lanka made considerable headway in terms of containing the first wave of the pandemic, the second pandemic wave seems to have continued unabated in Western Province and elsewhere. Blaming the other, whether they are drug addicts, prisoners or ethnic minorities as super spreaders of the infection lies at the heart of the pandemic of hate. The paper seeks to elaborate the symptoms of this pandemic of hate also exploring its connections with preceding social crises and intergroup tensions. Finally, the paper explores possible ways of containing the hate pandemic in ways that contribute to social development, evidence-based decision making and ethical reporting and information sharing in the era of digitization and neoliberal globalization.

Key words: Hate speech, Disease clusters, Corona-Jihad, Pandemic

1. INTRODUCTION

It is well established in the medical sociology and medical anthropology literature that epidemics and pandemics often trigger hate targeting possible infectors as well as infected. When infections are believed to be harboured and triggered by marginalized social groups hate campaigns take the form of reinforcing existing inequalities and prejudices. This is how in the early stage of the HIV pandemic, it came to be identified as a 'gay plague' in North America and Europe targeting both gay people and IV drug users, already stigmatized in society and heavily discriminated against by the establishment, media and society in general. HIV prevention and control in this context called for an inclusive approach that involved reaching out to the specific vulnerable groups, establishing rapport with them, empowering them as persons with dignity and promotion of safe practices that eventually reduced their risk of infection. COVID-19 pandemic may be different in that here we are dealing with an acute rather than a chronic condition, but the public health implications would be similar especially when it comes to addressing hate campaigns. This is why the UN system has developed and popularized the key message "we are all in it together" so as to avert the emerging popular trend of blaming one stigmatized group or another for spreading the COVID-19 pandemic and reiterate the point that all parties must conform to the relevant institutional and behavioural safeguards irrespective of who they are.

Fear, hate and stigma have been closely associated with epidemic disease from ancient times. In one of the earliest medical sociological accounts of the phenomenon, Strong (1990) argued that just like the virus, during epidemics

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fear and hate have an infective character spreading from one person to another through gossip and rumour usually disseminated through word of mouth not subjected to any kind of censorship. Infective character also included the inherent capacity for gossip and rumour to get embellished with additions, expansions, and reinforcements along the way. As hate gathers momentum around particular social clusters with diverse resentments of their own, it acquires an explosive character with resentment and aggression clearly targeted against the suspected cohort or group of 'infectors'. "Personal fears may be translated into collective witch-hunts…such avoidance, segregation and persecution can be quite separate - analytically at least - from actions aimed at containing the epidemic. Such behaviour can occur with all types of stigma, not just with that of epidemic disease. We are dealing here with magic and taboo, not just with quarantine." (Strong, 1990).

The rapidity and intensity with which fear, and hate can spread in society have multiplied due to ITC revolution and development of social media as a new communication channel from the 1970s. Social media platforms have opened up the possibility for people with certain social prejudices to form social networks of diverse kinds and instantly share messages without being fact checked. This has become particularly evident in the COVID-19 pandemic. The full brunt of ITC revolution for promotion of hate speech has been realized in the COVID-19 pandemic that has been unfolding globally from December 2019. As a result, side by side with the outbreak of the pandemic itself, 'a pandemic of hate' has been generated. COVID-19 "has unleashed a raging pandemic of hate and widespread stigmatization, especially against the Chinese and the East Asian diaspora, in many countries" (Ng, 2020). The targets of hate, however, have varied according to social and political realities and epidemic dynamics in each country in ways that reinforce existing social fault lines and moral panics informed by dominant ideologies of race, class, gender, and ethnicity. This is how the pandemic of hate has latched onto a social virus already well established in society in ways that intensify existing social polarizations, hostilities, and resentments. As some authors put it "virus is not only infecting but also affecting" (de Kloet et al., 2020). This means that the virus also gives rise to certain sentiments among people vis-à-vis each other and the vulnerabilities involved in their exposure to each other.

This paper explores the COVID-19 triggered pandemic of hate in Sri Lanka focusing on hate campaigns targeting drug users and Muslims identified as super spreaders of the disease. It must be stressed here that mass media and social media campaigns against the two target groups had commenced sometime before the onset of the pandemic and the pandemic merely served to reinforce social prejudice and fault lines already in existence in society. The role of mass media and social media in the COVID-19 related hate campaigns is examined using purposively selected messages that target the two specific groups mentioned. Towards the end paper deals with the policy and program implications of the findings, also taking into consideration the adverse public health outcomes of hate speech connected with the pandemic.

2. DRUGS, INFECTIONS AND HATE SPEECH

Drug addicts had been identified as super spreaders of the pandemic in Sri Lanka since the onset of the disease. The attack on drugs, however, had been initiated before the onset of the pandemic in heightened police raids accompanied by a moralizing campaign targeting addicts and traffickers identifying them as the source of all evils including organized crime, urban mafia, disappearances, illicit weapons trade, theft and money laundering. As elaborated elsewhere (Silva, 2020b), hate speech targeting addicts as super spreaders of the disease came to reinforce the already established prejudices against them widely circulated in society as an outcome of the anti-narcotic operations of the police widely publicized in mass media.

A war against drugs had been launched in Sri Lanka since March 2019. This involved a vigorous campaign to round up and apprehend drug dealers and addicts, unsuccessful effort to implement the death penalty on convicted drug dealers, enhanced surveillance on the local and international networks involved in drug trafficking and organized crime that involved killing of rival drug dealers, inclusive of those in police or prisons custody and media hype surrounding narcotic offenses and operations. The apprehension of Makadure Madush, a Sri Lankan drug lord notorious for several high-profile organized crime, who continued his operations from Dubai to which he had escaped after a major attack against his rivals in prison custody in Sri Lanka was a key landmark in the war against drugs. Madush was finally deported to Sri Lanka only to be gunned down while in police custody adding to the drama connected with the war against drugs. As a side note it must be noted here that some 60 to 70 percent of all prison inmates are held in connection with narcotic and alcohol-related offenses. In effect, there is much overlap between prison population and those convicted of narcotic offenses in Sri Lanka. Both these groups became important disease clusters during the pandemic in Sri Lanka. While infected drug addicts became an important driver of the first wave of the pandemic, the reported fear of infections in crowded prisons led to a major prison riot and an intractable public health cum security problem during the second wave.

Networks of substance users became an important COVID-19 cluster by itself. The so-called Kandakadu cluster made up of a drug rehabilitation and a quarantine centre in eastern Sri Lanka reported 651 cases out of a total case load of 3471 COVID-19 morbidity (18.8% of all cases) in Sri Lanka as of October 5, 2020. In addition, addicts were also blamed for infecting the Navy, reporting a total of 950 COVID-19 cases (27.4 % of all cases), up to October 5, 2020. Thus it could be argued that a total of 46% of all COVID-19 cases at the time are attributable to infections emanating from the substance users, even though it could not be fully confirmed with the available data. The authorities and the media directly blamed a particular addict in Suduwella community located near the navy headquarters in Welisara for introducing the disease to the navy camp. The addict was suspected to have been exposed to the disease because of a previous detection in the area. Reportedly he resisted arrest by the Navy soldiers who themselves became exposed in the process. Some of the print media and TV channels typically reported this as an infection by a kudda (a derogatory Sinhala term for an addict, lit. one who is given to dust) to a group of ranaviru (war heroes) responsible for saving the nation during the war and the ongoing pandemic. The prisons reported their first case on July 7 in Welikada Prison and that too happened to be a transferee from the Kandakadu drug rehabilitation centre. Thus, apart from forming their own disease cluster triggered by their reported irresponsible behaviours such as close physical contact during drug use, sharing of substances, non-wearing of masks, and violation of quarantine regulations for securing drugs on which they were dependent, addicts are also blamed for contributing to the formation of other COVID-19 clusters in the country, including the protracted navy cluster that nearly demobilized the soldiers for an extended period of time.

In a news report in Mawbima Sinhala newspaper dated 28-4-2020 sensationally titled "Suduwelle Kudda: the turning point in the corona scourge in Sri Lanka" a youth addict from this community was identified as patient 206, a super spreader equivalent to infamous patient 31 in South Korea.[1] This person reportedly infected many other people in the community with whom he shared drugs. "Most importantly in a round up of addicts in Suduwella conducted as a quarantine operation, navy soldiers were forced to chase and apprehend him through a scuffle that resulted in these ranaviru being infected. This resulted in rapid disease transmission within the navy, which reported 129 new cases within a few days." Media briefings by high-ranking military

1 https://mawbima.lk/news-search/%E0%B7%83%E0%B7%94%E0%B6%AF%E0%B7%94%E0%B7%80%E0%B7%90%E0%B6%BD%E0%B7%8A%E0%B6%BD%E0%B7%9A/news-more/56947

and police officers reported in TV news openly blamed the 'Kuddo' for infecting the navy without mentioning any contributory factors from within the navy. The stigmatizing labels kudda (singular) and kuddo (plural) already widely registered in mass media and social media, as part and parcel of organized crime connected with the underworld, were extended to the public discourse on COVID-19 in some ways legitimizing the militarized response to the pandemic in Sri Lanka. Even the usually cool and composed, media spokesperson for the police blamed kudda for deliberately or unwittingly spreading the disease to ranaviru.

In a related event much publicized in media, a confirmed COVID-19 patient who was also drug addict who had been transferred to the National Infectious Disease Hospital in Angoda from the Kandakadu quarantine centre, ran away from the hospital in the early morning of July 24, 2020. The media reports on the event caused public panic and a mass fear as it was feared that he could indiscriminately infect innocent people in the capital city.[2] His pictures retrieved from hospital records and video clips captured from CCTV were instantly displayed on TV cameras in order to help identify him. His name and place of origin were also leaked to mass media, conveying his Muslim identity and further reinforcing the stigmatization process. He returned to the hospital later in the day, but efforts to trace his possible contacts continued using his own reports, CCTV footage and reports of people who had seen him during his outing. After causing much panic about this incident, health authorities later revealed that the person concerned had largely recovered from the disease and that he was probably non-infective at that stage.

These instances of fear and panic about the disease were not merely a result of mass hysteria connected with the fallout of the disease. In some instances, it was deliberately used by the establishments as a crisis management devise. For instance, following the prison riots in Mahara prison, a high-ranking defence official justified the shooting of prisoners by authorities on the grounds that if infected prisoners were allowed to break away, they would have infected many civilians in the capital city.[3] Even though this was by no means part of state policy, the imagery of bio-terror was deployed by certain officials in justifying their action during the pandemic response. For instance, the director of a certain health facility, identified patients who seek to enter his health facility without declaring his known COVID-19 positive status, as a potential suicide bomber who seeks to kill himself while causing the potential death of other people in the facility as well. Fortunately, these instances were exception rather than the rule, but they highlighted the need for greater sensitivity in issuing public statements through mass media during the pandemic.

The behaviour of social media during the pandemic was far more problematic from the angle of triggering hate speech. For instance, there was a wave of social media posts blaming the addicts, always labelling them as kuddas, for their contribution to the pandemic in the navy cluster in particular (See Figures 1 to 3).

This Facebook post (Figure 1) calls for shooting of addicts who move from place to place during the period of lockdown without wearing masks. In this post the addicts are insultingly referred to as dogs guided by their own instincts with no concern whatsoever for the wellbeing of others.

As already noted in the previous section based on a news report in print media, a Facebook post (Figure 2) claims that the navy soldiers became exposed to the disease as they had to man handle the addicts (kuddan) during the quarantine process in the village. Further it blames the addicts for being totally irresponsible in their behaviour during this quarantine operation carried out for public good.

2 . https://economynext.com/covid-positive-inmate-from-kandakadu-is-on-the-loose-after-escaping-from-idh-police-72309/

3 . https://www.newsfirst.lk/2020/12/02/mahara-prison-riot-could-have-led-to-serious-consequences-defence-secretary/

Figure 1. Facebook post condemning the neglect of safety procedures by addicts

Figure 2. Facebook post blaming addicts in Suduwella for introducing the disease to the navy cluster

The post in Figure 3 calls for authorities not to release addicts going through quarantine process even after they recover from the disease, implying that they are a continuous threat to society in ways that are not spelled out.

These Facebook posts invariable refers to the addicts using the derogatory label kudda (literally Mr. dust). Obviously, there is a convergence between mass media and social media in regard to branding people using derogatory labels such as kudda. In social media,

Figure 3. Facebook post asking the state not to release addicts (kuddan) to society even after they recover from COVID-19

there is a clear tendency to blame the addicts not only for becoming addicted and getting infected but also infecting others, including the very people, who are deployed to safeguard the nation (*ranaviru*). While this does point to the deep penetration of a certain hegemonic ideology, creating a pro-establishment narrative among Facebookers, it may not necessarily be a public opinion conducive to reducing panic and promoting compliance to safe practices and public health guidelines on the part of certain vulnerable groups in society. In so far as addicts are socially ostracized, they can become a reservoir of infection not easily detected or eliminated using standard public health measures. Stigmatization and blaming the victims are likely to make it difficult for them to re-enter the social mainstream and escape their addictions and traumatized life as substance users. A more enlightened approach is necessary in order to avoid stigmatization of victims, restore human dignity among all parties, including the infected persons with a history of addiction, prevent further infections in society and achieve improved compliance for disease control measures from all segments of the population, inclusive of socially and politically marginalized groups.

3. PANDEMIC OF HATE SPEECH DIRECTED AGAINST MUSLIMS

Anti-Muslim hate speech in social media was already firmly established in Sri Lanka prior to the onset of the pandemic, due to preceding events such as Easter Sunday attacks in April 2019 and a wave of anti-Muslim violence that escalated from 2012 onwards. COVID-19 related anti-Muslim hatred, simply took off from where it left in the preceding era building on already existing prejudices and hostilities. This is, however. not to say that COVID-induced hate pandemic in Sri Lanka is a one-way affair with sections of the majority Sinhala community directing hate against the Muslims. While this essay will primarily examine Sinhala hatred targeted against Muslims by exploring Sinhala media reports and social media posts, it must be recognized that hate was also directed by Tamils vis-à-vis Muslims and Muslims vis-à-vis both Sinhalese and Tamils. We do argue in this paper that anti-Muslim hate campaigns had a direct bearing on certain policy issues such as delay in granting official permission for burial of COVID-19 deceased Muslims and securing the uninhibited participation of Muslims in the public health campaign for control of COVID-19.

The upsurge in Islamophobia in western media following the 9/11 attack in 2001 also reverberated in mass media in India and Sri Lanka due to the rise of Hindutwa movement in India and politically motivated Buddhist movements in Sri Lanka with Bodu Bala Sena as the epitome of such movements. Inflammatory statements against Muslims by militant Sinhala Buddhist monks and media campaigns incorporating unsubstantiated charges of forced sterilization of Sinhala women by Dr. Shafi Shihabdeen, wide publicity given to so-called infertility causing substances secretly served to Sinhala customers in Muslim restaurants and Muslim textile shops had served to establish a distinctly anti-Muslim mindset in mainstream Sinhala media by 2019. The Easter Sunday attacks in Colombo and elsewhere by an extremist Islamist group on April 21, 2019 (4-21) added to the anti-Muslim propaganda in mass media and social media so as to register the obviously unfounded view that Muslims are the public enemy number 1 in Sri Lanka. Politically too, Muslim political parties were marginalized following the regime change in the presidential election held in November 2019. It is against this socio-political background that the hate campaign targeting the Muslims during the COVID-19 pandemic in Sri Lanka must be assessed.

A potential Islamic driver causing the onset of the corona pandemic in India and elsewhere had already been in the limelight of Western and Indian media in early 2020. In these reports several Tablighi Jamaat congregations held in Kuala Lumpur, New Delhi and Sulawesi in February and March 2020 were blamed for the cross-border transmission of the disease in those countries and elsewhere (Silva, 2020a). Even though some Islamic devotees from Sri Lanka may have participated in these religious gatherings, fortunately there was no media gaze around its implication for disease transmission in Sri Lanka. Instead, the media gaze around Muslims during the pandemic came as an extension of anti-Muslim propaganda from 2012 reported earlier, identification and media profiling of several Muslim clusters in predominantly Muslim locations such as Puttlam, Beruwala, Akurana, and Atalugama, reported non-compliance of Muslim residents for disease control and diagnostic efforts, active opposition to health workers involved as highlighted in the case of spitting reported in Atulugama and the campaign for burial of Muslims who died of the disease which received mostly negative publicity in local Sinhala media.

In electronic media reports, typically Muslim communities were not identified as such but visuals depicting mosques, women in abaya and certain commentaries by security forces and health workers interviewed conveyed the Muslim identity of the communities under surveillance. The relevant community members were also blamed for hiding vital information, poor uptake of diagnostics and lack of conformity with lockdown imposed in these locations. Following a pattern already well established in certain TV channels in

which Easter attacks were attributed to the entire Muslim community and mosques were incorrectly depicted as harbouring weapons and extremists, Muslim communities were portrayed as reservoirs of COVID-19 infections and blamed for the irresponsible behaviour leading to the escalation of the pandemic. During the second wave, the invasive nature of surveillance procedures increased, with drone cameras being used to monitor human behaviour during lockdowns in selected communities.

As the official morbidity and mortality statistics relating to COVID-19 in Sri Lanka are not segregated by any socio-economic categories like income level, livelihood, ethnicity, or religion, we cannot assess the impact of these socioeconomic variables on morbidity and mortality levels in the different communities. Against this background, vastly different estimates have been presented by different analysts regarding the disease prevalence in different communities. Challenging seemingly exaggerated media reports, Independent Professional Alliance stated on April 14, 2020 that only 6.3% of 191 COVID-19 confirmed corona patients at that point in time was Muslim[4]. On the other hand, an analysis of COVID-19 related deaths in the early phase of the pandemic conducted by the current author revealed that of the 7 COVID 19 deaths reported as of April 15, three were identified as Muslims (Silva, 2020a). The religious identity of the deceased was established through observation of summary funerals held in front of television cameras in order to dispose the dead bodies. This gives a Muslim ratio of 43% COVID-related deaths at that stage. This certainly gives a disproportionate ratio of Muslim mortality caused by the disease, relative to its 10% presence in the population as per the population census of 2012. Similarly, in webinar relating to the burial issue held in 2021, a Muslim social activist reported that nearly one-third of all COVID-19 related deaths in Sri Lanka as at that point in time were among the Muslims.

While this may not be a reliable index of actual morbidity level in different communities, disease control programme should certainly be guided by valid information regarding disease prevalence in different communities. For instance, if Muslims indeed reported a higher COVID-19 prevalence compared to other communities in the country, this is something to be recognized and addressed in terms of health education, targeting of interventions, and involving the community in responding to the pandemic. Muslims may in fact be more vulnerable to COVID-19 infection by virtue of their bazar type settlement pattern, livelihoods such as mobile trade, patterns of worship (e.g. congregation in mosques for five-times daily prayer), and local and international travel particularly for business purposes. All these are sensitive aspects of social life that call for effective community participation in the disease control programme. This is also an area where professional inputs from social sciences including sociology, psychology and social work could make a difference in terms of modifying interventions in culturally appropriate ways and enhancing their effectiveness in respect of containing the pandemic.

4. DISTORTED MEDIA REPORTS

There were many instances where mainstream media and social media presented distorted information to drive home the view that Muslims are super spreaders of COVID-19 in Sri Lanka. In one such instance a TV channel showed in its news telecast a large gathering in a mosque, reportedly violating a ban on public gathering at the time This was later shared in a Facebook group with over 70,000 members as a distinctly anti-social move by the relevant group of Muslims[5]. Widely circulated stories like this were deployed to create a narrative of Muslims as super spreaders of the disease in Sri Lanka. However, subsequent enquiry revealed that this story was false and that the gathering had been organized by the health authorities in the area to conduct PCR testing.

4 https://srilankabrief.org/2020/04/status-statement-ii-sri-lankas-response-to-covid-19-alliance-of-independent-professionals/

5 https://www.boomlive.in/world/coronavirus/false-muslims-ignore-covid-19-curfew-convene-at-mosque-in-sri-lanka-7603

Similar stories were deployed to justify the mandatory cremation of Muslims who died of a COVID-19. The reasons given by so-called experts for insisting on mandatory cremation were rather dubious in some instances. For example, BBC spoke to a Consultant Forensic Pathologist attached to the Ministry of Health who was dealing with the disposal of dead bodies. While insisting that the government had nothing against Muslims as such, he also noted that there was "a small fear about whether the virus can be used for unauthorised activities. Maybe an unwanted person could get access to a body and it could be used as a biological weapon." This imagery of COVID-19 germ as a biological weapon that one community used against another was explicitly stated in social media posts examined in the next section.

5. SOCIAL MEDIA POSTS WITH HATE CONTENT DIRECTED

Figure 4. Facebook Post Blaming the Muslims for Successive Disasters in Sri Lanka, namely Easter Sunday attacks in 2019 and COVID-19 pandemic 2020

AGAINST MUSLIMS

We present here (Figure 4) a Facebook post clearly identifying a linkage and continuity in the involvement of Muslims in 4/21 and the pandemic.

This post clearly blames the Muslims for both the terrorist attack in 2019 and the pandemic that broke out in 2020. These two vastly different disasters are interpreted as examples of bio terror mediated by the Muslim actors, in one as armed suicide bombers and in the other as patients harbouring the COVID-19 virus. The imagery is similar to images of bio-terror following 9/11 attacks. Importantly COVID-19 infection is presented here as a weapon of mass destruction deliberately used by Muslim actors to harm the ethnic and religious others as mischievously portrayed in Islamophobia in general. Interestingly, this social media post was invented in India and was later adopted in Sri Lanka modifying it to suit the actual events in Sri Lanka (Desai and Amarasingam, 2020). In the Indian context, the vastly contested term 'corona-jihad' was used to characterize a so-called jihadist tendency among Muslims to deploy the virus as an instrument of terrorism. Hindi text within the modified post confirms the Indian origin of this Facebook post. The modified post in Sri Lanka clearly illustrates the infective character of hate speech between countries as well as within countries, as indeed the case with corona virus as well. The well-known medical fact that people are innocent victims of COVID-19 virus irrespective of their identity is deliberately ignored in this post. This is post that clearly undermines the UN slogan that "we are in it together".

The malicious view that Muslims were super spreaders of COVID-19 in Sri Lanka is conveyed in a variety of Sinhala Facebook posts that circulated in in the early phase of the pandemic. Figure 5 gives a different twist to the narrative with COVID being imaginatively understood as a product of globalization processes.

This powerful Facebook post composed in pungent Sinhala mischievously attributed an uncomplimentary role to Muslims in the propagation of the corona epidemic in Sri Lanka. Chinese are identified here as the master mind behind the pandemic in the same way they produce various other commodities for the global marker. Importantly, Muslim traders, the same people who were the target of much of anti-Muslim violence as well as communal-minded shop boycott campaigns in Sri Lanka, carried out concomitantly with violence, are the targets of this Facebook post which is composed deploying the neoliberal

Figure 5. A Facebook Post in Sinhala

Source: https://www.facebook.com/ photo/?fbid=12099 4422874508&set=a.100605868246697) Accessed on April 2, 2020.

Translation

Made in China
Brand Name Corona
Distribution throughout Sri Lanka
By none other than Nana
(Nana is a Sinhala slang word for the ubiquitous Muslim trader in the distribution chain)

Composition and Art Work by 'Athal Fun Lovers'

language of mass production, marketing and consumption and attributed figuratively to the Chinese, Muslim traders and the Sinhala consumers respectively. There is pun intended in the rhyming words such as cheena, nana and corona, all identified as inevitable neoliberal evils confronting "we the Sinhalese". Even though this post grossly oversimplifies the parameters of the pandemic reducing it to two players, the attribution of a neoliberal logic to the pandemic shifts the blame game in a new direction with local Muslim traders configured as a mere instrument of this play of market forces. While Muslims are still blamed for the spread of the infections, they are spared of being inventors of the virus and deliberate bio terrorists using the virus to harm their enemies.

The blame narrative is twisted here to blame the Muslims for both the neoliberal push and the pandemic thrust in Sri Lanka, identified as related calamities in the local context. In these narratives Muslims are repeatedly blamed for all the calamities encountered by Sri Lanka in recent years including neoliberal disorders, security threats posed by terrorism and public health disorders caused by the pandemic.

Unlike in Figure 4 and Figure 5, where Muslim community as a whole is blamed for spreading the disease, in Figure 6, an actual

Figure 6. A Facebook post blaming an individual Muslim trader, identified through his photograph, for spreading the disease

Muslim trader from Akurana town is blamed for spreading the disease in the local area, having been infected during a business visit to India. Prejudice against Muslim traders is reiterated in this post that also point to his seemingly irresponsible behaviour in respect of infecting others.

These examples illustrate how mass media and social media in Sri Lanka targeted Muslim community in their reporting on COVID-19 and explaining its spread. These are clearly deliberate efforts to blame the ethnic and religious other as the cause of infection. Muslims are singled out as the super spreaders of the disease in a way that discredits the community and hold them accountable for triggering the pandemic at critical points. These obviously distorted and twisted narratives may resonate with biases and prejudices entrenched

in sections of the Sinhala community reinforced by a popular culture rather than robust empirical experiences and findings. How far such biased views and perceptions take attention away from one's own complicity in factors contributing to the escalation of the pandemic requires further investigation. What we have not been able to establish is how this representation and attribution impact on access to health care resources and other services in a country where Sinhala nationalist actors with a parochial mind set increasingly serve as gate keepers of various kinds. The denial of Muslim burial rights for persons who died of the disease is one instance where biased opinions clearly served to deny a cultural right of Muslims recognized in most countries in the world. Fortunately, this was corrected in February 2021, more than one year after the onset of the pandemic and causing considerable trauma to the Muslim community side by side with painful exposure to the pandemic itself.

6. POLICY IMPLICATIONS

First, efforts must be made to identify and implement required interventions for addressing hate speech. Effective interventions by the state, civil society, and private sector actors such as media agencies and social media platforms must be identified side by side with the efforts to contain the pandemic with required medical and public health interventions.

Second, the theme "we are all in it together" must be reinforced as a component of all health education efforts and training programmes relating to the pandemic response. The idea is to identify and respond to COVID-19 as a common threat to humankind irrespective of who they are and how they are individually affected by the pandemic.

Third, community participation must be promoted in all aspects of the disease control programme, including monitoring and evaluation, preparation of health and safety guidelines, diagnosis, quarantine processes and vaccination programme. This will enable the control programme to be responsive to people's needs and concerns in ways that facilitate more effective implementation of the activities, for people to understand the rationale behind the procedures followed and influence policies and programmes that affect their lives.

Fourth, there is a need to understand how disease prevalence varies according to socio-economic parameters and community dimensions and takes these differences into consideration in designing and implementing the disease control programme.

Fifth, social science inputs must be satisfactorily utilized in addressing human behavioural issues related to understanding and responding to the pandemic as it is unfolding in different social and economic contexts and presents new challenges for existing and new interventions.

REFERENCES

Desai, S. and Amarasingam, A. (2020). *Corona Jihad: COVID-19, Misinformation and Anti-Muslim Violence in India*. London: ISD.

de Kloet, J., Lin, J. and Chow, Y.F. (2020). "'We are doing better': Biopolitical nationalism and the COVID-19 virus in East Asia". *European Journal of Cultural Studies* 2020, Vol. 23, No.4, pp.635–640.

Ng, E. (2020). "Editorial: The Pandemic of Hate Is Giving Novel Coronavirus Disease (COVID-19) a Helping Hand". *American Journal of Tropical Medicine and Hygiene*, Vol. 102, No. 6: 1158-1159.

Silva, K.T. (2020a). *Identity, Infection and Fear: A Preliminary Analysis of COVID-19 Drivers and Responses in Sri Lanka*. Colombo: ICES, 2020. http://ices.lk/publications/identity-infection-and-fear/

Silva, K.T. (2020b). Stigma and Panic about COVID-19 in Sri Lanka. *Journal of Humanities and Social Sciences* 3 (2): 37-66.

Strong, P.M. (1990). "Epidemic psychology: a model". *Sociology of Health and Illness*, Vol. 12, No. 3, pp. 249–59.

II. Education

"Policies, strategies, and other interventions to build a resilient general education system in the country": Panel discussion on 'Education during COVID-19 pandemic'

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ABSTRACT

Formal school-based pre-school through Grades 1 -13 general education is the foundation for all higher and tertiary education. Education being a behavioral science, shaping up behaviors, values and skills is more important than the learning of content knowledge. The Covid-19 pandemic has stopped schooling for all children across the globe and Sri Lanka is no exception. In the whole of last year out of 210 expected days for schooling schools opened for only 62 days. Though several measures were taken by the authorities such as the TV Based Gurugedara, Internet based e-Thaksalawa, NIE YouTube channel, Radio based Gurugedara and even the distribution of printed materials to home by the authorities at the central and in the provincial levels, the lack of access to the Internet, lack of an appropriate devise to receive lessons, etc. have caused setbacks. The most of the affected are the youngest children at pre-school, grade 1 and 2 levels and the marginalised poor who are mostly not reached by the initiated interventions. Authorities are now exploring new avenues of reaching the unaccessed children through TV and home-based learning methods.

Keywords: Education and Covid-19 pandemic, Alternative general education, E-Thaksalawa and general education, Resilient general education

With *Covid-19* education is now in the back-burner. All schools across the globe remain closed. The global situation is 1.6 billion children are out of school. No one has shown a way out of the problem to find how we could educate the youngest age group comprising preschoolers and Grades one and two children. "The COVID-19 pandemic has been the worst shock to education systems in a century, with more than 1.6 billion children and youth not being able to attend school for months, and many are still not back in school. UNESCO is working with ministries of education, public and private partners and civil society to ensure continued learning for all children and youth" – (UNESCO 2020[1]). In the more developed countries the Internet is available in all homes, and has a device to enable the use the Internet. Developing countries — this includes upper and low-middle income countries — lack such universal access to Internet. Even "digital divide" in access exists across regions and countries, and such divides within countries make the impact of the Internet disproportionately disadvantageous to rural communities and the poor. In the context of *Covid-19,* broadband (or high-speed) Internet access is essential for

1 UNESCO: UNESCO's support: Educational response to COVID-19: https://en.unesco.org/covid19/educationresponse/support

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economic and human development in both developed and developing countries (World Bank[2]). The pandemic has placed serious limitations on the mobility of people and the worst affected are younger children under full control of the parents. Parent's desire to protect their children. Making them secure from Covid is a serious concern.

The socioeconomic disparities and inequities had been major concerns for developers, development advocates and development workers; and governments are obliged to take affirmative steps to mitigate socialeconomic disparities. The 'Education for All' (EFA) the Jomteien world conference on 26th March 1990 in Thailand was the first step towards universal access to education. Since then, the Senegal Dakar initiative, followed by the establishment of the Millennium Development Goals (MDG) in 2000–2015, and renewed initiative and the global declaration of Sustainable Development Goals (SDG) setting targets for 2015–2030 on 17 key SDG goals were geared for all governments to address disparities and mitigate poverty. In the eight MDG Goals one was to end poverty and hunger and Goal two was to achieve universal primary education (MDG Report 2015[3]). The Rio de Janeiro, June 2012 initiative and subsequent endorsement by the UN affirmed the SDG goals with the first four again addressing issues of poverty, hunger, health and education and the vast disparities in society. "*Everything we do during and after this crisis [COVID-19] must be with a strong focus on building more equal, inclusive and sustainable economies and societies that are more resilient in the face of pandemics, climate change, and the many other global challenges we face*" – (Guterres 2020[4]). Guterres, Secretary-General, United Nations points out that all reviews show there is slow progress yet and disparities are widening. The new addition to disparities is the Digital Divide and in amidst *Covid-19* it is even more serious than before because of the limits on human mobility aggravated by lockdowns imposed for movements protection from *Covid-19* hurt the poor by restricting their ability to make a living.

It is in this context that this conference examines resilience of education.

1. WHAT IS A RESILIENT SYSTEM OF EDUCATION?

'Resilience means sustaining high levels performance despite the presence of stressful events and conditions.' Can we sustain high level of performance in education despite of the threat of Covid-19. How is the issue to be addressed?

The damage of *Covid-19* on literacy as well as cognitive and social development of children is not yet felt by the society. The pandemic is adversely affecting formal schooling. It is not only that children do not learn cognitive skills to read and write, more seriously the child has lost the opportunity to socialization with their peer group. Sri Lanka has two strengths in the education sector: i.e. educated parents and the schools close to home. Sri Lanka is the only country in South Asia having a school within 2 kilometer radius. These two factors could serve as the basis of resilience. The *Covid-19* challenge has to capitalize on these two factors.

1.1. Educated Population

The most important positive factor is that Sri Lanka has a highly literate population with a literacy rate of over 92%. Moreover over 70% of population has at least Junior Secondary Education with a good level of attainment. Of parents of the present schooling generation for primary school children in the age range of 5–10 their parents are in the age group of 20–35 and over 80% has completed over 9 years of compulsory education and 70% Junior Secondary with GCE ordinary Level (11 years of schooling) qualification. This is confirmed by the fact that over the last five decades the Junior Secondary Completion rates in Sri Lanka is

2 https://www.worldbank.org/en/topic/digitaldevelopment/brief/connecting-for-inclusion-broadband-access-for-all

3 United Nations: The Millennium Development Goals Report (2015) : https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%20 2015%20rev%20(July%201).pdf

4 António Guterres, Secretary-General, United Nations (2020)- The Sustainable Goals Report 2020

well over 80%. These parents know the value of education for their children. They do whatever is possible to see that their children are literate and educated. This single factor is the foundation of resilience that the government should count on. Whatever the steps that Sri Lanka's policy makers take to sustain the high level of performance in education, the system has to capitalize on the educated parents – (Sedere, 2016[5])

1.2. Small School Closer to home

Sri Lanka also has a well spread out school system. Despite disparity among schools, an average student can find a primary school within 2 km radius of home. Although there are schools with excessive enrolment, more than 50% of the schools have fewer than 200 students and this helps Sri Lanka to easily adhere to *Covid-19* heath guidelines, particularly the one meter social distance. Most parents like to send their child to bigger schools and with the *Covid-19 pandemic* all big-schools, with over one thousand students, are unable to open the school subject to the required social distance, whereas the small schools could be opened.

The danger is that Covid-19 could spread through school children because of child behavior and way of life. Children are used to being close to their friends, share things freely, play together hold hands and share friendship. The Covid-19 safety guidelines are difficult to follow in such surroundings. Inability to follow essential guidelines such as Social Distance, Wearing of Mask, Hand Washing, and Sanitization could take the situation beyond control.

2. POSSIBLE IMPACT OF COVID-19 ON EDUCATION

If schools remain closed and no alternative education is offered to children at home, the long term impact could be perilous. Since 1944, Sri Lanka gradually increased opportunities for free education. The school system grew from 4000 schools in 1944 to over 10,000 schools by 1965 with every village having a school. The 54 Central Schools expanded to 1044 (1AB Schools). The Year 2018 Statistics for Education (Ministry of Education 2019) shows that 98.5% of the entry cohort to Grade 1 in school had completed Grade 5 of primary school. This means just before the Covid-19 threat Sri Lanka had high degree of internal efficiency with high degree of grade completion and very low degree of school dropouts. Except a small percentage all young children completing primary education achieved basic literacy. Will this be sustained under the pandemic? In 2020 of the 210 days of expected schooling, Covid-19 denied the children schooling on most days leading to an average attendance of 62 days.

- Did the students in Grade 1, 2, and 3 achieve the basic skills expected from Key Stage One of primary education?
- Will the most important Indicators of Sustainable Development Goals #4 Educational Achievement be satisfied by 2030?

The fear is for children of the marginalised population. Covid-19 denied casual employment and opportunity to earn a basic living wage for most daily waged laborers. Social inequity and disparities seriously hamper opportunities for the children of the poor to learn at home. Most poor parents have neither the Internet nor a devise for learning, besides their lack of the necessary level of education to coach their children. Only 40% of Sri Lankan home Internet connection and less than 30% have a suitable devise to follow lessons on-line.

The lack of on-line learning opportunities at homes imposes serious handicaps. The virtual classrooms and advanced learning platforms that are available are of no use to the marginalized homes by Internet.

A resilient system of education to take on the Covid-19 threat to schooling has to be designed taking these factors to consideration.

5 Sedere Upali M (2016): http://nie.lk/pdffiles/other/Kannanga2016_English.pdf

3. WHAT STEPS HAS SRI LANKA TAKEN TO FACE IT?

Opening schools as usual could be a false dream for a few more years. Therefore, alternative education is mandatory. So far, the State Ministry of Educational Reforms together with the National Institute of Education (NIE) have taken several important measures to reach students to continue to learn at home:

3.1. On-line Learning: e-Thaksalawa

The national on-line education platform is e-Thaksalawa which has lessons for Grades 1 to 13. The government has given free-data facility or 'White Listing' for e-Thaksalawa. Anyone using e-Thaksalawa can download any lesson free of charge for the data. This facility is accessed by many with daily logging-in exceeding a million, yet only 40% of students have Internet connectivity and even less a devise to access it. The intention of the government is to provide Internet to all, but it will take a few more years. However, all schools are expected to have fiber optic connection within an year.

Many teachers and schools have started teaching on-line using devises such as Zoom, Teams and Skype. Many institutions have developed virtual learning systems. This is mostly true of higher education institutions, private schools and schools catering to the more affluent people. However, such lessons are not always well designed as the teachers and lecturers lack formal training in the designing of learning material for on-line teaching.

3.2. TV Lessons and 'Gurugedara'

Nearly 95% of the Sri Lankan homes have a Television. Hence Television (TV) access can be used to reach almost all homes for teaching. Taking this into account, the Ministry and the NIE started the 'Gurugedara' television teaching program in March 2020. Since the 2nd wave of Covid-19 this was further expanded, and the Media Ministry, particularly the Rupavahini Corporation offered two dedicated TV Channels (Eye and Nethra Channels) to provide lessons in Sinhala and Tamil for Grades 3 to 13. To date nearly 5000 TV lessons have been telecast and have been accessed by most of the students. However, this has serious handicaps as TV time is expensive and cannot offer lessons in all the subjects to the required extent. Preparation of lessons was a highly challenging task under the Covid pandemic. NIE stretched its resources to the fullest to successfully cater to most Grades.

3.3. NIE YouTube Channel

The Television and E-Thaksalawa are further supported by the NIE YouTube Channel to offer a large number of lessons from Grade 1 to 13. Many students access it. Yet Internet connectivity and the lack of a devise to reach remain serious limitations.

3.4. Radio Lessons

Radio is the commonest medium accessible to all. Yet, it was difficult to secure time slots on Radio owing to pre-booked paid programs. The State Ministry of Educational Reforms has now set up Radio Education in collaboration with regional radio networks of the Sri Lanka Broadcasting Corporation; and UVA Radio, Ruhunu Radio Service, Kandurata Radio and Rajarata Radio already offer four hours of education programs daily. Other regions also will be covered by such regional services in time to come.

4. EDUCATIONAL REFORMS AND THE PROPOSED RESILIENT SYSTEM OF EDUCATION?

4.1. Curriculum Reforms

The Sri Lankan school system will have a new curriculum in January 2023. The curriculum addresses the critical issues discussed above and to offer a more skills-oriented modular curriculum based on self-learning and authentic learning principles. If the school system opened and the normality setts in these modules will be utilized at school and classrooms in formal learning. If the pandemic continues a module is prepared for 10 hours of learning and a student should be able to learn it with minimal teacher assistance as authentic learning allows one to construct

knowledge through the proposed instructional activities. This will be a new approach to Sri Lankan students and teachers. This may help to sustain learning that Sri Lanka has maintained.

4.2. Home-Based Learning System

The proposed learning system is based on Self-Learning principles, and self-learning allows a student to carry out home-based activities to construct knowledge. The constructivist theory of education is employed here to generate a learning process that allows the child to find content and construct knowledge. The home-based learning system will have the teacher serving as a guide, facilitator, mentor and monitor of learning by the student. Of course, the teacher will also teach where necessary. The teacher has to initiate activities for active learning. The student will return to school if the old normalcy returns to us. Otherwise, under the new normal a teacher will assign the study module and students will follow the guidelines as given in the module and continue to learn through activities. Students and the teacher will come to school for a day or two in the week confining to the health rules and examine each child's work and assess progress, coverage, and grade learning on the assessment rubrics provided for the students in the study module and teachers in the teacher guide. Then teacher will assign the study modules for the following week. With limited formal meetings of the students and the teacher learning will continue. We hope that this approach will help to the students to keep learning and achieve the expected the learning outcomes.

4.3. 'Gurugedara' TV Based Learning

Given the present context and the available modes of learning the TV-based teaching is the most feasible modality for reaching all students and homes. Currently, the lack of availability of TV time poses serious handicaps. Although TV time is expensive, the Rupavahini Corporation has generously assisted in this venture. However, with two dedicated TV Channels one for Sinhala medium students and the other for the Tamil medium students, the maximum of six core subjects could be covered by neglecting the initial grades, namely pre-school and primary school. There is a limit to TV coverage as well. No TV channel is viewed by all homes in Sri Lanka. ITN has the widest coverage in Sri Lanka. However, Sri Lanka needs Satellite TV network to reach all homes. Satellite TV may be soon available in Sri Lanka. If it comes it can make a great contribution to address the situation. The need is for each grade level to have a dedicated channel. The Ministry of Education is trying to achieve this to ensure literacy and education and have a fairly resilient system in Sri Lanka. If the TV can offer Pre-school, Grades 1 and 2 lessons on TV with live classes it will be help to literate the very young children. The TV lessons will be supported with an activity book for students to use at home with parental guidance. This will help in mitigation of illiteracy. There are very effective pre-school and primary school programs on TV in developed countries for children to enable the learner to acquire basic literacy.

4.4. On-line Learning

Telecommunication Regulatory Commission (TRC) and Sri Lanka Telecom (SLT) are exploring the possibility of providing Optical fibre connections to all schools. It is projected that all new and old national schools about 1170 schools will get the optical fiber internet connections by the end of year 2021. The government is planning to provide internet to all 10165 schools by the end of 2023. Internet connectivity to All Schools would be a big advantage as this enable children in all schools to use e-thaksalwa, the NIE YouTube Chanel, etc. at school. All 5000 small schools with less than 200 students will also get a Smart TV Classroom by the end of year 2021. This will reduce the inequity and the digital divide to some extent. The monthly payments for the internet facility to schools is proposed to be paid by the treasury. Moreover, as a by-product of the Optical fibre lines to schools all communities will also have the access to obtain Internet connections to homes, of course paying for the service Optical fiber connection. This would increase the percentage of home having internet connections. Internet facility

to schools will facilitate blended learning to students and enhance quality of education. This will be the future for learning whether or not Covid-19 prevails. Even when the Covid-19 threat fades off, the blended learning will be needed to prepare our students for the emerging IT literacy demands of the 21st Century. Also, this will help schools to overcome the equity issues due to poor deployment of teachers.

5. REFERENCES

Sedere, U. M. (2016). Education Reforms Beyond Kannangara, Dr. C.W.W. Kannangara Memorial Lecture, #27, National Institute of Education, Maharagama, Sri Lanka http://nie.lk/pdffiles/other/Kannanga2016_English.pdf

Sustainable Goals Report 2020: https://unstats.un.org/sdgs/report/2020/#sdg-goals

https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

UNESCO: UNESCO's support: Educational response to COVID-19: https://en.unesco.org/covid19/educationresponse/support

The World Bank: Connecting for Inclusion: Broadband Access for All, https://www.worldbank.org/en/topic/digitaldevelopment/brief/connecting-for-inclusion-broadband-access-for-all

Re-creating and re-positioning of the technical and vocational education and training sector to meet the needs and challenges in a pandemic context

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ABSTRACT

As of April 2020, nearly 1.6 billion students comprising 91.3% of the total student population in 188 countries have been affected by system closures caused by the COVID-19 pandemic as per UNESCO statistics. The pandemic led to change in the lifestyles of people and adversely affected the economic, health and education sectors. Technical and Vocational Education and Training(TVET) in Sri Lanka has been severely affected as skills development proved challenging amid COVID-prevention measures including social distancing. The Ministry of Skills Development, Vocational Training, Research and Innovation with the support of the Tertiary and Vocational Education Commission (TVEC) came up with several initiatives to stabilize the situation and explore feasible options to deliver training amidst challenges faced by trainees, trainers and administrative staff.

Delivery of TVET during the pandemic was explored using three methods. Firstly, the complementary television lessons and e-material were delivered using social media, websites and learning management systems. Secondly, e-Learning platforms were used to deliver the course content by deploying Virtual Learning Environments (VLE) through Learning Management Systems (LMS). Thirdly, TVET chose the blended learning model which uses an appropriate blend of online learning, face-to-face learning and skills development practical sessions to offer an immersive learning experience to the learner. Accordingly, the new normal situation was approached positively to enable trainers and learners to use innovative approaches and technologies to fulfil the current and future labour market demands.

Keywords: Blended-learning, COVID-19, Education, E-learning, TVET

1. NEW SKILLS IN RESPONSE TO CHANGES IN LABOUR MARKET AND EMPLOYMENT

The Sri Lankan economy suffered a serious blow from the COVID-19 pandemic resulting in a fall in GDP growth rate from +2.3% in 2019 to -3.6% in 2020. The Industry Sector was most affected with its GDP contribution falling from +2.6% in 2019 to -6.9% in 2020, according to data published by the annual report of Central Bank of Sri Lanka (CBSL, 2020). Sri Lanka's labour market was negatively impacted during the period with labour force participation rate falling from 52.3% to 50.6% and mean unemployment rate rising from 4.8% in 2019 to 5.5% in 2020. The number of newspaper

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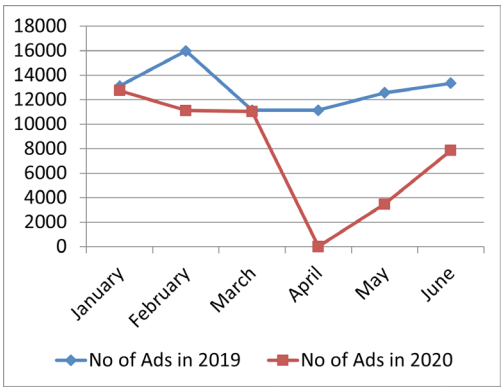

Figure 1. Newspaper Job Advertisement in the first 6 months of 2019 and 2020

(Source: TVEC Newspaper Advertisement Survey)

job advertisements fell drastically during the pandemic as shown in Figure 1 (TVEC, 2020a).

A considerable fraction of contract, temporary and daily-paid employees had been laid off owing to the shrinking of the economy and issues of cash flow in the SME sector. The informal labour market was severely affected in this scenario showing a marked downward trend in the employment of non-NVQ holders owing to the volatility of the market for unskilled workers (TVEC, 2020a). Wages of TVET graduates dropped significantly during 2020 amid considerable job losses for contract and daily-paid workers.

Despite the economic downturn and reduction in labour force participation rate, the ICT and telecommunication sectors showed an upward trend owing to the rise in ICT use and an increase in "Work From Home" (WFH) using IT and telecommunication facilities. Further, the patterns of working hours in 2020 drastically changed compared to the previous years.

Figure 2 shows that 7% lost employment and 38% shifted to working from home. Some employees in the informal sector changed employment as a result of the emergence of new jobs in the labour market. Work opportunities in sectors such as transportation of goods, health services, ICT etc. increased as a result of the pandemic. Introduction of strict health

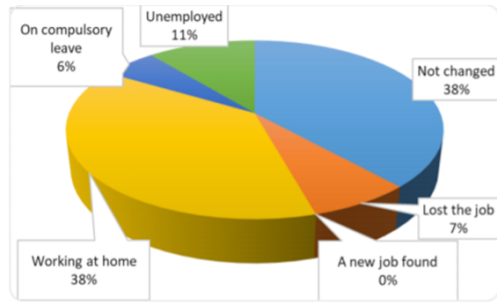

Figure 2. Change of Employment Status due to COVID-19 in Sri Lanka

(Source: The economic impact of the COVID-19 pandemic in Sri Lanka, University of Ruhuna)

guidelines altered the scope of jobs and skill requirements in certain occupations. Thereby, some competencies of the workforce needed to be realigned to match the "new normal" situation.

The transformation of jobs and work occurred during this period with changes in the sets of skills required to perform specific jobs. Face-to-face communication was transformed into IT-based communication using various web and mobile applications including social media. This boosted the demand for IT-related jobs and telecommunication jobs to meet the rising demand for remote communication and the increased use of ICT applications.

As for the direct impact of the COVID situation for operation of training centres, all schools and TVET centres were closed from March 2020 to July 2020 and started to re-open by August 2020. With the partial lockdown owing to second wave of COVID-19 in October 2020, schools and TVET centres were issued with strict health guidelines to follow when re-commencing the studies and special health precautions were issued for TVET centres to avoid physical contacts during the practical sessions.

2. RE-CREATING AND RE-POSITIONING OF TVET PROGRAMMES

Since the outbreak of the pandemic and restriction of physical gatherings,

many countries were moved towards IT learning platforms, supported by other IT applications, especially mobile applications using both synchronous and asynchronous communication methods (Jena, 2020; Ali, 2020). These applications largely support transferring theoretical knowledge and were backed by video-based material (Basilaia & Kvavadze, 2020).

Technical and Vocational Education and Training (TVET) programs in Sri Lanka adhere to National Competency Standards (NCS) with competency-based curricula and thus have a higher skills acquisition component than most educational programmes in the academically oriented curricula. A vocational qualification is awarded when a candidate is found competent to perform identified tasks or a combination of tasks that require underpinning knowledge, practical skills and relevant behavioural soft skills. Time spent to gain practical skills dominates certificate level craft training programmes and gradually reduces towards diploma level programmes. Nevertheless, practical skills are an essential key component of TVET. Therefore, the main challenge for training delivery during the pandemic with restricted practical workshop/ laboratory sessions is the imparting of practical skills. Further, COVID-19 has brought the challenge of re-skilling the workforce for the changing working environment and health and safety issues (Majumdar et al., 2020).

In the Sri Lankan TVET sector, the teaching/learning process could reach only about 50% of students during the pandemic. That led to a digital divide between urban youth who had Internet and devices and rural youth who did not have such facilities and access to necessary infrastructure. Know-how for using remote learning systems and applications was minimal among the students and the trainers. That resulted in difficulty in sustaining remote learning which was encouraged by the government and the relevant training organizations. Online learning tools such as "Zoom", "Teams" and "Meet" were extensively used in the teaching-learning process and "Whatsapp" was used as the communication platform for organizing and sharing links for such online collaborative activities.

It was reported that the access devices did not provide the expected level of performance for use with the online collaborative tools and many parents could not afford suitable devices because of their low-income levels. However, the use of devices increased substantially during this period as many trainers tried to deliver knowledge components of their courses using online collaborative tools and other ICT based learning platforms. Open Learning Management Systems (LMS), especially "Moodle", were very popular to deliver lessons while social media were greatly used for text-based communications and video-based lessons delivery.

TVEC with the support of the line Ministry and other stakeholders has published a report on reforming the vocational education system to cater for the trends in the labour market to support re-creating and re-positioning of TVET programmes (TVEC, 2020c).

3. LOCAL INITIATIVES

As local initiatives, it is imperative to develop an education system that will provide distance education with a skills-based job-oriented higher education system using self-learning, guided learning, group learning and project training to produce a creative employee. It will also encourage trainees to learn and acquire new knowledge and skills, without disrupting their employment. Online education, distance education and open learning will be used to deliver these courses in future with proper quality assurance.

3.1. TVET Centre Displays

At the centre level, COVID-19 prevention guidelines were displayed in various banners, boards and stickers as a precautionary measure. (Please see Figure 3 for information therein). Getting the message across to all trainees was the aim of displaying the boards and strict adherence was expected by the line ministry and the TVET apex body, Tertiary and Vocational Education Commission.

Figure 3. Display of COVID-19 Prevention Guidelines

(Source: TVET providers)

3.2. Open Access for e-Resources

The use of e-resources dramatically increased during the pandemic period as physical contact was severely restricted. Different initiatives were adopted to offer e-material (Vilar & Zabukovec, 2017) using web resources and social media from the respective training providers. As the apex body, Tertiary and Vocational Education Commission (TVEC) made available all National Competency Standards (NCS) online and curricula free of charge to anyone, especially prospective training providers, trainers and students during the period.

3.3. Launch of National Skills Passport

National Skills Passport (NSP) was a new initiative of Sri Lanka to recognize the skills of a person with an authenticated profile. National skills passport is a tri-partite project and the partners are the Employers Federation of Ceylon (EFC), the International Labour Organization (ILO), Colombo Office and the Tertiary and Vocational Education Commission (TVEC) under the guidance of the Ministry of Skills Development, Employment and Labour Relations. The skills profile in NSP includes National Vocational Qualification (NVQ) and confirmed experiences. This is linked to the online portal (www.nsp.gov.lk) where anyone could verify using the QR code the credentials of a person. This will support recognition of individual skills related to re-skilling, up-skilling and certification. Returning migrants are encouraged to obtain the skills passport after transforming informal skills to formal qualifications through recognition of prior learning (RPL) process. This initiative supports the government's long-term skills planning for the economy and facilitates easier matching of opportunities for future employment creation. The system further supports tracking the employability of the NVQ holders with an up-to-date database. The NSP database will provide information to streamline migrant workers and returnee workers by skill-type, and bridge the gaps in the labour market both locally and overseas. Eventually, NSP will help attract migrant returnee workers to industries

such as construction, which are currently facing high demand, with no local workers to bridge the gap.

3.4. Implementing e-Learning in TVET

Several recommendations were made in the broad areas of infrastructure, training and institutional requirements for the development and implementation of e-Learning in the TVET sector in Sri Lanka. Infrastructure development was a key recommendation with the setting up of a centralized server facility with an internet connection to every training centre. Trainer capacity building and thereby converting traditional training course modules to e-Learning based material were among important recommended activities (Jayalath, 2010).

Delivery of TVET through e-Learning entails a blended learning approach. Learning that using face-to-face interaction and via the online medium is referred to as blended learning here. The success of the blended mode depends on building a sustainable online learner community, who share experiences using critical reflections on learning themes. Technological interaction and learning maturity help maintain a sustainable virtual community with transparent and consistent communication practices. Practical sessions need more instructor attention to provide hands-on experience to convey the required competencies. Learner progress depends on factors such as motivation and engagement with the learning content and the flow.

3.5. Implementing Blended Learning in TVET

Blended- learning will have the right "blend" of physical and virtual learning. Physical components comprise face-to-face learning, assignments, projects, practical and on-the-job training among others. Virtual components comprise discussion forums, interactive digital contents, virtual lessons and classes etc. TVET desires the blended learning model owing to its advantage of asynchronous components which provide more trainer-learner flexibility. Blended learning supports work-based learning and addresses issues such as time, context and the pace of an individual learner. The quality criterion for e-Learning has been transformed to match a blended learning model by adding the relevant additional components and TVEC has published a manual and quality criterion for registering Blended/eLearning/online courses in the TVET sector (TVEC, 2020b). Roadmap, which is proposed to implement distance learning in terms of supporting e-material, e-Learning and blended-learning provide guidance for the TVET providers with milestones discussed in next section.

3.5.1. Roadmap for the Development of a Distance Learning System in the TVET Sector

The roadmap for development of a distance learning system in the TVET sector has been developed in consultation with different stakeholders and proposed for implementation in the TVET sector (Jayalath, 2020). The following sections describe each activity to implement by the respective training providers with the coordination of the central agency handling the quality assurance.

Develop blended e-Learning strategy with leadership and planning

Prepare a shared vision document considering the use of new and emerging technologies focusing on the delivery of vocational education programs. The document shall state how other management and administration functions would support in developing blended e-Learning development and implementation. A suitable policy needs to be established for strengthening the delivery of the knowledge component of every course with a step-by-step trainee engagement plan. Social and institutional acceptance is mandatory with the proper quality assurance of e-Learning courses. Leadership support is critical to the process of transforming the delivery and assessment system from traditional learning to blended learning.

Develop e-Learning culture in TVET institutes

TVET trainers must be encouraged to use the e-contents available free of intellectual property restrictions on the web and use e-Learning with the active participation of trainers and trainees. It is encouraged to use the Learning Management System (LMS) to upload the content and arrange online learning activities. Due recognition and acceptance should be granted by employers and society to blended e-Learning course, on par with classroom/lab learning provided in the institutes.

Develop ICT infrastructure

All TVET centres should be equipped with a range of ICT equipment with stable broadband Internet connectivity. Each trainee must have at his/her disposal a device to access contents with a free access policy for all learning content. The number of courses with local content and courses in local languages must be increased and made readily available for free access. Content development or acquisition needs to be strengthened to make trilingual local content available in all craftsman level courses. An E-Learning unit or a dedicated section needs to be established for administration and maintenance of the central system.

3.5.2. Trainer Training on e-Learning development and implementation

All trainers and training managers shall undergo e-Learning development and implementation courses online and build capacity to convert their existing courses and/or start new courses for delivery in the blended e-Learning mode. Trainers must be encouraged to promote peer learning and peer validation of courses and contents among trainees to improve the quality of delivery. Trainers must be instructed to adhere to e-Learning quality criteria stipulated by the TVEC. Training of Trainer (TOT) programs need to be formalized and mandatory for accreditation of training programs.

Quality Assurance of Online, e-Learning and Distance Learning Programs

TVEC as the apex body is responsible for quality assurance of e-Learning courses in the TVET sector in Sri Lanka. Development of quality standards is a requirement for accreditation of e-Learning courses (Jayalath, 2014). Accordingly, TVEC has developed quality standards with stakeholder participation including private and public sector training organizations, industry and universities by benchmarking with Open "ECB Quality Check" in Europe (Ehlers & Joosten, 2009).

Assessment of Students following blended Learning Courses in TVET

Assessment being a key element in the TVET system, it should be carefully implemented to maintain the quality of the output. Continuous assessments and course end evaluations must be embedded in the online/offline modes to support monitoring of trainee performance. The knowledge component of the assessments could be fully implemented in the online mode which offers greater effectiveness and efficiency than offline assessments. Item banks need to be established to implement the testing facility by transforming existing IT centres into online testing centres.

Develop e-Learning as an integral part of all TVET courses as a means of delivering entire knowledge component

Trainers must be equipped with the necessary tools, methodologies and interactive material to convert the entire knowledge component of the course to online content. All trainees must be provided with orientation training to access online content and follow a course with the support of tutors, content and relevant teaching-learning activities.

Implement supporting courses for Apprenticeship Training

It is required to set up blended courses for Apprenticeship Training programs in enterprises with the support of other

infrastructure and resources. Online programs need to be established for the capacity building of inspectors and other related staff in the system. This could be linked with the industry as a facilitation role in the online system with a proper digital platform for the TVET sector and industry information. Mobile learning could be explored for possible knowledge transfer during the free time of learners (Mahazir et al., 2015).

4. REGIONAL AND GLOBAL INITIATIVES

Measures have been adopted in the countries of South Asia to continue education with some innovative approaches. Access has not been very successful owing to lack of infrastructure, inadequate awareness and prevalence of poverty. Online classes in some countries have widened the digital divide. Some countries seek to use television and radio which have wider coverage than broadband Internet.

However, opening schools and TVET institutes will have greater risk due to adhering to health measures is difficult and costly. Considering the rising number of victims, online and distance methods are preferred to avoid close contacts. International Labour Organization has come up with a policy response to address protecting workplaces and supporting employment while stimulating the economy and labour demand with finding solutions through social dialogue as shown in Figure 4 (ILO Policy Brief, 2020).

5. CHALLENGES AND OPPORTUNITIES

5.1. Main challenges to TVET continuity

TVET systems face challenges in responding quickly and adequately to changing skill demands. To help address the serious economic disruption caused by the pandemic, it will be especially important that restrictions to demand-responsive training provision are addressed and that training programs and skill development systems are appropriately reimagined, reset and reworked taking into account:

- Schools and many businesses are closed and the health emergency is at its peak;

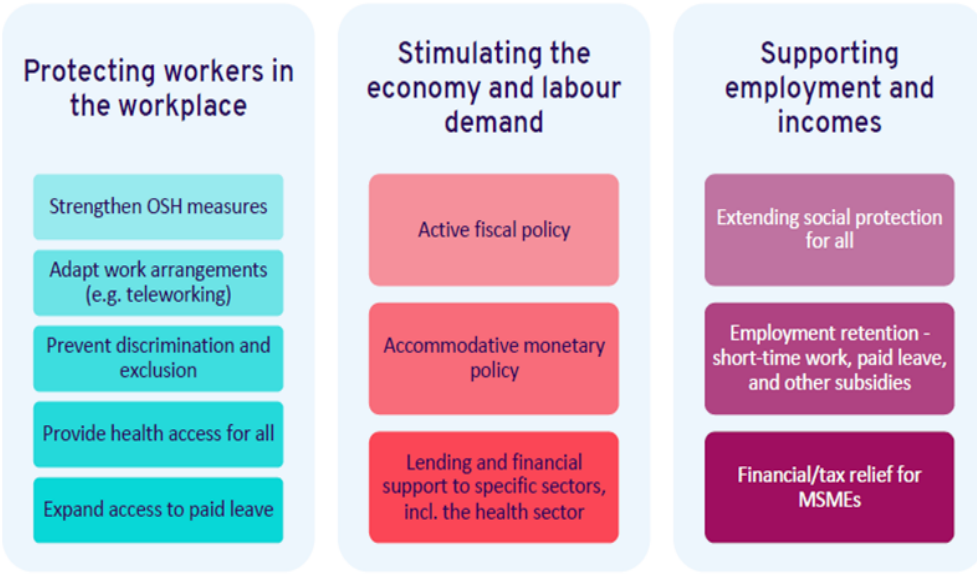

Figure 4. Policy framework: Three key pillars to fight Covid-19 based on International Labour Standards

(Source: ILO Policy Brief, 2020)

- TVET's focus on practical skills and its potential to deliver short-term, targeted and modular training can be harnessed to rapidly up-skill workers in essential sectors and to reskill personnel to engage in the emergency response. TVET's focus on work-readiness could also imply that TVET students could relatively easily be engaged in the emergency response

5.2. Possibilities and opportunities in TVET during the pandemic

During the COVID-19 pandemic, teaching and learning has moved from classrooms to remote access, facilitated by the Internet, television, radio, or printed material. But the extent to which learning can occur outside the classroom is constrained by many factors, which are most compelling in low-income contexts and for vulnerable students. Owing to the change in employment practices, relevant changes in TVET need to be more focused on challenges relating to health-related issues. Learning new content in the context of change in the kind of work in the workplace and remote working need to be embedded into TVET curricula to address the demands of the "new normal" situation (Hoftijzer et al., 2020).

6. RECOMMENDATIONS AND CONCLUSION

Owing to the pandemic, the learning paradigms have shifted towards self-led learning and/or attention to individual learning. This is in line with self-paced self-learning using e-Learning which could be rather more student-centred with Artificial Intelligence supported systems for individual adaptable learning systems. This also could deploy motivational mechanisms such as "gamification" for an immersive learning experience making learning as game-like situations in TVET (Jayalath & Esichaikul, 2020). To deploy blended learning in the TVET context, the following steps are proposed to successfully implement the process.

6.1. Set up of Steering Committee for Project Implementation

A Steering Committee shall be set up for project implementation to evaluate implementation, challenges and possible solutions to the TVET providers in distance mode. A centralized resource pool shall be maintained to provide necessary assistance and consultation to start new courses and convert existing courses into the distance mode.

6.2. Maintaining a Strong Monitoring Phase

The entire e-Learning process should be monitored by a team to improve overall performance of the system. Further, the monitoring process should be sub-divided into salient aspects such as training delivery, online examinations, submission of assignments, user feedback, technical performance, etc.

6.3. Policy for Connectivity

A free data access policy for education should be provided for all users engaged with the e-Learning platforms and other educational resources. Appropriate concessions in connection charges should be given to instructors and students to encourage their use of online systems. In Sri Lanka, there are only a few public and private Internet Service Provider (ISP) companies that provide data connection facilities. However, access to data may face difficulties in remote locations.

6.4. Online Digital Information and Resources Platform

It is required to establish an Online Digital Information and Resources Platform (ODIRP) to maintain training centre information, student information, course information, staff information, assessment information and quality-related information. This system needs to analyze and visualize sector data and link with labour market information to facilitate informed decisions regarding the human resource demand of the industry. This information could be used as career guidance tools. Such a centrally managed data system is

central to assess the overall performance of the TVET sector.

6.5. Virtual Library

A Virtual library should be attached to the e-Learning system where instructors and students can gain the relevant subject knowledge by referring to online material such as video programs, audio programs and E-books. Therefore, the respective reference materials should desirably be stored in a virtual library facilitating access by current and future students.

7. CONCLUSIONS

During the pandemic, the closure of TVET centres for in-class learning had a negative impact on the teaching-learning process of students in all districts of Sri Lanka. Thus the only options available were online, distance and blended learning methods to suit the learning style of the student in his/her field of knowledge, context and pace. Innovation in the teaching-learning process with equitable, inclusive access and better connectivity could be promising. Online digital content creation needs to be strengthened to support the production of quality learning content.

In implementing distance learning using ICT and other means, it is recommended to support trainers, and trainees must be offered the necessary devices to access lessons and broadband connectivity to the Internet at a concessionary price with instalments. The use of the Internet need to be free for education as a government policy to assure the right of every student to education, even in remote, poor and vulnerable situations. The trainers must be given proper training to use the necessary devices and applications related to the delivery of lessons, including basic ICT skills. Also, the expertise to develop online content is required for a trainer to develop his/her content and lessons to deliver online. Policies that are conducive to promote online learning and blended learning must be developed in support of informal learning including assessments and evaluations.

REFERENCES

Ali, W. (2020). Online and remote learning in higher education institutes: A necessity in light of COVID-19 pandemic. *Higher Education Studies*, 10(3), 16-25.

Basilaia, G., & Kvavadze, D. (2020). Transition to Online Education in Schools during a SARS-CoV-2 Coronavirus (COVID-19) Pandemic in Georgia. *Pedagogical Research*, 5(4), Article e0060

CBSL (2020). Annual Report of Central Bank of Sri Lanka 2020. https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2020

Ehlers, U. D., & Joosten, J. (2009). Quality evaluation of e-Learning through an international peer-review community, e-Learning Papers, www.elearningpapers.eu, December 2009 • ISSN 1887-1542

Hoftijzer, M., Levin, V., Santos, I., & Weber, M. (2020). TVET Systems' response to COVID-19: Challenges and Opportunities. *World Bank Group Publications*

ILO Policy Brief (2020). COVID-19 and the world of work, Global impact and policy recommendations https://www.ilo.org/global/topics/coronavirus/impacts-and-responses/lang--en/index.htm

Jayalath, J. & Esichaikul, V. (2020). Gamification to enhance motivation and engagement in blended e-Learning for technical and vocational education and training. *Technology, Knowledge and Learning,* 1-28.

Jayalath, J. (2010). Feasibility of using e-Learning in capacity building of ICT trainers and delivery of technical, vocational education and training (TVET) courses in Sri Lanka. *SEAVERN Journals*, *2*(1).

Jayalath, J. (2014). Development of Quality Standard for eLearning Courses in TVET Sector, Sri Lanka, 9th May 2014. p161, Conference on Changing the Trajectory: Quality for Opening up Education, Logos, Berlin.

Jayalath, J. (2020). Roadmap for Distance Learning Development in TVET Sector, Janaka Jayalath on LinkedIn https://www.linkedin.com/pulse/roadmap-distance-learning-development-tvet-sector-janaka-jayalath

Jena, P. K. (2020). Impact of pandemic COVID-19 on education in India. *International Journal of Current Research (IJCR),* 12.

Mahazir, I. I., Norazah, M. N., Rosseni, D., Arif, A. A., & Ridzwan, C. R. (2015). Design and development performance-based into mobile learning for TVET. *Procedia-Social and Behavioral Sciences,* 174, 1764-1770.

Majumdar, S., Araiztegui, I., & Tknika, B. V. (2020). Technical Vocational Education & Training–reflections on the issues facing TVET and its potential in the time of COVID-19.

TVEC, (2020a). Newspaper Advertisement Survey in Labour Market Information Bulletin 2019-20, http://www.tvec.gov.lk/wp-content/uploads/2020/11/LMI_ 2019_ Dec_Vol_II.pdf

TVEC, (2020b). Manual of Quality Standards for E-learning, Online Learning and Blended Learning Courses in TVET Version 3.0, https://www.tvec.gov.lk/wp-content/uploads/2021/03/ QUALITY_STANDARD_FOR_ELEARNING_COURSE_Ver3.pdf

TVEC, (2020c). Report on Reforming Vocational Education System to Cater the Trends in Labour Market. Tertiary and Vocational Education Commission, Ministry of Skills Development Employment Relation and Labour.

Vilar, P., & Zabukovec, V. (2017). Using e-materials for study: students' perceptions vs. perceptions of academic librarians and teachers. the Information Behavior Conference, Zadar, Croatia, 20-23 September, 2016: Part 1, (paper isic1619).

Online teaching and learning activities of Sri Lankan state universities during the COVID-19 period

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ABSTRACT

When the COVID-19 pandemic hit the world, the Sri Lankan education system also had to face a complete closure in March 2020. However, with the available infrastructure, the State University Sector that comes under the University Grants Commission of Sri Lanka resorted to online teaching and learning activities. Learning Management Systems (LMS) that were present in the University servers and a remote video conferencing facility provided by Lanka Education And Research Network (LEARN) became the livewire of the State Universities to convert their day to day activities to Emergency Remote Teaching (ERT) within a week of closure. This paper presents the status and the trend of online teaching and learning activities of the State Universities from March 2020 to Jan 2021.

Keywords: COVID-19, Emergency remote teaching, Online education, State universities, University Grants Commission

1. INTRODUCTION

The Sri Lankan higher education sector has fifteen State Universities (with an assortment of faculties in each University) and eighteen other educational institutions under the University Grants Commission (UGC). These faculties and institutions together have more than 180,000 students and above 6500 academic staff. Even before the COVID-19 pandemic, most State Universities followed a blended learning approach using Learning Management Systems (LMSs) such as Moodle. The servers which host these LMSs are connected by high-speed Internet through the Lanka Education and Research Network (LEARN). University members could access the servers on the LEARN network through public Internet facilities by using paid services of Internet Service Providers (ISPs) in Sri Lanka. With the closure of universities and the lockdown in parts of the country, students and teaching staff had to continue their work through these LMSs (Ragel, 2020a). High data cost proved one of the significant drawbacks of the process. Under the guidance of the President, the UGC, in collaboration with Telecommunication Regulatory Commission (TRC) and the ISPs, was able to obtain free data access to the servers in the LEARN network of universities to overcome the data cost problem. This initiative motivated the study from home practices among staff and students of the state universities and institutions.

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In addition to obtaining free access to the LMSs, LEARN introduced *LEARN-Zoom* (Pallie & Hussain, 2020) as a video conferencing solution to facilitate synchronous teaching and learning activities at the State Universities. With the beginning of the pandemic, LEARN started setting up its media servers (Ragel, 2020b) with its member network and provided a faster and cheaper solution to its members (teachers and students). As a result, it was possible to keep the Video conferencing data traffic within the LEARN network, thus avoiding international data bandwidth. As an extension of earlier discussions with ISPs, *LEARN-Zoom* media server IP addresses were also got whitelisted, allowing students and staff to use video conferencing free of data charges. Students and teachers quickly adapted this solution based on these facilities, thus moving from traditional physical classes to the virtual environment. Usage statistics of this *LEARN-Zoom* solution are used in this study to offer useful insights into the online teaching and learning process's progress to the parties concerned. With these insights, authorities could identify any problem and thereby take the necessary steps to ensure that the Higher Education sector moves forward while enabling all students to continue studies despite the pandemic.

2. METHODOLOGY

From the beginning of the lockdown, *LEARN-Zoom* usage statistics were gathered weekly from the zoom admin dashboards and displayed to the public and delivered to the relevant educational authorities (Pathirana, 2020). The number of sessions and number of participants gathered from the collected data were used for online teaching and learning performance comparisons. Sessions data comprise statistics of the number of online sessions (lectures, discussions, meetings, etc.) conducted weekly and the number of participants (the number of students and staff who attended such sessions). In the present study, data was considered in three different time frames to analyze performance. The time frames are as below:

1. The first phase of COVID-19 University Closure is from week 01 – beginning 23rd March 2020 to week 21 - ending 16th August 2020.

2. In-class period from week 22 - beginning 17th August 2020 to Week 28 - ending 4th October 2020.

3. The second phase of COVID-19 Online Activities from week 29 - beginning 5th October 2020 to early January 2021.

In addition to data collected through *LEARN-Zoom*, the data gathered from frequent surveys across all the institutions under the UGC were used to gain insights into the readiness of State Universities to facilitate virtual teaching and learning in the post-pandemic context. The information about server infrastructure availability, IT infrastructure (Laboratories, Computers, etc.) and WiFi coverage within each Faculty was collected via a survey. The data were normalized with the number of students in each faculty to yield the average for each University.

3. RESULTS AND DISCUSSION

The weekly usage of *LEARN-Zoom* from 23rd March 2020 to 10th January 2021 is displayed in Figure 1. Despite sudden drops on occasions like the New Year holidays and national election holidays, the weekly number of sessions and participants increased gradually during the first phase of COVID-19 University Closure. *LEARN-Zoom* recorded peak usage for this phase in Week 18 with nearly 540,000 participants, which is a 27 fold improvement on usage at the beginning of the lockdown, during 12,000 zoom sessions which is a 16 fold increase over that at the beginning of the lockdown. At the end of the first phase, numbers began to decline as most universities had completed their online teaching for the relevant semesters.

With the fall in number of reported cases, the country began to move towards normalcy, and University Vice Chancellors exercised authority to decide on the academic activities

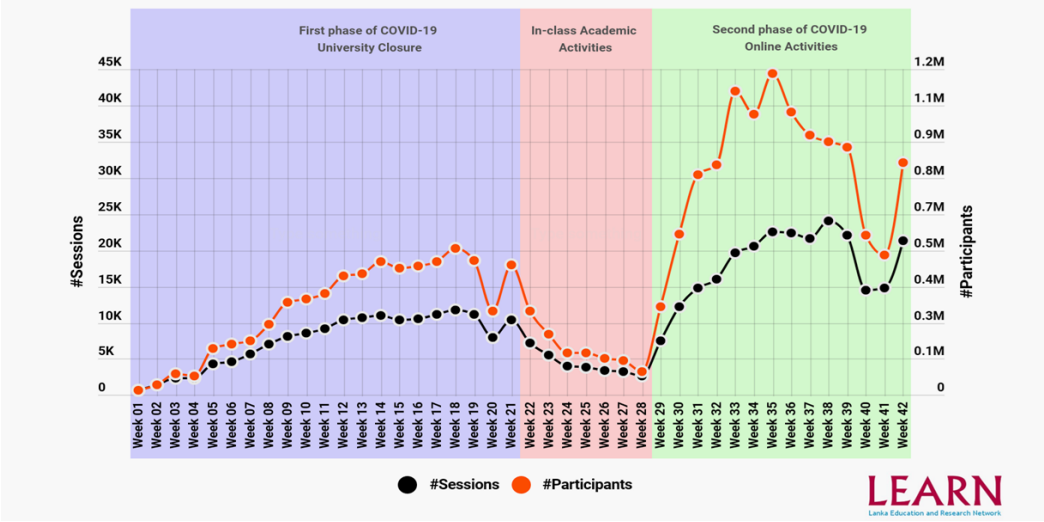

Figure 1. Comparison of Weekly Synchronous (LEARN-Zoom) Activities between First and Second Waves

of the universities. As a result, most universities returned to physical in-class work, but with fewer students amid maintaining health protocols. During this time, the number of weekly sessions and participants fell and at the height of activity during the In-class Activities period to reach a minimum of nearly 85,000 participants, which is four times higher than at the beginning of the lockdown, spanning 2500 zoom sessions which is thrice the number of sessions at the beginning of the lockdown.

Following the sudden spike in reported cases, the authorities decided to close the universities to help control the virus outbreak. The weekly number of sessions and participants peaked during the second phase of COVID-19 Online Activities. As evident from the figure, *LEARN-Zoom* recorded peak usage for this phase in Week 35, with nearly 1.18 million participants, a 59 fold improvement since the beginning of the lockdown, spanning across 22,400 zoom sessions which is 30 times the number of sessions at the beginning of the lockdown. At the time of writing (Week 42), the current usage statistics are recorded as 0.85 million (43x) participants spanning 21,200 (28x) zoom sessions.

During the 21 weeks of the first phase of COVID-19 University Closure, *LEARN-Zoom* recorded a total of 6.7 million participants in 160 thousand zoom sessions. During the seven weeks of the In-class Activities period, *LEARN-Zoom* recorded a total of 1.2 million participants in 30 thousand zoom sessions. During the 14 weeks of the second phase of COVID-19 Online Activities, *LEARN-Zoom* recorded a total of 11.7 million participants in 253 thousand zoom sessions. In all, the State Universities had conducted nearly 450 thousand zoom sessions with about 20 million online participants in 14.7 million meeting hours from 23rd March to 10th January 2021, as shown in Figure 2.

The usage statistics of zoom for the year 2020 are displayed in Figure 3, and the comparison of the numbers is in Table 1.

It may be seen that there was minimal video conferencing usage prior to the pandemic. However, with the start of distance learning, Video conferencing showed a gradual increase. Universities, UGC, LEARN, and several other organizations participated in awareness sessions and hands-on workshops on these tools and academic staff and students, regardless of field of study, started adapting to virtual learning. Although the students and teachers took considerable time to switch from physical to virtual learning during the first phase; switch from physical to virtual was quicker during the second wave outbreak as

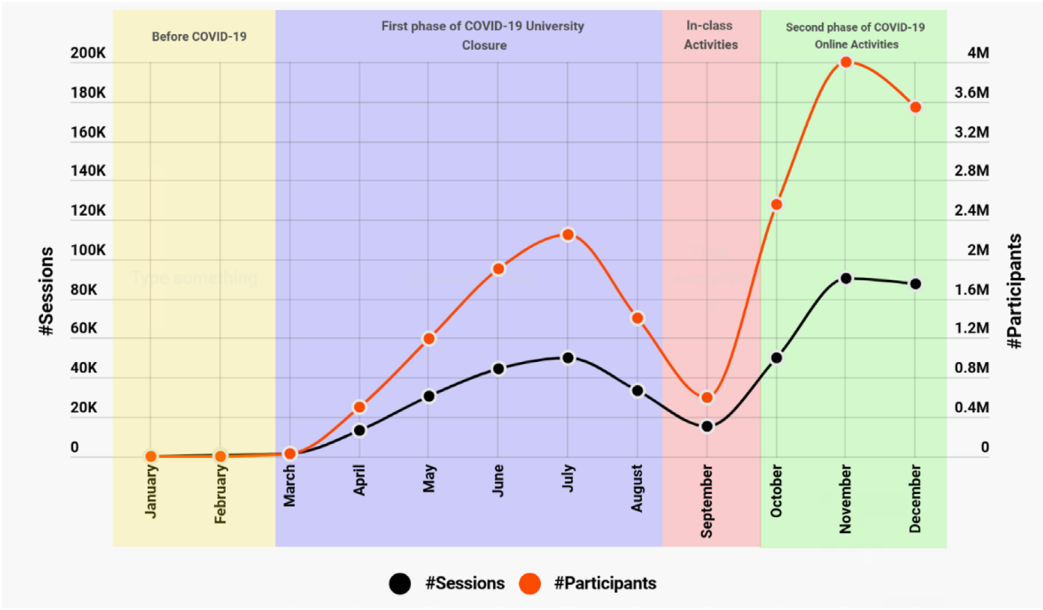

Figure 2. Monthly Video Conferencing Activities of the Year 2020

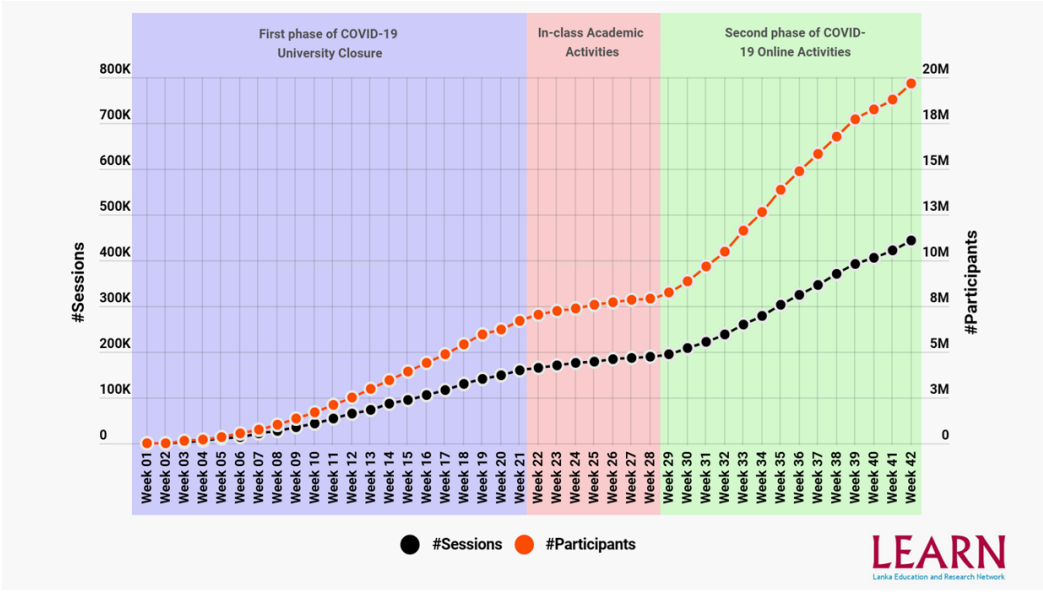

Figure 3. Aggregated Zoom Usage Statistics from the 23rd of March to the 10th of January 2021

they were equipped with all the platforms and the necessary guidance on their use to continue teaching/learning.

The results obtained through the survey among State Universities are presented in Figure 4, Figure 5 and Figure 6 without individual identification. The main intention of the survey was obtaining insights into the readiness of universities to continue online education using online technologies even after resumption of physical work. There is considerable variation in availability of server infrastructure, IT infrastructure and WiFi Coverage among state universities.

Of the 15 state universities, most can accommodate about 70% of the courses (subjects/modules) offered by them in the LMS with the available server capacities. Four

Table 1. Comparison of LEARN-Zoom statistics before and after the COVID-19 outbreak

Week	#Sessions	#Participants	Increase (since normalcy)
W -2 (09-03-2020 to 15-03-2020)	28	194	-
W -1 (16-03-2020 to 22-03-2020)	144	1660	8x
W 1 (23-03-2020 to 29-03-2020)	725	19,640	100x
W 2 (30-03-2020 to 05-04-2020)	1,417	37,586	188x
W 35 (16-11-2020 to 22-11-2020)	22,493	1,184,236	5920x
W 41 (28-12-2020 to 03-01-2021)	14,774	515,665	2578x
W 42 (04-01-2021 to 10-01-2021)	21,268	854,322	4270x

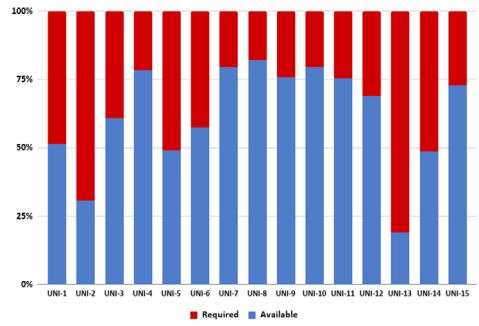

Figure 4. Availability of Server Infrastructure at the State Universities

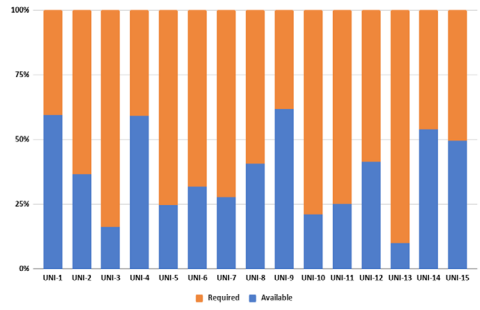

Figure 5. Availability of IT Infrastructure at the State Universities

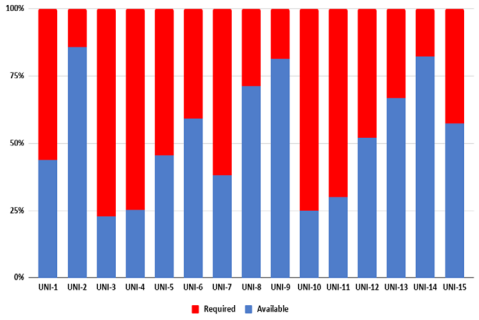

Figure 6. WiFi Coverage of Campuses at the State Universities

universities can accommodate only less than 50% of the LMS courses owing to limited availability of server infrastructure at the faculty/institute as shown in Figure 4.

Of the 15 state universities, three have 20% or less of IT infrastructure facilities (This is the percentage of students that can be accommodated for virtual learning with the IT infrastructure available within the university). All but five universities have less than 50% IT infrastructure available and need to upgrade facilities to provide virtual education to all the students, as shown in Figure 5.

Of the 15 state universities, four have 30% or less WiFi coverage than necessary for the total number of students. All but three universities currently have less than 80% WiFi coverage available on their premises.

4. CONCLUSION

The trends discernible in the number of sessions conducted through *LEARN-Zoom*, it may be concluded that all academic staff, regardless of field/specialization, are adapting to conduct online teaching through online platforms. There is a significant improvement in student participation since the beginning of online work, consequent upon the acquisition of devices. In addition to teaching, the *LEARN-Zoom* solution can be used as a live proctoring method in assessment procedures, which some institutions already implement.

The online teaching/learning trends can be enhanced by taking the necessary steps to enable students lacking in appropriate

devices to borrow or obtain on loan devices from the institution to pursue their online studies. However, there is a substantial volume of practical and fieldwork in some fields/specializations that require physical sessions.

5. REFERENCES

Hussain, M., & Pallie, S. (2020, May 16). *Rethinking education in Sri Lanka, after a nationwide lockdown | ARTECULATE.* https://arteculate.asia/rethinking-education-in-sri-lanka/

Pathirana, T. (2020, December 20). *LMS/Zoom Access State Universities.* Google Data Studio. http://datastudio.google.com/reporting/db5d9ff0-04ff-41dc-a320-3af0bc03e68a/page/faBKB?feature=opengraph

Ragel, R. (2020a, April 18). *LEARN sets up local Zoom media servers for free remote learning. Official Blog.* https://learnaclk.wordpress.com/2020/04/18/learn-sets-up-local-zoom-media-servers-for-free-remote-learning/

Ragel, R. (2020b, May 29). *LEARN expands the use of Learning Management Systems (LMS). Official Blog.* https://learnaclk.wordpress.com/2020/05/29/learn-expands-the-use-of-learning-management-systems-lms/

Online education during Covid-19 lockdown - Student experience in the non-state higher education in Sri Lanka

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ABSTRACT

The objective of this paper is to analyze the effectiveness of online education in both teaching and learning, based on data captured from the Moodle LMS, Eduscope Lecture Video Management System and two students' feedback surveys at the Sri Lanka Institute of Technology (SLIIT) from January to December 2020. Regression analysis and chi-square test were used as data analyses tools. The data were analyzed using simple linear regression and Analysis of LMS data showed that with each user logging into LMS 3 to 4 times a day with a minimum of 10 user actions per login. The study also found that the percentage of 'satisfactory' ratings by students for all aspects considered under four criteria, namely lecture delivery, technology, support services and overall satisfaction exceeded 80% irrespective of the faculty and time of the year. However the students' responses for individual criteria within four aspects were significantly associated ($p < 0.05$) by the nature of the faculty. More than 75% of students claimed that the online delivery is working well and enabling them to continue with their studies. No significant difference was found with respect to overall satisfaction by the students between the two periods. The inferences of this study can be used effectively to provide better online education environment in higher education organizations in Sri Lanka. and The infrastructure upgrades, including overall bandwidth, new services including Zoom, Webex and MS Teams, staff training on online delivery enabled a quick transition to online delivery. The incorporation of Respondus lockdown browser and Respondus Monitor online proctoring system further enhanced the integrity of online assessments and examinations.

Key words: Covid-19, LMS, Eduscope, Institutional response, Online education, Zoom

1. INTRODUCTION

The closure of both state and non-state universities due to COVID-19 pandemic continues to have a severe impact on higher education in Sri Lanka. The government provided the Zoom Pro video conferencing facility to all state university staff and students via the Lanka Education and Research Network (LEARN) free of charge. In addition, the Telecommunication Regulatory Commission of Sri Lanka offered several subsidized data packages through the Internet Service Providers (ISPs) to reduce the financial burden on the teaching staff and students for participation in video conference-based teaching and learning. The packages covered both Zoom and Microsoft Office 365, which includes Microsoft Teams.

Such facilities and online technologies, however, pose new challenges of both technical and non-technical nature. Although both state and non-state higher education sectors have taken additional steps to further support

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online teaching learning process, the real impact on online education (both learning and teaching) has not been deeply investigated. This is primarily due to the lack of a continuous data series over time and the lack of facilities to monitor students. In this paper, we present the measures taken to support online teaching and learning and the student feedback during two semesters in 2020 at the Sri Lanka Institute of Information Technology (SLIIT), Malabe, Sri Lanka.

1.1. Background

Although the literature has emerged from around the world on online education during the Covid-19 pandemic emerging, owing to the recent nature of the experience reliable long term data sets are not available to clearly understand the dynamics of the process. Some countries report insignificant change in academic achievement before and after transition from face-to-face to online education in higher education (Said, 2020; Dhawan, 2020). However, it must be noted that this is possible when the transition takes place for the entire student body without a significant drop-out rate during the transition. The experience of Bulgaria (Ilieva et al., 2020), further studies the challenges faced by the students and teachers in detail.

A report by Hayashi et al. (2020) for the Asian Development Bank provides the most comprehensive coverage of measures taken by Sri Lanka in the transition, covering both state and non-state sectors, based on descriptive statistics. They used data collected through three online surveys during 17–29 June 2020, covering both state (46) and nonstate (10) higher education institutions. The study claimed that Sri Lanka made a remarkably quick transition to online tertiary education after all educational institutions were forced to close in March 2020 because of the COVID-19 pandemic and the level of access to online education is comparable to developed countries like Japan. Nevertheless, the report also highlights the challenges faced by teachers and students during the transition. Poor internet connectivity in remote areas, cost of internet access (to sites other than the university LMS) and the cost access devices were the challenges of non-academic nature. The highlighted academic challenges were poor student attendance in some disciplines, inability to perform laboratory activities, limited assessment and examination options, and poor of adjustment of pedagogical methods to online and blended mode by lecturers. No other detailed studies were reported on online education in Sri Lanka.

1.2. Introduction to SLIIT

SLIIT is the largest and highest ranking non-state higher education institution in Sri Lanka. SLIIT had more than 10,500 students in 2020, with 5 faculties namely: Computing, Engineering, Business, Humanities & Sciences (HS) and Graduate Studies & Research. Teaching and Learning at SLIIT is supported by a Moodle Learning Management System (LMS) named CourseWeb since 2006, and a Lecture Capture / Lecture Video Management System (LVMS) by Eduscope, since 2019.

1.3. Environment in SLIIT

Multiple technologies and methodologies were put in place at SLIIT, before and during the pandemic as shown in Table 1. During the pre-pandemic period, the primary delivery method was face-to-face. However, each module had a course page on the LMS which contained supplementary material including presentation slides and reference material. During mid-term assessments, Moodle-based examinations were extensively used for Multiple Choice Questions and short answer questions. The Eduscope lecture capture facility was available at 3 lecture halls, which recorded face-to-face lectures during the day and uploaded to the Eduscope portal. The viewership remained below 200 views per day in this period.

1.4. First Wave and lockdown (Semester-1, 2020)

Sri Lanka went into the first Covid lock down during the 2nd week of March 2020 during the 5th week of the first semester. SLIIT announced fully online delivery starting from

Table 1. Teaching Learning and Assessment methodologies used at SLIIT

	Before Covid-19	**Jan – June 2020**	**July – Dec 2020**	**Feb – June 2021**
Face-to-face Teaching	Yes (Primary delivery method)	No	Laboratory only for selected programmes	No
LMS (Moodle)	Yes Compulsory to maintain an updated course page	Yes Compulsory to maintain an updated course page	Yes Compulsory to maintain an updated course page	Yes Compulsory to maintain an updated course page
Online Exams (Moodle)	Mid-term examinations	All	All	All
Viva Examination via Zoom / Teams	Limited	Yes	Yes	Optional due to real-time invigilation
Eduscope (Lecture Video Management System)	Limited	Yes Compulsory to upload Recorded Offline Lectures (Primary delivery method)	Yes Compulsory to upload Recorded Live Lectures	Yes Compulsory to upload Recorded Live Lectures
Zoom Meeting	No	Limited (Supplementary delivery method)	Yes (Primary delivery method)	Yes (Primary delivery method)
MS Teams	No	Limited (Supplementary delivery method)	Yes (Supplementary delivery method)	Yes (Supplementary delivery method)
Cisco Webex	No	Limited	No	No
Respondus Lockdown Browser	No	Limited	Yes	Yes
Respondus Monitor	No	No	No	Yes

the 18th of March. The recommended mode of delivery was recorded videos uploaded to the Eduscope Lecture Video Management System (LVMS) platform and linked to the relevant course page on the LMS. The system had 7398 views by 1845 unique students (individuals) on the first day as shown in Figure 1. SLIIT Management was able to secure free access to LMS and LVMS for students and staff from three service providers, thus reducing the financial burden on students.

1.5. Limited university operations and the Second Wave (Semester-2, 2020)

During the 2nd Semester of 2020, live delivery according to a timetable was enforced using Zoom and MS Teams. The live sessions were recorded on the Cloud and the recordings were uploaded to LMS and made accessible via the LMS. After the mid-semester examinations, the campus was accessible to students from the month of September until suspension of on-campus activities from 6th October owing to the 2nd wave of Covid-19 until end of the Semester. The drop in the number of views noticed in Figure 2, during September 2020 is for this reason. The Respondus lockdown browser was introduced for the first time to ensure reliability of online assessments during this semester and made mandatory for most examinations.

1.6. Limited university operations and the Third Wave (Semester-1, 2021)

As shown in Figure 3, this ongoing semester allowed on-campus activities for selected academic activities such as laboratory work and examinations. The lectures were delivered via Zoom and Teams and uploaded to the LVMS. For the upcoming end semester

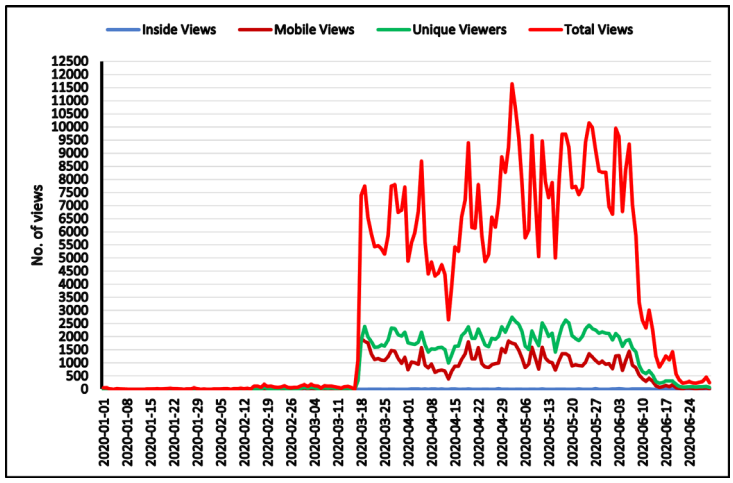

Figure 1. Eduscope LVMS access pattern during Semester-1 (Jan – June, 2020)

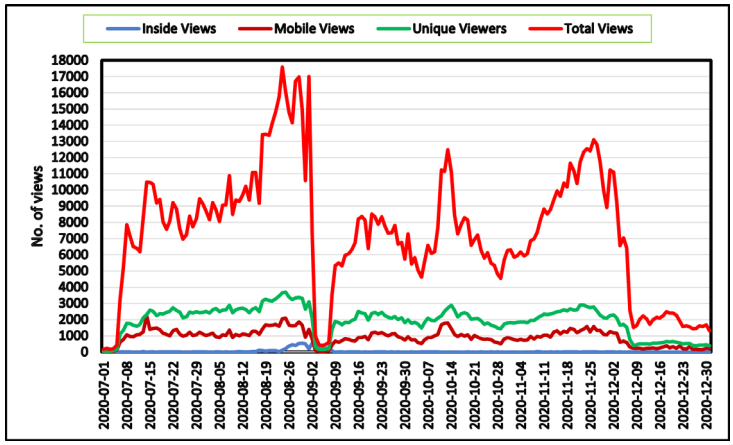

Figure 2. Eduscope LVMS access pattern during Semester-2 (July – Dec. 2020)

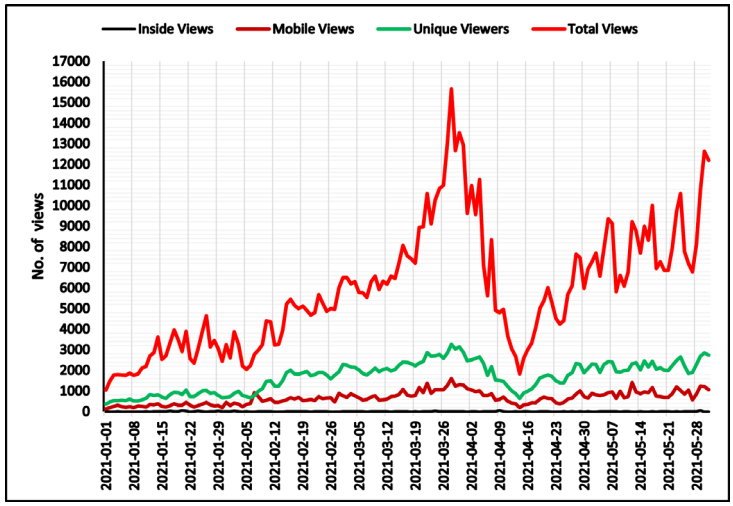

Figure 3. Eduscope LVMS access pattern during Semester-1, 2021

examinations, Respondus Monitor proctoring system will be introduced to further improve the integrity of assessments.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Moodle LMS

Moodle user activity was recorded on a daily basis from March to June 2020 to monitor user login (User_login), unique user login (Unique_UL) and user action (User_action) daily.

2.1.2. Eduscope Lecture Video Management System

The daily view statistics were obtained from the Eduscope LVMS which provided the daily views and daily unique views.

2.1.3. Students Feedback Survey Semester-1, 2020 (Jan-June 2020) & Semester-2, 2020 (July-Dec 2020)

The questionnaire for feedback survey for Semester-1 comprised four main factors and there are six, three, three and one aspects (variables) for Factors 1, 2, 3 and 4, respectively. Each aspect has 5-point Likert scale (1 = Strongly agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly disagree) The total number of students who responded was 2564 from the four faculties of SLIIT, namely Engineering, Computing, Business and Humanities & Sciences (HS) and the School of Architecture.

2.1.4. Students Feedback Survey Semester 2-2020 (July-Dec 2020)

The questionnaire for the students' feedback semester 2 also consists for four main factors, but with additional aspects for the factors. There were ten, seven, four and one aspects for factors 1 to 4, respectively. Each aspect also has 5-point Likert scale as explained above. The total number of students responded was 1093 from the four faculties.

2.2. Data analysis

Correlation analysis and simple linear regression were carried out to find the relationship between User_login, Unique_UL and User_action. Students' feedback data in both surveys were analyzed by ignoring the neutral responses as it does not has impact for the objective of studies. Also, both agree and strongly agree were pooled as "agree" and both disagree and strongly disagree were pooled as "disagree" for better interpretation since both agree and strongly agree and disagree and strongly disagree are very subjective. The percentage of responses for agree and disagree were taken initially, irrespective of five faculties mentioned above. The 2-way frequency analyses were carried out using chi-square test statistic to test whether there is a significant association between faculties and each aspect considered individually within all factors.

3. RESULTS AND DISCUSSION

3.1. Analysis of LMS activity data (March – June 2020)

The Moodle LMS has been extensively used since 2006 at SLIIT and it is compulsory for the lecturers to maintain a course page on the LMS to supplement the face-to-face delivery. It was found that there is a significantly high multi-collinearity among User_login, Unique_UL and User_action and all correlation coefficients are more than 0.9 with p value of 0.001. In order to determine the usage of LMS soon after the first lock down, a simple linear regression model was developed as shown in Figure 4. It was found that the fitted model is significant ($p < 0.05$), and it has captured about 95% of the variability of user logins. Similarly, a linear regression model was developed between user actions and user logins as shown in Figure 5. It is also significant ($p < 0.05$) and can explain about 90% variability of user action. Based on the two models and the 95% confidence interval for the parameters, it can be concluded that the students were actively using the LMS with each user logging in 3.7 to 4.0 times a day with a range of 10-12 user actions per login.

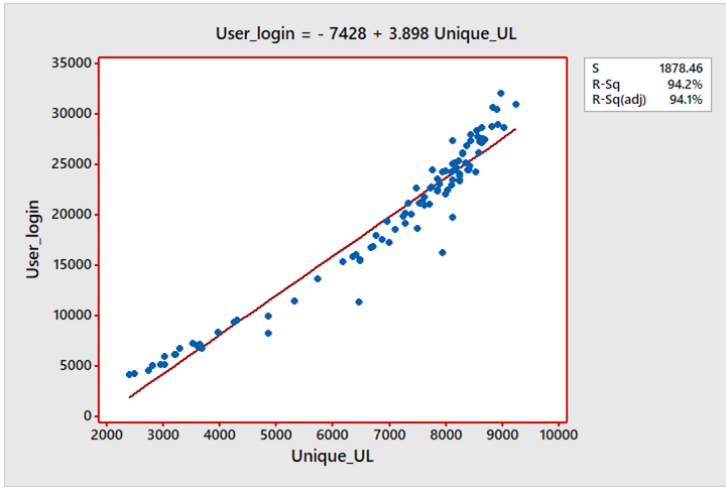

Figure 4. Relationship between Unique user logins and total logins

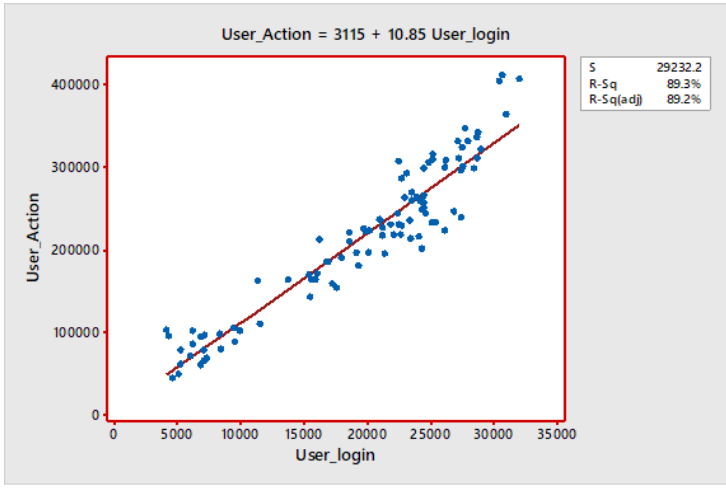

Figure 5. Relationship between number of user actions and user logins

3.2. Cleaning of survey data

The number responding considered for the data analyses in both surveys, by ignoring the neutral responses as shown in Tables 2 and 3 respectively for the two surveys. The total numbers of the student's response for the two surveys were 2564 and 1093 respectively.

Results in Table 2 indicate that the number of responses for non-neutral point of Likert scale varies from 1946 (minimum) for the question, "Queries to Faculties/Departments are addressed in a timely manner" to 2152 (maximum) for the question, "the Online delivery is working well and enabling me to continue with studies". As a result, the corresponding percentages varies from 75.9 to 83.9. Similarly in the second survey (Table 3) also, non-neutral point of Likert scale varies from 79.1% ("essential students services were available to support online learning") to 91.2% ("easy to access the site").

3.3. Student's response to the questions

Results of percentage responses for each variable within a factor for the two surveys are shown in Table 4 and Table 5, respectively. Results in Table 4 show that percentages of 'agree' for all questions exceed 80%, with a marginal exception for overall assessment, at

Table 2. Number of subjects used for the analysis for each aspect in Survey 1

Factor/Variable	A	B	C
Lecture Delivery			
Live/ recorded videos were clear and audible.	2142	422	83.5
Speed of delivery is optimal.	2136	428	83.3
Presented in a manner that kept students engaged and focused	2075	489	80.9
Supplementary material provided is useful and well prepared.	2119	445	82.6
An effective online forum is available to post questions and discuss course content.	2030	534	79.2
Online assessments are well organized and effective.	2145	419	83.7
Technology			
Video streaming is high quality.	2101	463	81.9
Easy to access the site.	2232	332	87.1
Easy to navigate the site.	2202	362	85.9
Online help services are effective.	1999	565	78.0
Support Services			
Sufficient online library services are available to support online learning.	1952	612	76.1
Required student services are available via online.	1972	592	76.9
Queries to Faculties/Departments are addressed in a timely manner.	1946	618	75.9
Overall Assessment			
Online delivery is working well and enabling me to continue with studies.	2152	412	83.9

(A – No. used for the analysis, B – No. of neutral cases & C – % subjects used with respect to the initial total)

Table 3. Number of responses subjects considered for the analysis for each aspect in the Survey 2

Variable	A	B	C
Lecture Delivery			
Both live and recorded videos were provided, and they were clear and audible.	971	122	88.8
Only recorded videos were provided, and they were clear and audible.	946	147	86.6
Online laboratory sessions were well delivered.	889	204	81.3
The module instructor responded to queries Promptly.	969	124	88.7
The speed of delivery was optimal.	973	120	89.0
Lectures were presented in a manner that kept students engaged and focused.	969	124	88.7
The supplementary material provided was useful and well prepared.	956	137	87.5
An effective online forum was available to post questions and discuss course content.	918	175	84.0
Online assessments were well organized and effective.	941	152	86.1
Online review sessions were provided to support learning	908	185	83.1
Technology			
Video streaming was of high quality.	995	98	88.5
Easy to access the site.	930	163	91.2
Easy to navigate the site.	939	154	91.0
Online technical help services were adequate.	956	137	85.1
My overall experience with Eduscope was positive.	868	225	85.9
Zoom was the technology used for online teaching.	891	202	87.5
MS-Teams was the technology used for online teaching.	860	233	79.4
Support Services			
Good online library services were available to support online learning.	891	202	81.5
Webinars presented by the Library facilitated access to online resources.	860	233	78.7
Essential student services were available online.	865	228	79.1
Queries to Faculties/Departments are addressed in a timely manner.	872	221	79.8
Overall Assessment			
Online delivery was working well during this semester and enabled me to continue with my studies	935	158	85.5

(A – No. used for the analysis, B – No. of neutral cases & C – % subjects used with respect to the initial total)

79%. It is clear that the high level of 'satisfactory' ratings were obtained for the various aspects of online delivery system introduced by the SLIIT irrespective of faculty and despite problems faced by students such as power cuts, signal problem, income status etc. which are outside the purview of the SLIIT. It should be noted that the 'agree' percentage is more than 85% for "easy to assess the site" and "easy to navigate the site" referring to the Eduscope video portal which was designed to give the impression of a private YouTube channel.

In the second survey (Table 5), the 'agree' percentage for "Online delivery was working well during this semester and enabled me to continue with my studies" (85.5) is higher than the corresponding percentage in the first survey, but no statistically significant difference was obtained ($p > 0.05$) between those two percentages Is this a long winded way of saying that "the difference between the two ratings is insignificant". The percentage of students' 'agree' for all features, under technology factor, namely "Video streaming was of high quality", "Easy to access the site" and "Easy to navigate site" are around 85%. These percentages clearly indicate that the students were satisfied with the technologies and facilities made available for online learning.

The dedicated section on Eduscope was not available in the first survey, but 85% of the students were satisfied with the experience they gained from Eduscope for their online learning. It helped students to follow the recorded lectures when and where they wanted them.

3.4. Association between faculties and the response of the students

As described above, the association between faculties and each variable within a factor was analyzed using chi-square test and the summary results are shown for each factor separately for both periods (Table 6 and Table 7). Since there were no responses from the School of Architecture during July-December, their results cannot be used for comparison of the two periods. The parenthesis represents the percentages of 'agree' for the aspects. Those are the percentages of 'satisfactory' (agree) obtained with respective faculty total for a given aspect.

3.5. Aspects on 'Lecture Delivery' factor

As chi-square statistics are significant for all six variables, it can be concluded with 95% confidence that there is significant association ($p < 0.05$) between student's response and type of faculty for all six aspects under each variable.

Table 4. Percentages of response of the students (irrespective of faculty) for Survey 1: (Jan. - June), 2020

Factor	Variable	Agree (%)	Disagree (%)
Lecture Delivery	Live/ recorded videos were clear and audible.	81.8	18.2
	Speed of delivery is optimal.	83.7	16.3
	Presented in a manner that kept students engaged and focused.	80.9	19.1
	Supplementary material provided is useful and well prepared.	82.4	17.6
	An effective online forum is available to post questions and discuss course content.	81.9	18.1
	Online assessments are well organized and effective.	82.9	17.1
Technology	Video streaming is high quality.	83.2	16.8
	Easy to access the site.	85.1	14.9
	Easy to navigate the site.	85.5	14.5
	Online help services are effective.	83.2	18.8
Support Services	Sufficient online library services are available to support online learning.	81.4	18.6
	Required student services are available via online.	83.9	16.1
	Queries to Faculties/Departments are addressed in a timely manner.	82.5	17.5
Overall Assessment	Online delivery is working well and enabling me to continue with studies.	79.0	11.0

Table 5. Percentages of response of the students (irrespective of faculty) for the Survey 2: (July to December) 2020.

Factor	Variable	Agree (%)	Disagree (%)
Lecture Delivery	Both live and recorded videos were provided, and they were clear and audible.	86.8	13.2
	Only recorded videos were provided, and they were clear and audible.	76.2	23.8
	Online laboratory sessions were well delivered.	80.9	19.1
	The module instructor responded to queries promptly.	88.5	11.5
	The speed of delivery was optimal.	88.6	11.4
	Lectures were presented in a manner that kept students engaged and focused.	87.8	12.2
	The supplementary material provided was useful and well prepared.	88.4	11.6
	An effective online forum was available to post questions and discuss course content.	86.7	13.3
	Online assessments were well organized and effective.	88.3	11.7
	Online review sessions were provided to support learning.	86.8	13.2
Technology	Video streaming was of high quality.	88.3	11.7
	Easy to access the site.	89.3	10.7
	Easy to navigate the site.	87.9	12.1
	Online technical help services were adequate.	88.9	11.1
	My overall experience with Eduscope was positive.	84.8	15.2
	Zoom was the technology used for online teaching.	83.7	16.3
	MS-Teams was the technology used for online teaching.	64.6	33.4
Support services	Good online library services were available to support online learning.	87.8	12.2
	Webinars presented by the library facilitated access to online resources.	84.7	15.3
	Essential student services were available online.	86.7	13.3
	Queries to Faculties/Departments were addressed promptly.	86.9	13.1
Overall	Online delivery was working well during this semester and enabled me to continue with my studies.	83.8	16.2

Table 6. Summary results of chi-square analyses for the aspects of lecture delivery during (Jan-June), 2020

Variables related to the factor 'lecture delivery'	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Live/ recorded videos were clear and audible.	405 (91.4)	856 (77.6)	342 (82.2)	140 (83.3)	x_3^2 =45.5, p = 0.001
Speed of delivery is optimal.	424 (92.6)	857 (79.1)	360 (85.3)	135 (84.4)	x_3^2 =48.3 p = 0.001
Presented in a manner that kept students engaged and focused.	406 (92.5)	798 (76.0)	334 (80.3)	130 (82.3)	x_3^2 =62.7 p = 0.001
Supplementary material provided is useful and well prepared.	425 (93.2)	822 (77.1)	348 (83.7)	140 (83.8)	x_3^2 =65.6, p = 0.001
An effective online forum is available to post questions and discuss course content.	403 (92.9)	795 (77.9)	315 (78.9)	136 (84.6)	x_3^2 =56.7 p = 0.001
Online assessments are well organized and effective.	421 (93.8)	851 (82.9)	349 (82.7)	143 (78.1)	x_3^2 =63.6, p = 0.001

The percentages of 'satisfactory' for all six aspects within the factor of lecture delivery are more than 75% in all faculties with exceptional in the Faculty of Business (90%) confirming that the facilities offered for online teaching by all faculties are satisfactory. Furthermore, the percentages of 'satisfactory' for all six aspects are highest for the Faculty of Business during Jan-June, 2020.

The corresponding percentages are lowest for the Faculty of Computing. The reasons for these aspects were not investigated in this study as we used already collected data. By testing two proportions using binomial distribution, it was found that all percentages of satisfactory in the Faculty of Business are significantly higher ($p < 0.05$) than the corresponding percentages in the Faculty of Computing. The results in Table 7 for the second period also confirm that there is strongly significant association ($p < 0.05$) between the student's response and the faculties for all ten aspects.

Percentages of 'satisfactory' were sustained during the second period as well, by all faculties for the six aspects assessed during Jan-June, 2020. Of the additional new four aspects included in the second survey, percentages of 'satisfactory' are lower for two aspects, namely "Only recorded videos were provided, and they were clear and audible" and "Online laboratory sessions were well delivered" in two faculties.

3.6. Aspects of "Support Services" factor

The results of summary of the chi-square analyses with respect the association between faculties and the student's response for the aspects within the support services factor in both surveys are shown in Table 8 and Table 9, respectively.

As Chi-square statistics are significant in Table 8 and Table 9, it is clear that there is significant association ($p < 0.05$) between the faculties and the students' response to various aspects of the support services factor. The percentage of 'satisfactory' is significantly higher for the Faculty of Business for all three aspects during the first survey. However, the percentage of 'satisfactory' for these aspects

Table 7. Summary results of chi-square analyses for aspects of lecture delivery during (July-December), 2020

Variables related to the factor 'lecture delivery'	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Both live and recorded videos were provided, and they were clear and audible	609 (89.7)	184 (78.6)	24 (96.0)	26 (78.8)	x_3^2 =22.3, p = 0.001
The speed of delivery was optimal.	619 (91.3)	194 (81.9)	23 (88.5)	26 (82.1)	x_3^2 =43.8, p = 0.001
Lectures were presented in a manner that kept students engaged and focused.	623 (91.3)	177 (76.0)	22 (95.7)	29 (93.5)	x_3^2 =33.6, p = 0.001
The supplementary material provided was useful and well prepared.	630 (91.6)	165 (77.8)	24 (100)	26 (81.2)	x_3^2 =33.4, p = 0.001
An effective online forum was available to post questions and discuss course content.	603 (90.4)	148 (72.9)	19 (100)	26 (89.7)	x_3^2 =41.3, p = 0.001
Online assessments were well organized and effective.	621 (91.3)	165 (78.2)	20 (100)	25 (83.3)	x_3^2 =30.2, p = 0.001
Only recorded videos were provided, and they were clear and audible.	540 (81.9)	147 (62.8)	18 (78.3)	16 (53.3)	x_3^2 =43.8, p = 0.001
Online laboratory sessions were well delivered.	542 (86.9)	147 (65.3)	18 (94.7)	12 (57.1)	x_3^2 =59.5, p = 0.000
The module instructor responded to queries promptly.	618 (91.0)	189 (81.1)	24 (96.0)	27 (84.4)	x_3^2 =17.7, p = 0.001
Online review sessions were provided to support learning	603 (90.4)	148 (72.9)	19 (100)	26 (89.7)	x_3^2 =63.7 p = 0.001

Table 8. Summary results of chi-square analyses for the aspects within support services during (Jan – June), 2020

Variables related to the factor 'lecture delivery'	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Sufficient online library services are available to support online learning.	393 (94.5)	807 (81.0)	278 (71.8)	102 (76.8)	x_3^2 =73.8, p = 0.001
Required student services are available via online.	391 (93.3)	763 (77.7)	312 (79.5)	118 (83.7)	x_3^2 =44.8, p = 0.001
Queries to Faculties/Departments are addressed in a timely manner.	391 (93.5)	783 (78.7)	312 (79.5)	118 (83.7)	x_3^2 =48.3, p = 0.001

Table 9. Summary results of chi-square analyses for the aspects within support services during (July – December), 2020

Variables related to the factor- lecture delivery	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Good online library services were available to support online learning.	587 (89.9)	157 (79.3)	15 (98.5)	23 (92.0)	x_3^2 =18.5, p = 0.001
Essential student services were available online.	573 (90.1)	144 (75.8)	14 (77.8)	19 (90.5)	x_3^2 27.4, p = 0.000
Queries to Faculties/Departments were addressed promptly.	577 (89.2)	145 (78.8)	15 (75.0)	21 (100.0)	x_3^2 =19.2, p = 0.001
Webinars presented by the Library facilitated access to online resources.	556 (87.7)	132 (72.9)	20 (95.2)	20 (83.4)	x_3^2 = 5.5, p = 0.001

decreased slightly in the second survey. There is noticeable improvement for all three aspects in the Faculty of HS in the second survey. Percentages of 'satisfactory' for "webinars presented by the library facilitated access to online resource" is high and it varied from 72.9% in the Faculty of Computing to 95.2% in the Faculty of Engineering.

3.7. Aspects of "Technology" factor

The response of student for all aspects of technology factor is also significantly associated ($p < 0.05$) with the faculty (Table 10 and Table 11). Three additional aspects for technology factor were included for the second survey.

On comparison of results in Table 10 and Table 11 it was found that there was no significant difference ($p > 0.05$) in the percentages of 'satisfactory' between two periods with respect to four aspects: "Video streaming is high quality", "Easy to access the site", "Easy to navigate the site" and "Online help services are effective" in all Faculties. Of the new aspects added to the second survey, the percentage of 'satisfactory' for the "overall experience with Eduscope was positive but significantly varied among faculties from

Table 10. Summary results of chi-square analyses for the aspects of technology during (Jan – June) 2020

Variables related to the factor- lecture delivery	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Video streaming is high quality.	415 (93.4)	856 (79.6)	335 (82.2)	142 (84.3)	x_3^2 =45.7, p = 0.001
Easy to access the site.	429 (93.7)	949 (85.1)	361 (83.3)	146 (87.4)	x_3^2 =36.3, p = 0.001
Easy to navigate the site.	425 (92.5)	948 (84.0)	347 (83.7)	142 (86.1)	x_3^2 =34.6 p = 0.000
Online help services are effective.	407 (94.2)	795 (78.9)	307 (79.9)	136 (88.3)	x_3^2 =55.2, p = 0.001

Table 11. Summary results of chi-square analyses for the aspects technology factor during (July – December), 2020

Variables related to the factor- lecture delivery	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Video streaming was of high quality.	623 (91.6)	189 (79.6)	16 (88.9)	26 (89.9)	$x_3^2 = 26.1$, $p = 0.001$
Easy to access the site.	637 (91.8)	207 (83.1)	21 (87.5)	25 (89.3	$x_3^2 = 15.3$, $p = 0.001$
Easy to navigate the site.	624 (89.5)	205 (83.3)	22 (88.0)	24 (88.9)	$x_3^2 = 6.7$, $p = 0.087$
Online technical help services were adequate.	613 (91.5)	174 (81.3)	18 (85.7)	22 (88.0)	$x_3^2 = 65.6$, $p = 0.001$
My overall experience with Eduscope was positive.	609 (90.0)	151 (70.6)	12 (63.2)	24 (82.8)	$x_3^2 = 54.5$, $p = 0.001$
Zoom was the technology used for online teaching.	615 (89.0)	137 (65.8)	22 (95.7)	26 (78.8)	$x_3^2 = 67.6$, $p = 0.001$
MS-Teams was the technology used for online teaching.	432 (69.2)	110 (55.8)	6 (31.6)	13 (53.6)	$x_3^2 = 25.5$, $p = 0.001$

90% (Faculty of Business) to 63.2% (Faculty of Engineering). Furthermore, percentages of 'satisfactory' by the students for the use of Zoom are higher than the use of MS-Teams, irrespective of faculty.

3.8. 'Overall' Factor

Results in Table 12 indicate that there is significant association between the faculties and students' response for the overall performance in both surveys. The percentage of overall 'satisfactory' in the Faculty of Business is 93.4% during Jan-June' 2020 and it is significantly higher ($p < 0.05$) than the corresponding percentages in other three faculties. Though the percentages of overall 'satisfactory' in Faculties of Engineering and Humanities and Sciences increased, the increase is not statistically significant in view of the very small sample size for the second survey. There is no significance difference ($p > 0.05$) between the two percentages of overall 'satisfactory' in the Faculty of Computing.

4. CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS

Based on the results of data analyses obtained from Eduscope LVMS maintained by SLIIT, the LMS and students' feedback acquired during January to June, 2020 and during July to December, 2020 the following conclusions and recommendations can be made.

4.1. Conclusions

- As 80% of students are satisfied that online delivery was working well during the two semesters and enabled them to continue with their studies irrespective of the nature of the faculty, the infrastructure developed by SLIIT for the online teaching and learning is considered as effective and efficient.

Table 12. Summary results of chi-square analyses for the overall factor in two periods

Variables related to the factor- lecture delivery	Faculty				Chi-square
	Business	Computing	Engineering	HS	
Online delivery is working well and enabling me to continue with studies – (Jan-Jun) 2020	422 (93.4)	792 (72.5)	324 (77.3)	140 (84.8)	$x_3^2 = 87.5$, $p = 0.001$
Online delivery was working well during this semester and enabled me to continue with my studies-(July-Dec), 2020	570 (88.5)	170 (70.1)	22 (95.7)	20 (80.1)	$x_3^2 = 66.6$ p = 0.001

- In 2020, irrespective of gender, income, and semester about 80% of the students expressed satisfaction in all the aspects tested under lecture delivery, technology, and support services.
- The percentages of students reporting 'satisfactory' are not significantly different for almost all aspects of the periods (Jan-Jun) 2020 and (July – Dec) 2020.
- As chi-square statistics indicate the response of the students for almost all aspects is significantly associated with the nature of faculty, but the percentage of 'satisfactory' varied between 70 and 90.
- The students indication of 'satisfactory' for the use of Zoom technology is significantly higher than for Microsoft Teams

4.2. Recommendations

- High quality video streaming, easy access to the site, easy means to navigate the site and an effective online help service are important to providing efficient technology to improve online learning by the students in higher education organizations.
- Sufficient online library services and providing prompt solutions for queries receiving to Faculties and Department are necessary for efficient online learning.
- The availability of the Eduscope Learning Video Management System was beneficial during the transition from face-to-face to online mode. It provided access to recorded live lectures so that students who had connectivity issues could access the lectures at a convenient time. In addition, the peaks in the usage graphs refer to examination periods indicating that students use the videos extensively for the purpose of revision. Therefore, it is recommended to maintain a video repository of lectures to support the learners.
- Zoom and Microsoft Teams have become the primary mode of interaction and it may be useful to provide staff development programmes on how to use these two platforms effectively.
- It is necessary to explore online tools for attendance tracking, gamification, surveys, collaborative whiteboards and brainstorming to supplement video conferencing. This could boost learner engagement and motivation to attend lectures online.
- It is better to get the views by filtering the 20% students who claimed that online delivery is not satisfied to provide better service for the students.

REFERENCES

Ghada Refaat El Said (2021). How Did the COVID-19 Pandemic Affect Higher Education Learning Experience? An Empirical Investigation of Learners' Academic Performance at a University in a Developing Country, Hindawi Advances in Human-Computer Interaction Volume 2021

Dhawan, S. (2020). Online Learning: A Panacea in the Time of COVID-19 Crisis. Journal of Educational Technology System. 49(1), 5-22

Ilieva, G., Yankova, T., Klisarova-Belcheva, S. and Ivanova, S. (2021). Effects of COVID-19 Pandemic on University Students' Learning. Information 2021, 12, 163. https://doi.org/10.3390/info12040163

Hayashi, Ryotaro, Garcia, Marito, Maddawin, Angelica, Hewagamage, K.P. (2020). Online Learning in Sri Lanka's Higher Education Institutions during the Covid-19 Pandemic, ADB Briefs, September 2020.

Innovations in teaching and learning in distance mode during COVID-19 in Sri Lanka and Bangladesh

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ABSTRACT

Internet or broadcast TV were the only options available for distance education during school closures due to COVID-19, but Internet resources are limited in poor countries, and broadcast TV for distance education is largely untested.

We surveyed purposive sample of teachers who had made a good faith effort to engage students in the distance mode during lockdown in Sri Lanka and Bangladesh, respectively, to uncover innovations, if any, in Internet or Broadcast TV based for education during COVID-19.

Our survey reveals that Internet-based distance education reached only 45% of in public schools in Sri Lanka. We also note that broadcast TV was not successful due to technical and pedagogical reasons. Yet, the country is rich in other resources. For example, the availability of (1) Free textbooks for all subjects in grades 6-11 (3) Sufficient digital content developed by state and non-state providers (3) TVs with USB ports for viewing digital content offline (2) A low student to teacher ratio of 8.6 in the bottom 50% of schools (4) Mobile phone ownership in 96% in households, (Zainudeen & Amarasinghe, 2020) and (5) Tested technologies for using regular phones for conference calls, opens many low-tech possibilities.

Observation of teachers from a better-endowed set of schools in Bangladesh show that high-tech distance education can offer blended learning experiences which are superior to face-to-face experiences in some respects. Observations by teachers in Sri Lanka and desk research show that a low-tech distance education using offline resources too can offer blended learning for students with no access to the Internet.

Key words: COVID-19, Distance-education, ICT in education, Self-directed learning, Integrated curricula

1. INTRODUCTION

Internet or broadcast TV were the only options available for distance education during school closures due to COVID-19, but Internet resources were limited in poor countries, and both modes of distance education were largely untested. *For example, in 2018, 48% of households with school-age children in Sri Lanka owned a smartphone or a computer, but only 34% accessed the Internet. In Bangladesh, the respective figures were 21% and 11%* (LIRNEAsia, 2020). When schools closed on March 13th, 2020, officials and teachers had to adapt overnight to provide distance education to the 4.2 million schoolchildren in Sri Lanka and 39.8 million in Bangladesh.

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COVID-19 put a distance-between the teacher and students and gave students more time for self-directed learning. How did schools use this opportunity? Are there any lessons that will inform the implementation of the proposed curricular reforms?

2. METHODOLOGY

The study consisted of a teachers' survey in the two countries. Since the purpose of the research was to identify good practices, in both surveys we used a purposive sampling method where we picked teachers who would have made a good-faith effort to reach out to their students during lockdown. Here we expect any statistics on distance education derived here reach to be a reasonable estimate of the higher limit.

In Sri Lanka, we surveyed a stratified sample of teachers representing all 25 administrative districts in the country, selecting teachers who are likely to have made a good-faith effort to reach out to their students. This purposive sample included 86 teachers with at least two from each district, one representing a better endowed or congenial school and the second representing less well-endowed school 'non-congenial' school. The districts with more than 100,000 in the student population were oversampled to ensure that there was at least one teacher per 50,000 students in each district. A network of civil society organizations affiliated with the Education Forum Sri Lanka assisted in the selection of teachers.

In Sri Lanka, the classification of schools by size is a good indicator of the congeniality or how well-endowed is a school. Of the 10,165 schools reported in 2019, 77% had less than 500 students, 23% had 501 or more student. We oversampled the larger schools to get more or less equal number of schools in each type (i.e. 49% and 51%, respectively) because we wanted to get good practices in distance education and smaller schools were not expected to reach many students for online line education during school closures. Our results indeed confirmed this hypothesis (See later). The survey was conducted between November and December 2020, by telephone.

A survey of teachers in Bangladesh was carried out for comparison. Bangladesh is a large country with a population of 163 million and 171,779 schools enrolling 39.8 million children (UNESCO, 2020). Since representation from across the country or even a stratified purposive sample such as the one used for Sri Lanka was not feasible, we used a convenience sample of 20 teachers representing six schools in Dhaka and 10 teachers representing a school in Chittagong. The survey was carried out with an online survey form during the August 27 to September 10 period in 2020. A focus group discussion was held on September 18th with 8 teachers from the school in Chittagong participating. Noting that these schools largely represent better endowed private schools in Bangladesh, we used the survey data strictly for the purpose of benchmarking good practices that can be achieved when schools have facilities more or less optimum for a country.

For Sri Lanka we also use the results of a parents' survey where we asked one teacher each from the five districts – Colombo, Gampaha, Kandy, Matale and Trincomalee - for 5 contacts for parents of children in Grade 6 with whom they were able to engage in some form of distance education during the COVID-19 lockdown from March 13th- May 15th. We limited the parents' survey to five districts out of 25 due to cost concerns. A total of 44 parents responded to the survey. The purpose of the survey was to understand from parents' perspective the modes of communication that teachers used during COVID-19.

We were also able to closely observe activities within two WhatsApp groups consisting of teachers and students in Grade 6 and 8, respectively, from several schools in one education zone in from May 02nd 2020 to December 31, 2020, with 130 and 200 students in each group, respectively.

3. RESULTS AND DISCUSSION

This section is organized under three sub sections – (1) Access to the Internet or TV in Bangladesh and Sri Lanka in 2018, and (2) Distance Education in Sri Lanka - With Internet or TV as a medium for distance learning, and (3) Good Practices in Distance Education in Bangladesh during COVID-19 in 2020.

3.1. Access to the Internet and TV in Bangladesh and Sri Lanka in 2018

A 6-Country study of access and use of ICTs was carried out by LIRNEasia in 2018. For Sri Lanka, they used a random sample of 2000+ households a representative of the geographical and economic diversity of the population in Sri Lanka. Looking at the subset of households with children under 18, they deduced that 48% of households with school-age children owned a smartphone or other device for accessing the Internet but only 34% accessed the Internet; These data are compatible with data from the International Telecommunication Union (ITU) or the Census Department of Sri Lanka. For example, in 2017, ITU reported that 34% of individuals in the population used the Internet while Census reported in 2019 that 29% of the individuals in in Sri Lanka used the Internet. LIRNEasia data are more useful for the present study because their data are collected and reported with the household as the unit of analysis.

To present a composite of data for ownership of TV, Smartphones, and the Internet in the two countries, we use data for for all households, not just households with school age children, because data for the latter is not available for Bangladesh (Table 1).

The situation in four other countries Cambodia, India, Nepal, and Pakistan as reported in the LIRNEasia study shows that Internet access in Asia can be as low as 8% as was the case for Pakistan (LIRNEasia, 2020). Has the situation in Bangladesh and Sri Lanka changed between 2018 and now? How did the ICT infrastructure situation affect distance learning in education in these two countries?

Table 1. Percent of households owning TVs, Smartphones, or Internet Connection, by country, 2018

	TV	Smartphones	Internet
Bangladesh	56%	21%	11%
Sri Lanka	91%	46%	32%

3.2. Distance education in Sri Lanka in 2020

There were two modes of distance education in Sri Lanka in 2020 – Online education via the Internet used in an ad hoc manner by teachers and local education administrators, and the TV broadcasts for learning initiated by the Ministry of Education (MoE) in partnership with the National Institute of Education (NIE).

3.3. Internet as the medium

In our teacher survey we asked each teacher how many students were in his/her class and how many they were able to reach using Internet-based applications such as Whatsapp, Viber, Zoom and Team etc. Together 86 teachers reported that they were responsible for 2582 students, but they were able to contact only 1153 students for an average of 45% students reached online, with 4% using Zoom, Teams etc. for a virtual classroom experience for students and 41% using WhatsApp/Viber to send notes and assignment as pictures or PDF files. Since 90% of school-age children attend government schools we can take these percentages as reflective of the percent of households with school children. Therefore, Internet use households increased 34% reported in 2018 to about 45%, but not enough to reach out to all the students. In fact, 55% of the students are left out.

3.4. Transmission mode of teaching continued

Education literature identifies three styles of teaching – Transmission, Transaction and Transformation. The fact that education in Sri Lanka is largely about preparing students for examinations in the transmission mode is widely accepted (NEC, 2017).

Our survey of 46 parents in 5 districts confirmed that teachers continued to send notes and assignments as PDF files largely on WhatsApp which parents received on their Smartphones. Only 10% of parents reported using a laptop. More than 50%of parents with children in Grade 6-9 reported that they received assignments for 8 or more out of the 13 subjects in the Grade 6-9 curriculum. Contrary to our expectations, most of the parents had no issues with the transmission mode or the large number of facts so transmitted. Perhaps that is what they understand to be an education. The main concern of the parent was the lack of follow-up to assignments submitted by students, the inability of a student to clear any doubts about a lesson, difficulties in getting good signals on their smartphones and the cost of connectivity.

Observation of two WhatsApp groups of teachers and students in Grade 6 and 8 in one education zone from May 02nd 2020 to December 31, 2020, showed that initially teachers shared PDF files of notes that they would have shared on their blackboards in a regular classroom. As school closures continued, teachers were increasingly sharing links to online resources, or videos of master teachers. The assignments and assessment still concerned the describing of concepts and procedures, missing were higher order skills such as applying concepts to problem solving and reasoning (TIMMS, 2017).

3.5. Broadcast TV as the medium

Although the media in Sri Lanka reported as if online education is the only form of distance education, the Sri Lankan Government was more sensitive to the disparities in access to the Internet. With 91% of households in Sri Lanka and 51% households in Bangladesh owning a TV, broadcasting of lessons on TV was a natural choice for distance education. As UNICEF noted, despite disparities in ownership, television "is the main channel used by governments to deliver remote learning, with 3 in 4 governments out of 127 reporting countries using television as a source of education for children" (UNICEF, 2020).

To their credit, the National Institute of Education (NIE) together with the Ministry of Education (MoE) started broadcasting lessons on TV through the government owned channels soon after school closures, first targeting students sitting for the three-national examination. The government has also made a special allocation of Rs 30 million for producing TV programs and the government's budget for 2021 included an allocation of Rs: 3,000 million for distributing TVs to schools.

We asked the teachers in our survey about the TV lessons broadcasted by the Government. Of the 86 teachers only 70% were able to say how many of their students watched TV programs. According to their estimates of those who reported, only 28% of their studentswatched the TV broadcasts at least once.

3.6. Observations of teachers about TV broadcasts

Asked about what they would do to improve the lessons on TV, 75 out of 86 teachers gave their suggestions. Of those, three said that the programs were good without any further comments, but the other 72 gave thoughtful feedback. We organized their suggestions into four categories of issues – Connectivity (68%), Pedagogy (51%), Logistics (36%) and Parents (28%), with the percentages showing the percent of teachers who commented. We will discuss them in the order-connectivity, parents, logistics and pedagogy, elaborating on the last two issues. The first issues we believe are not solvable in the short-term.

3.6.1. Connectivity issues

These were mentioned by 68% of the respondents. Note that this number represents only the percent of teachers who felt that some or all children in a classroom had problems watching TV lessons due to poor TV signal where they live. Three teachers mentioned that even they could not watch the program due to poor TV signal in his/her home. We do not elaborate the issue of TV signals because it is not policy amenable in the short term.

3.6.2. Parent issues

Parents' disinterest was noted by 28% of the teachers. This could be due to poverty, lack of technical know-how or cultural practices such as engaging children in labor or prioritizing entertainment over education. Whatever the reasons for the disinterest of parents, these teacher observations underscore the importance of the schools and teachers playing a stronger role in the lives of these marginalized children.

In Sri Lanka we have a teacher to student ratio of 16.5 , but smaller schools have a much lower student to teacher ratios. Although there is reported to be much mismatching in allocation due to shortage of teachers in some subjects and oversupply in other, it is of no small consequence that there are sufficient trained teachers or teachers holding degrees in the system, at 49% and 48%, respectively (MoE, 2019), to follow up with students.

Provincial, zonal, or divisional authorities should take heed of these statistics and instruct schools to ensure that marginalized children are contacted by a teacher at least once a day during pandemic or other emergency induced distance education.

3.6.3. Logistics of delivering TV lessons

Of the 72 parents commenting on TV broadcasts, 36% had something to say about logistical issues such as TV Channels, Timing and duration; Timetables; or Informing the users. Despite teacher suggestions for a dedicated channel, more user surveys should be done before investing further. Is TV the best medium for communicating material in curricula to school children? Or is the medium better for co-curricular material which are entertaining as well as educative for school children?

NIE has taken steps to resolve the issue of timetables by assigning easily identifiable time of the day for each grade in school - for example, 9 AM for Grade 9. Although teachers had concerns about the presentation of subject matter, once the rush to produce sufficient programs is over, presentation issues can be resolved in a second round. Some of the presentation issues highlighted by the teachers can be summarized as follows

One of the other important logistics issues was communicating the information about programs to schools and parents. Teachers correctly argue for the need to know the timetable and the details of each broadcast well in advance, but is it realistic to have teachers across the country synchronizing their teaching plans to a central timetable?

Overall, the logistical issues concerning TV broadcasts prompts the question whether TV broadcasts are the best way to make lessons available to children in distance mode. Though teachers are asking for more information about TV broadcasts, have they really thought of the alternative of being able to access a lesson when and where students or teachers want to use? In fact, the broadcasted lesson are available for downloading and newly purchased TVs now come with USB ports to which a data storage device like a flash drive could be attached.

Educational videos are also produced by private or non-profit entities. As some education authorities in a remote education zone informed us, and as communicated to us by OPEnE, a civil society organization in Mannar, both groups have already successfully distributed educational videos on pen drives to families during COVID-19.

3.6.4. Pedagogical Issues

The uptake of technology in education has not been as rapid as it should be across the world and teacher factors play a major role (Gamage & Tanwar, 2019, and references therein) . Transmission of digital content via TV, WhatsApp or Zoom is not education. Neither is a child watching a video is education. Education happens when a child engages with learning material critically, creatively, collaboratively and learns to communicate what one has learned. Teachers' comments on such pedagogical issues regarding success of TV programs provide a treasure trove of

ideas not just for improving TV lessons, but for improving technology-mediated education in general.

The highest pedagogical concern of the teachers is that that there are children of different levels of ability in any class and weaker students are left out in distance education using broadcast TV. Making the lessons more practical or interactive are also requests from teachers. There were nine comments where teachers felt that not having a 'live' teacher or a teacher who interacts with the viewer as a problem. But TV lessons by design do not have a 'live teacher' . Some of the newer programs developed by NIE have the teacher interacting with a group of students as part of the program, but, overall, interactivity has never been the strong suit of low-tech TV.

But additional comments on how teachers can be brought on to supplement the TV lessons point to ways we might make digital learning materials work better.

LACK OF FOLLOW UP: "TV programs fails because they have no method to follow up with the children. Programs should be developed with a methodology that can be followed up with the child.; What if further clarification is required in the presentation? It is difficult for the child to continue the lesson because he cannot [go back] to the things he does not understand; Children are helpless because they have no one to explain the difficult points and to listen to them."

The teachers suggested linking pre-video activities and post-video activities to TV lessons by class teacher or subject teacher. Essentially, these teachers are talking about blended learning where digital learning materials are supplemented by interactions with a teacher.

3.7. Internet v. Broadcast TV as modes of distance education

The percentage reached by Internet or TV varied according to the type of school. When teachers tried to reach the students over Internet-based applications, the reach was 8% for the smallest schools and 59% for schools with 1001+ students with the reach increasing with decreasing size (Table 2).

This is consistent with the popular notion that larger schools have better facilities. The percent of students who watched one or more TV programs was distributed across school sizes with 22% of students in schools with 1-100 students saying they watched a TV program. Although, the overall percent reached by TV is low, the fact that students in less well-endowed schools were better reached by TV than Internet shows that TV has the potential to reach out to children without access to the Internet. However, the cost benefit of TV broadcasts must be evaluated before further investments.

3.8. Distance Education in Bangladesh - Good Practices

Schools in Bangladesh have been closed since March 12th, 2020. According to a presentation made by Mr. Mamoun of Bangladesh Ministry of education at a virtual UNESCO conference on Resilient Education on October 15, 2020, there are 39.8 million school children in Bangladesh (Cf. 4.5 million in Sri Lanka) and 171,779 schools (Cf. 10,165 schools in Sri Lanka). The education system in Bangladesh is massive and the challenges are much larger in scale. The ICT infrastructure situation is improving but at present it is at a lower stage than Sri Lanka (Table 1).

In Bangladesh we set out to identify good practices under the best of conditions and selected a better endowed set of schools for our study. The idea was to identify good practices

Table 2. Percent of students reached for distance education via Internet or TV, by size of school, November 2020

School Size	Internet	TV
1-100	8%	22%
101-500	27%	33%
501-1000	46%	35%
1001+	59%	24%
ALL	45%	28%

under optimal conditions for benchmarking good practices. While 90% of the teachers in Sri Lanka used WhatsApp technology, the teachers in the Bangladesh sample of teachers form schools with better facilities seem to use a variety of more advanced products. As one teacher described, he used WhatsApp for communication, Zoom for teaching, and Google Classroom for assessments. In fact, teachers are finding that online classes are better than face-2-face classes in some respects. As the interviewer noted:

"It was claimed by the teachers that regular classes have some limitations, i.e., shortage of equipment, and the internet. On the other hand, online classes helped them to overcome the problems that they faced in regular classes. They got the opportunity to use online resources to make teaching-learning more effective and easier. They can use audio/visual content like animation, pictures, video, or different effective and students friendly learning content from the internet which helped them to deliver the lecture with proper examples and explanation. Most of the teachers used Zoom and WhatsApp to conduct online classes. Besides with Zoom and WhatsApp, some teachers used Google Classroom, Facebook live, and messenger.

Although we did not carry out a systematic study of elite schools in Sri Lanka, there is anecdotal evidence to suggest similar teacher sentiments.

One of the participants informed us that they conducted a discussion-based class instead of lecture-based classes. Teachers regularly uploaded their class contents/lectures in the WhatsApp group and these students were instructed to contact the concerned teacher to get help. "Like regular classroom teaching we are trying our best to make them understand the lessons. If they get any problem, they could contact the teacher to clarify it. Moreover, we upload all the classwork and homework in a WhatsApp group which they could follow, and it also helps the absentees", a teacher said.

Above practices quoted by teachers approach what one might call blended learning where teachers use a combination of face-to-face interactions and technology in the teaching and learning process. A flipped classroom is a variation of blended learning where students watch a video on their own and the teacher use interaction time with students to discuss the material.

Bangladeshi teachers agreed that it is likely to carry over these good practices to regular classrooms?

These Bangladesh case studies from better-endowed schools indeed show that innovations in distance education are easier to observe in better endowed situations. The challenge is to adapt these practices to low resource conditions. Inputs from Sri Lankan teachers helped us bridge that gap. Our findings are summarized in the conclusion.

4. CONCLUSIONS AND RECOMMENDATIONS

We estimate that in Sri Lanka only 45% of the students in the public-school system were reached in distance mode using Internet-based applications in 2020. TV broadcasts of lessons by the Government of Sri Lanka first introduced on March 22nd reached only 28% of students. Statistics are not available for Bangladesh. To our knowledge such data are not reported for Bangladesh or other countries in Asia or anywhere. There is an urgent need to monitor the reach of distance education in each country and take steps immediately to bring those unconnected using appropriate combinations of pedagogical and technological initiatives.

4.1. Blended learning, High-Tech or Low-Tech

Distance education for school children cannot be driven by technology alone. One-to-one or one-many interactions between teacher and students are essential for learning. Therefore, blended learning which is essentially about combining student and teacher interactive sessions (face-to-face or ICT mediated in distant mode) with self-learning

by students using digital content is essential in distance learning.

Observations of teachers from better endowed set of schools in Bangladesh show how teachers innovated during COVID-19 imposed distance education using combinations of digital tools like Google classroom, WhatsApp, and Zoom to provide a satisfactory blended learning experience to their students.

Observations by teachers and secondary data sources from Sri Lanka show that it is indeed possible to provide a low-tech version of a blended learning experience to children without internet access by using offline resources.

4.2. Implications for Other Countries in Asia

Access to and use of ICT in six countries in Asia has shown that that Internet use in countries in the region can be as low as 8% (LIRNEasia, 2020) While the long-term solution for distance education in pandemics or other emergencies will involve online solutions, in the short-term, these countries must come up with offline solutions that involve offline digital content, broadcast TV, or radio options to deliver education. Each country needs to take a glass is half-full approach and use their offline resources to the maximum extent to reach out to every student during school closures.

REFERENCES

Gamage, S. N, & Tanwar, T. (2018). Factors affecting the use of ICTs in the classroom by teachers: A systematic review of the literature. *Information Technologies & International Development*, 14 (Special Section). http://itidjournal.org/index.php/itid/article/view/1487/592

LIRNEasia (2019/2020). After Access: ICT access and use in Asia and the Global South (Version 3.0). Colombo: LIRNEasia. https://lirneasia.net/wp-content/uploads/2019/05/LIRNEasia-AfterAccess-Asia-3.0-update-28.05.2019.pdf

MoE (2019). School Census 2019: Education Statistics of Government Schools. Ministry of Education, Colombo, Sri Lanka. https://moe.gov.lk/wp-content/uploads/2020/12/National-Level-Tables-Part1.pdf

NEC (2017). New Education Act for General Education in Sri Lanka: Context, Issues and Proposals. Nugegoda, Sri Lanka: National Education Commission. http://nec.gov.lk/wp-content/uploads/2017/02/NEC-GEP-final-English6.pdf

TIMSS (2017). TIMMS 2019 Assessment Frameworks. Mullis, I. V. S., & Martin, M. O. (Eds.). TIMSS Boston: TIMSS & PIRLS International Study Center

World Bank (2018).World Development Report 2018: 'Learning to Realize Education's Promise'

UNESCO (2020). ICT enabled Resilient Education. Webinar. October 15, 2020.

UNICEF (2020). https://www.unicef.org/eap/press-releases/unequal-access-remote-schooling-amid-covid-19-threatens-deepen-global-learning

Zainudeen, A & Amarasinghe, T (2020). E-learning opportunities in the Asian global South, Colombo: Education Forum Sri Lanka Policy Dialogues, Colombo, May 2. https://lirneasia.net/2020/05/e-learning-opportunities-in-the-asian-global-south-presentation.

BIBLIOGRAPHY

Patrinos, H. A., Velez, E., & Wang, C. Y. (2012). Framework for the Reform of Education Systems and Planning for Quality, *World Bank Policy Research Working Paper*: No. 6701. World Bank, Washington, DC.

PTF (2020). Reimagining Education: Report of the Presidential Taskforce on Education Affairs. Office of the President, Colombo, Sri Lanka. http://nec.gov.lk/wp-content/uploads/2020/10/6.Re-imagining-Education-Sri-Lanka-Summary-Report-by-Presidential-Task-Force.pdf

Impact of Covid-19 pandemic on the learning process of undergraduates: Current and future implications

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ABSTRACT

The entire world had to face changes in lifestyles due to the ongoing global pandemic of corona virus disease 2019 (COVID-19). Knowing the nature of such changes and their effects, the respective authorities can build up effective solutions. Focusing on undergraduates, we attempted to explore the perception of Sri Lankan undergraduates towards the unanticipated changes in their learning process due to COVID-19 pandemic. Moreover, we suggest mechanisms to handle possible implications.

Data were gathered from science undergraduates through an online questionnaire. The results revealed that, during this pandemic, the students are overloaded with assignments. That may be one reason for their increased stress levels. Thus, there should be a proper formulation of formative assessments as well as an active student support system which can help maintain students' mental wellbeing under the distance learning environment. With the witnessed continuation of the interruptions on students' learning due to poor internet connectivity, the authorities should not ignore their responsibility in enhancing IT infrastructure facilities and financial assistance for online learning. Moreover, students would get the maximum benefit of this time of distance learning if the universities could motivate students to acquire external knowledge by arranging a series of webinars on topics related to various specific professions, together with industry linkages. Such a directive can be effective in making future graduates more employable.

In conclusion, it is essential for the higher educational institutes to seize the opportunities to perform better for their survival, efficient functioning and also for the benefit of future Sri Lankan graduates.

Key words: COVID-19, Distance teaching-learning process, Undergraduate education

1. INTRODUCTION

The outbreak of novel corona virus disease 2019 (Covid-19) was declared as a Public Health Emergency of International Concern (PHEIC) by World Health Organization on 30th of January 2020 (Team, 2020). The epidemic originated in Wuhan, China with the identification of a cluster of pneumonia cases of unknown origin in December 2019. Within one month since the first reported case, it rapidly spread to other regions in China and other countries as well (Luo et al., 2020). In Sri Lanka a Chinese tourist was reported as the first Corona infected patient in February 2020 (Ranasinghe et al., 2020). Thereafter, a gradual increase of both imported and locally transmitted Covid-19 incidents were reported within Sri Lanka.

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Under such circumstance, the Sri Lankan government took necessary actions such as arrangement of quarantine facilities, closure of educational institutes and workplaces, closure of the Colombo International Airport for all arrivals and ultimately a decision to impose island wide curfew, in order to control the disease spread.

This ongoing global pandemic led to transformations in operational processes related with most of the sectors. As a result, unanticipated changes happened in the lifestyles of people in the entire globe. These changes produced positive and negative effects. Considering the adjusted teaching learning environment in the higher education sector, we focused on exploring the effects of this transition, how effectively the undergraduates used their study from home and the expectations of undergraduates towards a better future. Moreover, we attempted to characterize the future implications of such investigation.

Many studies (Gallè et al., 2020; Kapasia et al., 2020; Sahu, 2020) discussed the impact of COVID-19 pandemic on higher education sector. It was reported that many of the students encounteredhuge challenges with the sudden shifting of face-to-face lectures to online platform (Kapasia et al., 2020). During this pandemic educators should not only focus on the teaching learning mechanism but also attention is needed on assisting students to maintain their mental health and well-being(Sahu, 2020). Hence, knowing the nature of the changes and their effects, the respective authorities would be able to effectively take steps to improve the existing distance teaching-learning environment.

2. METHODOLOGY

Survey method was used to gather data for this study. A web link to an online questionnaire was sent to Dean's Offices of science faculties in nine Sri Lankan state universities requesting to distribute it among science undergraduates. Data were analyzed by obtaining descriptive summaries and the association among factors was evaluated according to the chi-squared test.

3. RESULTS AND DISCUSSION

Even though we tried to share the online questionnaire among science undergraduates in several state universities, unfortunately, we received only 421 responses. This represents 5%, 41% and 54% response from the respective categories of students in University of Kelaniya, University of Peradeniya and the University of Sri Jayewardenepura respectively. Online survey methods can be considered as the most suitable way of assessing perceptions of individuals regarding various topics by maintaining the social distancing. However, with the large number of online surveys during this unprecedented pandemic situation, we have to expect a lower response rate.

According to Figure 1, during the closure of the university more than 30% of students had faced difficulties related to their studies. Most of these problems were caused by the transition of the mode of delivery of lectures from face-to-face to online.

Table 1 reveals that during the initial few days of online lectures, the majority of students had faced problems such as feeling depression (60%) and poor internet connectivity (82%). Chi- square test disclosed that compared to the first few days of online lectures, many students (35%) felt that their level of stress and problems in completing assignments on time had worsened at the present. A majority of students are still having difficulties in joining online lectures due to lack of necessary material (41%), unfavourable study environment (42%) and poor internet connectivity (48%). In contrast, a considerable proportion of students (32%) felt that even though the lecturers had not showed much interest in teaching through online mode during the first few days, but now the lectures are conducted in an interesting manner.

As shown in Table 2, it was observed that the majority of students never used online library resources or services (45%) and never participated in online meetings (55%), free

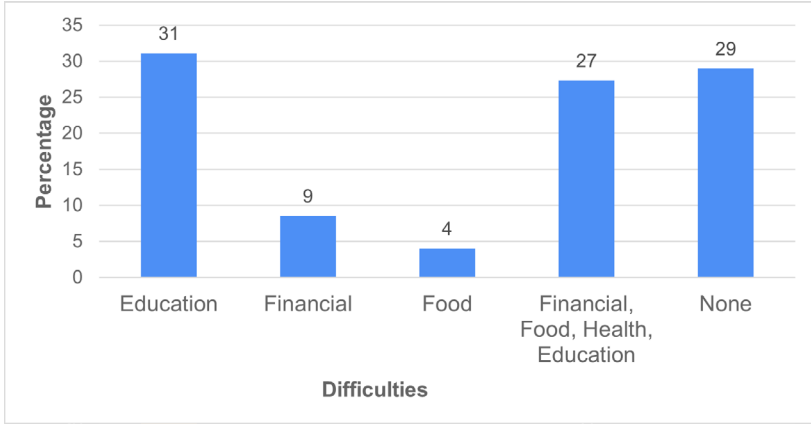


Figure 1. Main difficulties faced during the closure of the universities

Table 1. Status of problems faced by students during the pandemic situation

First few days \ At present		Yes, Better than before	Yes, Same as before	Yes, Worse than before	No	Row %	p-value
Feeling of stress, depression	Yes	28	23	35	15	60	0.000
	No	7	14	16	63	40	
Not having necessary materials	Yes	29	41	15	16	49	0.000
	No	13	13	3	70	51	
Not having favorable environment	Yes	22	42	26	11	47	0.000
	No	9	14	4	73	53	
Problems related to internet connection	Yes	21	48	25	6	82	0.000
	No	3	12	8	78	18	
Teachers not interested in teaching	Yes	32	38	17	13	33	0.000
	No	11	13	1	76	67	
Not having proper time table for lectures	Yes	28	38	22	12	47	0.000
	No	13	12	4	71	53	
Not having enough time to complete assignments	Yes	20	36	35	10	46	0.000
	No	14	15	4	66	54	

online courses (61%), free webinars (59%), online research conferences (77%), online examinations (69%) and research activities (68%) before the Covid-19 pandemic. However, around 76% of students frequently or occasionally used LMS/ Google Classroom during their studies. During this pandemic situation a majority of students had frequently participated in online meetings (66%), moderately participated in free online courses (30%) and frequently used LMS/ Google Classroom (76%) even though they never involved with these technologies before the pandemic situation. In contrast, a majority of students had frequently or moderately participated in free webinars, online research conferences, online examinations, innovations or inventions and online library resources or services during this pandemic situation, only if they used these technologies before the pandemic situation.

As depicted in Figure 2, a majority of students have positive attitudes towards (49% - 57%) studying through recorded video lessons, having more time for self-studying, using assignments as a formative assessment method, responses of lecturers on their questions and guidance from the university on free webinars and online courses. However, they are dissatisfied (51%-73%) with the temporary termination of face-to-face lectures, postponed lab practical sessions and examinations, participating in online

Table 2. Involvement with technologies before and during the university closure due to the Covid-19 pandemic

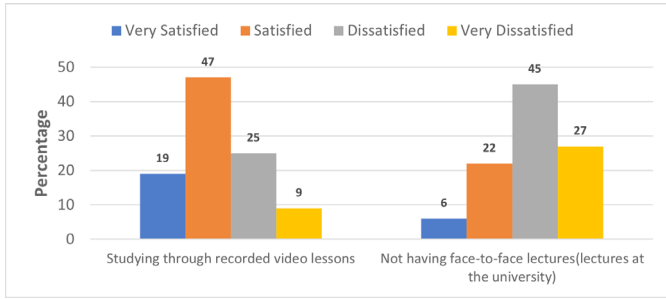
			During the university closure				
			Yes, frequently	**Yes, moderately**	**Yes, rarely**	**Never**	**Row %**
Participation/ usage before Covid-19	Online meetings	Yes, frequently	81	16	3	0	9
		Yes, moderately	51	35	12	2	12
		Yes, rarely	66	26	7	1	24
		Never	66	22	11	2	55
	Free online courses	Yes, frequently	75	20	0	5	5
		Yes, moderately	41	55	4	0	12
		Yes, rarely	20	43	31	6	22
		Never	28	30	19	23	61
	LMS/ Google Classroom	Yes, frequently	94	6	0	0	40
		Yes, moderately	72	22	5	1	36
		Yes, rarely	76	20	4	0	12
		Never	76	12	10	2	12
	Free webinars	Yes, frequently	65	35	0	0	5
		Yes, moderately	21	60	19	0	11
		Yes, rarely	20	33	41	6	25
		Never	18	25	21	37	59
	Online research conferences	Yes, frequently	57	29	14	0	2
		Yes, moderately	8	75	17	0	6
		Yes, rarely	8	17	68	8	16
		Never	3	6	23	68	77
	Online exams	Yes, frequently	90	10	0	0	2
		Yes, moderately	11	75	11	3	9
		Yes, rarely	16	25	48	11	20
		Never	5	19	31	45	69
	Online library resources or services	Yes, frequently	66	24	7	3	7
		Yes, moderately	24	53	14	8	20
		Yes, rarely	8	36	50	6	28
		Never	3	12	22	63	45
	Innovations and inventions	Yes, frequently	56	44	0	0	2
		Yes, moderately	8	52	32	8	6
		Yes, rarely	5	18	59	19	24
		Never	1	2	13	84	68

examinations andabsence of financial support from the government on online learning.

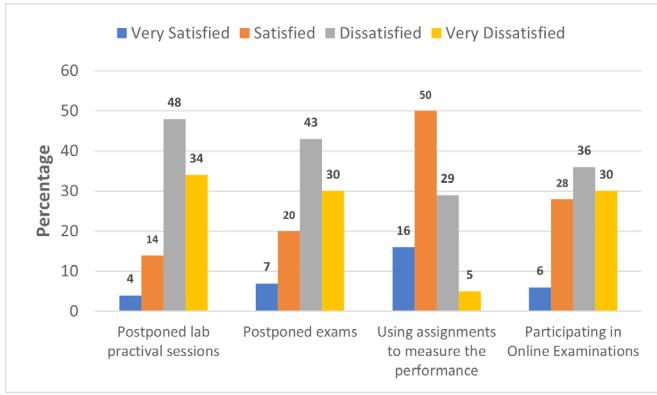
The transition in the teaching-learning platform from in-person to online led to some positive changes in various skills (Figure 3). Specifically, a majority of students (52%-92%) improved their abilities in participating in webinars, self-learning, using computer/ laptop, mobile phone, internet, online teaching resources and study-related software. Conversely, a higher proportion of students (44%-58%) believe that their English language skills, creativity, adaptability and research capabilities remained as the same before the pandemic situation. Moreover, 64% of students think that their skills in sports had become worse during this pandemic situation.

Figure 4 illustrates how the students managed their time during the period of university closure. It revealed that they have allocated a higher proportion of time on completing assignments, online lectures and self-learning on university courses, respectively. Other than their studies, a higher proportion of remaining time is allocated on self-learning on new subject areas, technologies and tools. Then they focused on improving soft skills and involve in research work, respectively. Comparatively less time is allocated on freelance jobs, webinars and online courses related to the industry.

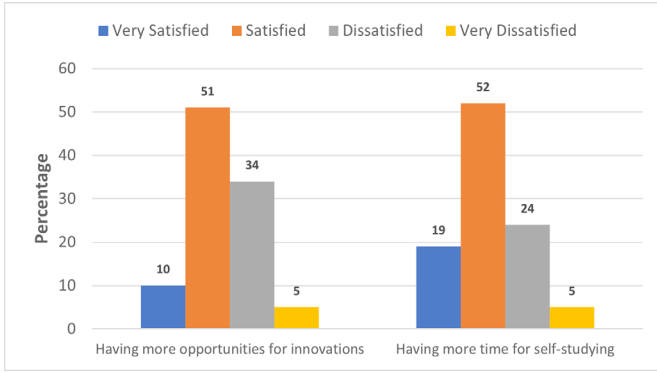
In terms of the effectiveness of online lectures, a majority of students have positive attitudes (Table 3). Only around 27% of students



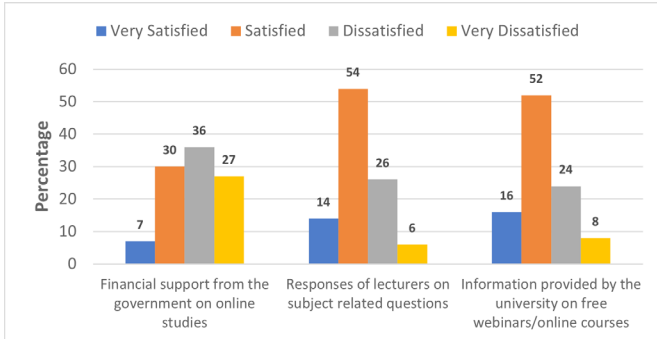
(a) Perception towards mode of learning



(b) Perception towards assessment



(c) Perception towards the opportunities



(d) Perception towards the Assistance on online learning

Figure 2. Perception towards the current changes in learning process

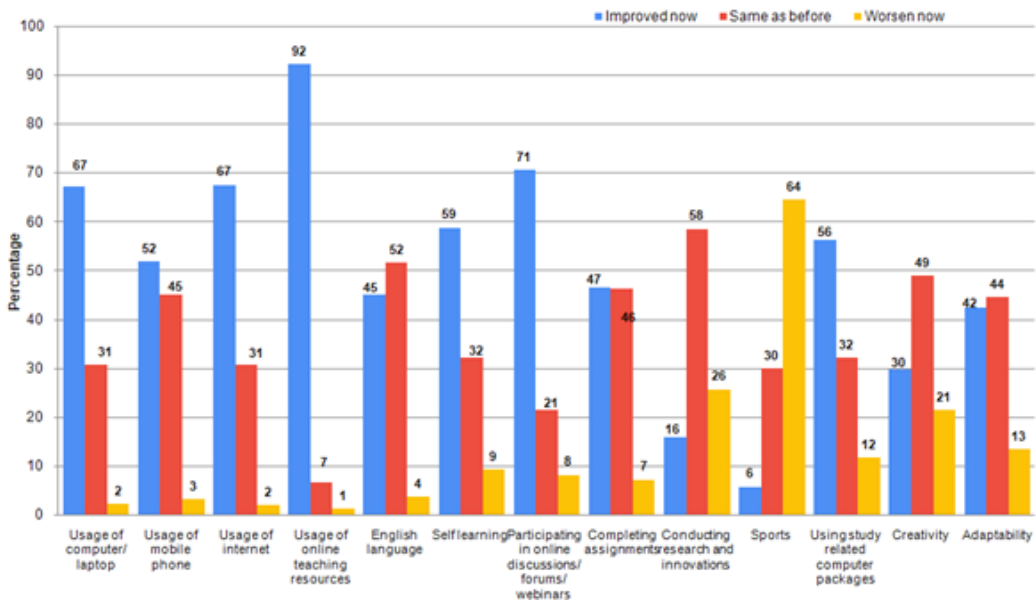


Figure 3. Changes in skill levels

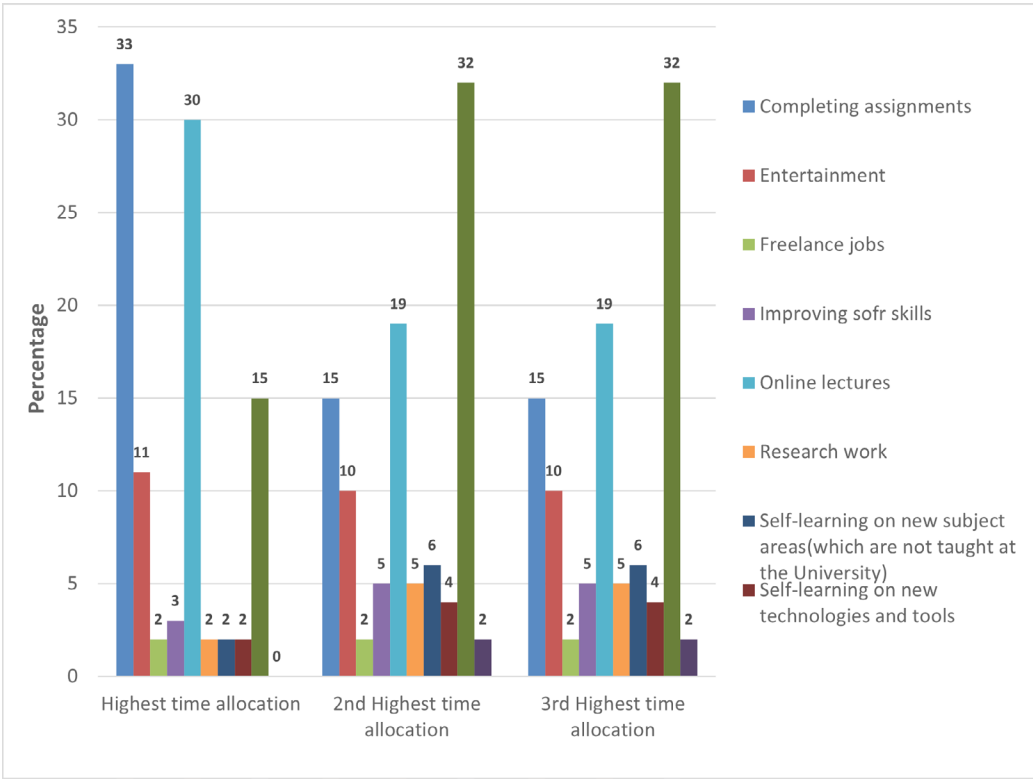


Figure 4. Chart of time allocation ranks for the activities during Covid – 19

Table 3. Perception towards online lectures

	Very effective %	Somewhat effective %	Somewhat ineffective %	Very ineffective %	No Idea %
Effectiveness of online lectures	15	55	19	8	3
	Face-to-face lectures provided more clarification %		**Online lectures provided more clarification %**	**Both same %**	
Level of clarifications	57		23	20	
	Yes, for all %		**Yes, for some %**	**No %**	
Willingness to continue lectures in online mode after university reopening	13		48	39	

think that online lectures are ineffective. Comparison between face-to-face and online lectures with respect to level of clarifications provided through them reveals that a majority of students (57%) believe that face-to-face provide more clarification. Further exploration on the willingness of students to continue lectures in online mode after the reopening of the University disclosed that around 48% of students are willing for such directive only for some courses. However, the disagreement of around 39% of students regarding this point should not be ignored.

4. CONCLUSIONS

During the COVID-19 pandemic the major challenge faced by the higher education sector was the responsibility to continue study programs effectively without interruptions. The perception of students towards the changes in the teaching learning mechanism can be used to assess future implications. It was evident that the stress level of students had been increased compared to the initial few days of online lectures. Such increase may be caused by the unbearable workload which comprise of bundles of assignments and sedentary monotonous lifestyle that they had to spend due to the lockdown. This points to the need of proper formulation of formative assessments. Similarly, students would be benefitted by having an active student support system which can assist students to maintain their mental wellbeing during this kind of crisis situation.

Positive attitude of students on current teaching style of lecturers suggest that the lecturers had improved their lecture delivering ability through online mode. Moreover, a further teacher training will lead to higher effectiveness in online teaching learning process. The transition in the teaching learning process from face-to-face to online can be seen as an opportunity for students to enhance their skills in using new technologies and self-learning abilities. However, they have not experienced any improvement in their English language skills. Most importantly, students are highly dissatisfied with the lack of opportunities to participate in sports during this time of social distancing. Hence, the respective authorities should provide alternatives such as free webinars on English language, providing guidance to maintain their physical fitness, etc.

During the period of university closure students allocated a higher proportion of time in completing assignments, online lectures and self-learning on university courses. At the same time, they paid less attention on webinars and online courses related to the industry. This points to the need of higher educational institutes in motivating students to acquire external knowledge related to various specific professions by participating in webinars and online courses. Students would get the maximum benefit of distance learning if the universities could arrange a series of such courses together with industry linkages. Such directive would be successful in making future graduates more employable.

The majority of students were not able to overcome the issues related with poor internet connectivity and unavailability of a suitable study environment yet. Moreover, attention should be paid on the displeasure among students on the limited actions taken by the government to offer financial support to facilitate online learning. In a situation where the universities are focusing towards employing more advanced technologies to conduct teaching and assessments through online mode, studentsare strugling to maintain the pre requisities for such mechanism by themselves andunhappy about the absence ofsupport from respective authorities. This clearly implies the need for active intervention of the government on providing students with the essential requirements to continue their studies through online mode.

In conclusion, there are many opportunities to perform better. It is essential for the higher educational institutes to seize those opportunities for their survival, efficient functioning and also for the benefit of future Sri Lankan graduates.

REFERENCES

Gallè, F., Sabella, E. A., Da Molin, G., De Giglio, O., Caggiano, G., Di Onofrio, V., Ferracuti, S., Montagna, M. T., Liguori, G., Orsi, G. B., & Napoli, C. (2020). Understanding Knowledge and Behaviors Related to CoViD–19 Epidemic in Italian Undergraduate Students: The EPICO Study. *International Journal of Environmental Research and Public Health*, *17*(10), 3481. https://doi.org/10.3390/ijerph17103481

Kapasia, N., Paul, P., Roy, A., Saha, J., Zaveri, A., Mallick, R., Barman, B., Das, P., & Chouhan, P. (2020). Impact of lockdown on learning status of undergraduate and postgraduate students during COVID-19 pandemic in West Bengal, India. Children and Youth Services Review, 116, 105194. https://doi.org/10.1016/j.childyouth.2020.105194

Luo, H., Tang, Q. L., Shang, Y. X., Liang, S. B., Yang, M., Robinson, N., & Liu, J. P. (2020). Can Chinese Medicine Be Used for Prevention of Corona Virus Disease 2019 (COVID-19)? A Review of Historical Classics, Research Evidence and Current Prevention Programs. Chinese Journal of Integrative Medicine, 26(4), 243–250. https://doi.org/10.1007/s11655-020-3192-6

Ranasinghe, R., Damunupola, A., Wijesundara, S., Karunarathna, C., Nawarathna, D., Gamage, S., Ranaweera, A., & Idroos, A. A. (2020). Tourism after Corona: Impacts of Covid 19 Pandemic and Way Forward for Tourism, Hotel and Mice Industry in Sri Lanka. SSRN Electronic Journal. Published. https://doi.org/10.2139/ssrn.3587170

Sahu, P. (2020). Closure of Universities Due to Coronavirus Disease 2019 (COVID-19): Impact on Education and Mental Health of Students and Academic Staff. Cureus. Published. https://doi.org/10.7759/cureus.7541

BIBLIOGRAPHY

Eurosurveillance Editorial Team. (2020). Note from the editors: World Health Organization declares novel coronavirus (2019-nCoV) sixth public health emergency of international concern. Eurosurveillance, 25(5), 200131e. https://doi.org/10.2807/1560-7917.es.2020.25.5.200131e

NATIONAL SCIENCE FOUNDATION

Section 7

Building Resilience

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Building Resilience: Introduction

Dilanthi Amaratunga, Naduni Jayasinghe and Nishara Fernando

The recent COVID-19 pandemic has been perceived and experienced by most governments and societies across the globe as an unprecedented shock. However, facts reveal that pandemics have been far from alien. Before the advent of the Coronavirus, a number of outbreaks have repeatedly triggered the world ranging from those as early as the Spanish flu of 1918, the Asian flu of 1957 to more recent outbreaks such as HIV/AIDS in 1981, SARS in 2003 and MERS in 2012. Most countries have demonstrated a low level of preparedness for COVID-19, have failed to incorporate pandemics in their Disaster Risk Reduction (DRR) strategies, and to act on the basis of science and warnings about the threat of a pandemic. COVID-19 has given rise to complex risk scenarios and compound vulnerabilities which most countries have hardly anticipated. Most countries have barely recognized multi-hazard scenarios although now they are faced with the challenge of responding to extreme climatic events such as floods, earthquakes and landslides in the midst of their boundless efforts to curtail the spread of COVID-19. The pandemic has called into question the viability of existing response mechanisms to climatic events and urged relevant stakeholders to rethink their approaches, at all levels. The effects of the pandemic have not failed to transcend the health sector, cascading into other sectors such as the economy, society, legal systems and politics. This way, the pandemic has not just dismantled one part of a system but failed the entire system thereby showcasing the systemic nature of risks.

The effects of COVID-19 have been disastrous and complex, and it is nowhere near its end. Given how various epidemics and pandemics have been emerging and re-emerging in the recorded history, it is almost impossible to imagine a future devoid of similar outbreaks. COVID-19 has created a significant shift in people's lifestyle, behaviour and aspirations paving way to the 'new normal'. It is the 'new normal' that sets the context for interaction, communication, trade and development. These point towards the need to recover better from the COVID-19 pandemic with emphasis placed on taking transformational actions to strengthen resilience at all levels. National and local authorities can seize this as an opportunity to create the policy and structural changes that are capable of navigating the journey of resilience building. Such changes may range from strengthening health systems and health infrastructure; improving social protection to pursuing climate friendly policies.

Within this context, 'Resilience Theme' of "COVID 19: Impact, Mitigation, Opportunities and Building Resilience : From Adversity to Serendipity", Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka, is aimed at facilitating a discourse on how the 'new normal' should be visualized and preparedness for and recovery from COVID-19 can be geared towards strengthening the resilience of the society and community. This track is intended at providing an avenue for knowledge sharing and scrutiny of key topics namely, best practises of responding, re-opening and recovery with respect to COVID-19; combatting dual challenges of COVID-19 and natural hazards; systematic integration of public health and disaster risk management; business reactivation from systemic risk management; urban preparedness for effective response to COVID-19; effective and integrated risk communication and multi-hazard disaster preparedness incorporating pandemics. There are seven chapters which address these key components:

1. Analysing the effectiveness of varied stakeholder segments in preparedness planning for epidemics and pandemics in Sri Lanka: Application of Social Network Analysis (SNA);

2. Settling the ripples: An examination of Sri Lanka's approach to addressing cascading impacts of the COVID-19 pandemic

3. A more decentralized governance framework for pandemic response: A multi-stakeholder approach for COVID-19 preparedness and planning in Sri Lanka

4. Preparing, responding and re-opening: Lessons from the UK to emerge during the COVID-19 pandemic

5. COVID-19 nexus with food security and sustainable growth: Impacts, implications and road to resilience in Sri Lanka

6. Integrating pandemic and epidemic into disaster management/disaster risk reduction mechanisms in Sri Lanka: From the perspective of local government authorities

7. Health resilient cities in a post covid world

These chapters reflect on some of the core areas that demand attention on the path towards 'whole of society resilience' including the establishment of accountability for pandemic preparedness and response; addressing the cascading socio-economic effects of COVID-19; governance for pandemics; learning from success stories and adopting best practises; food security and sustainable growth in the context of COVID-19, the role of local governance in pandemic preparedness and response and integration of pandemic preparedness into urban planning.

The first chapter delves into who is accountable for pandemic preparedness and response in Sri Lanka while attempting to visualize the linkages between these stakeholders via the Social Network Analysis Approach. In doing so, the authors emphasize on the importance of widening the scope of stakeholders involved in preparedness planning for pandemics and other biological hazards in the country. The authors also advocate the enhanced participation of non-health sector stakeholders including the private sector and community based organizations in preparing for and responding to biological hazards such as COVID-19 thus, reflecting on the importance of cross sectoral collaboration. It also draws attention to the need for a unified legal framework and a streamlined system of governance to facilitate such cross-sectoral collaboration and to establish collective accountability for risk management pertaining to biological hazards.

The second chapter observes how the effects of COVID-19 have transgressed the health sector to give rise to unfavourable and long lasting economic and social effects. The chapter examines Sri Lanka's approach to addressing these cascading socio-economic impacts of the pandemic and outlines its major strengths and gaps. The authors demonstrate how such cascading effects can cause sustained vulnerabilities that call for solutions with a long-term focus as opposed to exercising immediate responses measures such as the provision of emergency relief. Accordingly, the authors recommend that increased attention be paid to building the resilience of both the society and the economy while outlining certain policy initiatives (E.g.: the establishment of a systematic and inclusive social protection system; enhancing state-citizen interactivity at the local/village level).

The third chapter draws lessons from other countries that have responded to COVID-19 and similar pandemics such as SARS and Ebola to demonstrate the importance of a multi-sectoral and decentralised governance mechanism for pandemic response in Sri Lanka. The authors argue that pandemic response should be contextualised/localised to suit the psychological, social, demographic and economic characteristics and needs of local communities while harping on the ineffectiveness of a national level blanket approach. The authors move on to discuss how the deconcentrated approach to DRR in the country can be leveraged and optimised to allow for decentralised

governance of pandemic response. The chapter also showcases the potential for involving a broader range of sectors such as education, higher education and mental health in pandemic response at the sub-national level to enhance effectiveness of response measures.

The fourth chapter highlights the best practises and shortcomings of UK's pandemic risk governance system with reference to actions taken by the UK Government across three stages of the COVID-19 pandemic: preparedness, responding and re-opening. Some of the best practises identified by the authors include increased capacities to carry out risk assessments; the prevalence of a sound legal and policy framework; undisrupted access to Early Warning systems; financial stability to invest in infrastructure during emergencies; use of scientific data and advice to inform policy making; and provision of adequate financial support by the government. The chapter recommends several measures to improve UK's pandemic risk governance system including (but are not limited to):ensuring clear, timely and accurate Early Warning communication; promoting research on pandemic impact; activating speedy responses as opposed to delayed responses and rebuilding lost public trust on government through sharing science based information on one hand and ensuring inclusivity in policy and decision making on the other hand.

The fifth chapter discusses how COVID-19 has impeded nations' progress towards Sustainable Development Goals mainly paying attention to its impacts on food security in Sri Lanka. The authors reflect on how food security in the country has been threatened due to numerous challenges posed by COVID-19: the loss of livelihoods, and income generating opportunities and disruptions to national and global food supply chains. The chapter also puts forward key interventions to improve food and nutrition security in Sri Lanka with a focus on protecting development gains and building resilience of communities. Some of the proposed interventions include re-engineering market access to food; situating Sustainable Development Goals at the heart of policy making across all sectors; promoting regenerative agriculture and scaling up climate-informed agriculture planning and climate-smart agriculture practices.

In the sixth chapter, authors identify the crucial role played by the Local government authorities (LGAs) during the COVID-19 pandemic in Sri Lanka in areas such as the coordination of provision of subsidized essential grocery packages, disinfecting public areas, providing basic facilities at quarantine centres, and acting as a nexus point between the government and the general public. The chapter also reveals some of the key challenges faced by LGAs in performing their duties during the COVID-19 pandemic, some of which are politicization of pandemic relief and provisions, conflict on their role in DRR planning, absence of inter-agency accountability, lack of appreciation of their services, limited technical capacities, lack of access to equipment and insufficient representation of LGAs in local Disaster Management committees. Further, the chapter suggests various steps that can be taken to overcome these challenges. Suggested measures include [but are not limited to] adoption of a provincial council disaster response framework, introducing representatives from LGAs to disaster management committees and providing specialized training for LGA officers on handling biological hazards and managing waste during pandemic situations. Authors also have re-emphasised the on-going concern that Local government authorities (LGAs) have not been adequately incorporated into the national disaster risk management framework of Sri Lanka.

The seventh and the final chapter draws attention to the increased exposure of condominium residents in Sri Lanka to COVID-19, while establishing the need to consider the potential effects of pandemics and similar biological hazards in urban planning. The chapter stimulates a discussion on how cities should be re-imagined in the context of the 'new normal' and how urban planning should be geared towards building health resilient cities. This may call for initiatives such as accelerating digitized and remote working; establishment of '15 minute cities' characterised by more sidewalks and less compact, greener buildings; strengthening the health resilience of transportation by incentivizing sustainable mass transit and promoting health driven urban renovation and infrastructure improvement.

As summarised above, the 'resilience' theme has aimed to pave way for knowledge production and exchange on the basis that a resilience building approach is critical to recover better from COVID-19 and mitigate the adverse human, psychological, social and economic effects of future pandemics and similar hazards. Scholarly work produced under this track has affirmed that it's necessary to build resilience of societies to protect development gains and steer uninterrupted progress towards achieving Sustainable Development Goals [SDGs]. Scholars have also demonstrated that resilience building should be holistic with attention being paid to issues within and links among different sectors. For this reason, a resilience building approach requires legal, policy and action frameworks that support synergy among multiple sectors and levels in the society. While contributors have addressed the theme of 'resilience' from many angles, their work provides impetus for further research in this area, particularly capturing 1) preparedness for multi-hazard scenarios and integration of biological hazards into such preparedness; 2) current status, gaps and directions for building private sector resilience against pandemics and similar hazards; 3) policy directions and ground level actions for strengthening the resilience of vulnerable groups; 4) role of resilience in post-COVID-19 sustainable development agenda; 5) role of data and science in pandemic governance for resilience building and 6) current status, gaps and directions for strengthening the resilience of health infrastructure.

Analysing the effectiveness of varied stakeholder segments in preparedness planning for epidemics and pandemics in Sri Lanka: Application of Social Network Analysis (SNA)

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ABSTRACT

The COVID-19 outbreak has caused severe disruptions in health, social, economic, and political sectors highlighting the need for focusing on the dynamic nature of systemic risks. The cascading impacts of the COVID-19 have already evidenced the systemic nature of risks related to biological outbreaks. Therefore, the emulation of a multi-sectoral approach for preparedness planning related to biological hazards has become a global concern. This research aims at outlining major stakeholders in epidemic and pandemic preparedness planning in Sri Lanka including those who are responsible for potential cascading impacts. The process of identifying stakeholders and their roles has drawn on a review of secondary literature and primary data gathered through in-depth interviews conducted with key informants in the disaster management and public health sectors in the country. Social Network Analysis approach was used to visualise and analyse the network of stakeholders. Findings have highlighted that currently, the preparedness planning related to epidemics and pandemics in Sri Lanka is a health sector-led process. There is a pressing need for a unified legal framework and a streamlined system of governance for risk management related to biological hazards in the country. Furthermore, it is important to broaden the scope of stakeholders involved in preparedness planning for biological hazards and to include the private sector, international development agencies, and community-based organisations. Moreover, there is a need to intensify the national focus on building economic and social resilience to address the potential cascading impacts. Key findings of this study will help to enhance the effectiveness of preparedness planning for biological hazards, through a multi-sectoral approach operational under a unified legal framework.

Key words: Social network analysis, COVID-19, Preparedness planning, Multi-sectoral approach

1. INTRODUCTION

The COVID-19 pandemic engulfed the whole world during the past year and over 100 million confirmed cases are reported currently with a death toll of over 2 million worldwide (WHO, 2020). Throughout history, infectious diseases such as COVID-19 have had devastating impacts on humankind from time to time (Jarus, 2020). The COVID-19 pandemic also upended the worldwide healthcare system with increasing rates of hospitalisation (Ornstein & Hixenbaugh, 2020; PAHO, 2020). Apart from the enormous pressure on the health sector, the COVID-19 outbreak has caused severe impacts on socio-economic sectors. Experts anticipated a deep recession in the global economy with a loss of about 5.2% in the global Gross

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Domestic Product [GDP] in 2020 (The World Bank, 2020b). The COVID-19 pandemic unreasonably affected the highly vulnerable communities and has paved the way for a social crisis. The World Bank warned that 150 million people would be pushed to extreme poverty by 2021 and this estimated rise in global poverty would occur for the first time in over 20 years (The World Bank, 2020a).

The COVID-19 outbreak has made it evident that a pandemic can render severe cascading impacts on humankind spreading across various sectors. For instance, labour-intensive industries experienced significant downfalls as thousands of people have lost their sources of income (Parikh & Desai, 2020). The agriculture sector incurred substantial losses since the demand from primary consumers and bulk buyers such as hotels dropped severely. Furthermore, impacts of the pandemic have cascaded across industries such as petroleum, manufacturing, tourism, aviation, education, construction and sports (Dave & Dave, 2020). From a psychological perspective, mental issues have emerged as a significant concern due to prolonged homestay and uncertainties. Additionally, the spread of Coronavirus has created severe problems in the political structures of the majority of the countries as well (Business Standard News, 2020).

These widespread negative impacts of the COVID-19 pandemic have highlighted the need for further improvements in global preparedness for biological outbreaks. Throughout history, gaps have been identified and analysed in preparedness plans for health security and revised based on the lessons learnt from pandemics. For instance, several European countries have proposed and implemented revisions in their preparedness and response plans for pandemics (Droogers et al., 2019). The impacts of biological hazards cannot be addressed through mere response measures. The COVID-19 pandemic has highlighted that these impacts are not limited to the health sector but cascade into other aspects of society too. It highlights the need for a multi-sectoral and multi-hazard approach in managing health crises such as pandemics (UNDRR, 2020) has been emphasised. Within this context, this research aims to outline and identify key stakeholders involved in epidemic and pandemic preparedness planning in Sri Lanka including those who are required to look into the cascading impacts. Social Network Analysis (SNA) has been considered in this study to identify the network of stakeholders and the behaviour of relationships between the stakeholders. Furthermore, the study attempts to identify the involvement of non-health sector stakeholders in preparedness planning, pertaining to epidemics and pandemics in the country.

2. A MULTI-SECTORAL APPROACH TOWARDS PANDEMIC PREPAREDNESS

The multitude of unfavourable effects of the COVID-19 pandemic made it evident that a pandemic is much more than a mere health crisis and it triggers failures in most of the aspects related to the socio-economic sector, national security and human rights (United Nations, 2020). The impacts of concurrent hazards amidst the pandemic have highlighted the need for a multi-hazard approach in addressing multiple risks. United Nations has emphasised the paramount importance of emulating a multi-sectoral approach, based on the early lessons of COVID-19 (UNDRR, 2020). This falls in line with the WHO's whole of society approach which aims at enhancing the preparedness beyond the health sector for the challenges of pandemic influenza (WHO, 2021; World Health Organization, 2009).

The International Health Regulations [IHR] 2005 developed by the WHO, act as a guideline that outlines the rights and obligations of member countries in enhancing global health security (World Health Organization, 2019). However, several criticisms have been made about IHR 2005 since they mainly depend on health authorities and fail to address non-health factors for enhancing the preparedness for pandemics (Oppenheim et al., 2018). The International Conference on the Implementation of the Health Aspects of the Sendai Framework for Disaster Risk Reduction

2015-2030 has made several recommendations on measures for the prevention and mitigation of health emergencies (UNISDR, 2016). Cooperation between health authorities and other relevant organisations to strengthen the disaster management mechanisms of countries to address health-related issues and implementation of IHR 2005 is identified as one of the key recommendations (UNDRR, 2020). Effective cooperation between health and disaster management officials is paramount in managing the impacts of pandemics and epidemics.

WHO's Health Emergency and Disaster Risk Management Framework identifies the health authorities as the leading stakeholders in Disaster Management (DM) mechanisms, pertaining to outbreaks of infectious diseases. It advocates that the health authorities collaborate with DM authorities in the country to enhance the effectiveness of prevention and preparedness planning (World Health Organization, 2019). Adapting a multi-sectoral and whole of society approach in preparedness planning for infectious disease outbreaks has the potency of preventing the failure of the entire system. A study conducted in Taiwan has set an example of how traditional government-led approaches failed during SARS and H1N1 pandemics due to lack of resources and low public trust in authorities (Schwartz & Yen, 2016). Integrating biological hazard preparedness into the Disaster Risk Reduction (DRR) planning of a country can therefore be identified as a dire need in the current context

This integrating mechanism needs inputs from a variety of stakeholders. It highlights the importance of advocating a multi-hazard approach in DRR planning (Koivisto, 2014). In this process, there are several issues that need to be addressed at the initial stage and these would include who are the key actors, who could influence the process, what are the outcomes, which groups or organisations need to be involved and whose capacity needs to be enhanced (WHO, 2005). These issues are addressed by performing a stakeholder analysis at the initial stage, where the stakeholders are identified and mapped to evaluate their roles in the particular process (Koivisto, 2014). Therefore, stakeholder analysis is important in attempting to address the need to integrate biological hazard preparedness into the Disaster Risk Reduction (DRR) Planning in a country.

3. METHODOLOGY

This study was carried out as part of a broader study on integrating epidemic and pandemic preparedness into the Disaster Risk Reduction (DRR) in Sri Lanka. This study addresses the major research question, which is "Who are the major actors that should be involved in effective, multi-stakeholder preparedness planning for epidemics and pandemics, including those involved with potential cascading impacts?". This study was planned in four steps as detailed below.

3.1. Desk study

A review of secondary literature including policy and legal frameworks, national and international reports, scholarly articles, and internet sources was carried out during the desk study. Table 1 summarizes referred policy and legal frameworks under two major categories as shown below.

3.2. Key informant interviews

In parallel with the secondary literature review, a series of in-depth key informant interviews were conducted. Thirteen (13) key informants were selected representing two main sectors and according to the identified key actors involved in epidemic and pandemic preparedness and response planning in Sri Lanka including possible cascading impacts (see Table 2). These interviews were conducted using a structured questionnaire relevant to the following aspects: stakeholders of EWS and risk communication for pandemics, mechanisms for the dissemination of information, EWS, and risk communication during COVID-19, gaps, and suggestions for using existing EW infrastructures for epidemic and pandemics preparedness.

Table 1. Summary of policy and legal frameworks

Category	Referred policy and legal frameworks
Public Health-related	Quarantine and Disease Prevention Ordinance [1897]
	National Influence Preparedness Plan [2012]
	Sri Lanka Preparedness and Response Plan COVID-19 [2020]
	National Action Plan for Health Security of Sri Lanka [2019-2023]
	Public Health Emergency Preparedness and Response Plan for Sea Ports
	Sri Lanka Exotic Disease Emergency Plan
	Manual for the Sri Lanka Public Health Inspector [2010]
	Strategic Plan for Health Sector Disaster/Emergency Preparedness [2015]
DRR related	Disaster Management Act [2005]
	National Policy on Disaster Management [2013]
	Sri Lanka National Emergency Operation Plan [2015]
	Sri Lanka National Disaster Management Plan [2013-2017]
	Regional Disaster Preparedness and Response Plan [2006]
	Grama Niladhari Division Level Disaster Preparedness and Response Plan [2006]

Table 2. Summary of key areas/organizations of key informants

Category	Key areas/ organisation
Public health-related	Health sector disaster preparedness and response
	Disease surveillance
	Broader health security
	Health education and promotion
	Community health
	Special campaigns for disease prevention
	Regional health authorities
Disaster management related	National level disaster management officials
	Subnational level administrative officials
	Subnational disaster management officials
	United Nations Development Programme [UNDP]
	Asia Pacific Alliance for Disaster Management [APAD]
	Chamber of Commerce

3.3. Identification of stakeholders

In order to identify the stakeholders in preparedness and response planning for biological hazards in Sri Lanka recently published action plans and Emergency Operation Procedures (EOPs) were referred. National Emergency Operation Plan (NEOP) [2015] is a recently published national operation plan by the Disaster Management Centre [DMC], Sri Lanka under the guidance of the National Disaster Management Council (NDMC). NEOP defines stakeholders to be involved in carrying out emergency operations in the event of an epidemic (Disaster Management Centre, 2015). Table 3 denotes the identified key stakeholders in carrying out emergency preparedness and response activities immediately before and during an epidemic.

3.4. Application of Social Network Analysis and visualising the network of stakeholders

Social Network Analysis (SNA) coined by John Barned in 1954 is a tool that maps and measures formal and informal relationships to identify what facilitates or impedes the knowledge flows that bind interacting units (Landherr & Heidemann, 2010; Serrat, 2017). This visualisation technique can be incorporated in developing communication behaviour in a network (National Research Council, 2009). Though history shows that SNA was tightly related to sociology, psychology, mathematics, anthropology, and network science, at present it is at the intersection of multiple sectors (Perez & Germon, 2016). Compared to the other approaches used in visualising network behaviour, SNA has several benefits such as identifying units that

Table 3. Stakeholders involved in emergency preparedness and response activities related to epidemics

Stage of the epidemic	Stakeholders
Before	Disaster Management Centre (DMC), Ministry of Health (MOH), Hospitals (HP), Divisional/ District Secretary (DDS), District Disaster Management Coordination Unit (DDMCU), General Public (GP), Public Media Institutions (PMI), SL Airport, and Aviation Services Pvt. Ltd (SLAAS), Public Health Inspector (PHI), Air Ports (AP), Ministry of Mass Media Information (MMMI), Ministry of Local Government and Provincial Councils (MLGPC), Local Authorities (LA), Grama Niladhari Divisions (GND), SL Army (SLA), SL Police(SLP)
During	Disaster Management Centre (DMC), Ministry of Health (MOH), Hospitals (HP), Divisional/ District Secretary (DDS), District Disaster Management Coordination Unit (DDMCU), General Public (GP), Public Media Institutions (PMI), SL Airport, and Aviation Services Pvt. Ltd (SLAAS), Public Health Inspector (PHI), Air Ports (AP), Ministry of Mass Media Information (MMMI), Ministry of Local Government and Provincial Councils (MLGPC), Local Authorities (LA), Grama Niladhari Divisions (GND), SL Army (SLA), SL Police(SLP), National Water Supply and Drainage Board (NWSDB), Non-governmental organisations (NGOs & INGOs)

play central roles, discerning information breakdowns, bottlenecks, and structural holes, and leveraging peer support (Serrat, 2017).

SNA is frequently used as a tool in disaster-related studies to analyse relationships between different units involved in DM mechanisms. (Rajput et al., 2020) have done a study on temporal network analysis of inter organisation communications on social media during disasters, taking Hurricane Harvey in the city of Houston as a case in point. This study was aimed at analysing communication networks between organisations on social media to characterise the roles of organisations and situational information communication. In this study, online organisational communication networks have been mapped and analysed based on their interactions on Twitter. (Kim & Hastak, 2018) have incorporated SNA for converting emergency social network data into knowledge of a disaster and analysed the aggregated interactions of social media users in the phase of disaster response. Furthermore, a study carried out in Thailand has examined the social network in disaster preparedness for earthquakes at local, provincial, and national levels of the country (Suwanmolee, 2014). In the Sri Lankan context, (Shehara et al., 2019) have utilised SNA to analyze the behaviour communication network of stakeholders at emergency disaster preparedness and response stages. In this study, key stakeholders have been identified based on the centrality parameters of communication networks.

In SNA, communication networks are visually expressed as a network consisting of nodes connected to each other. The centrality in a social network can be identified as a parameter that indicates the most important or central or influential node in a network (Das et al., 2018). Different centrality parameters are used to illustrate the behaviour of a communication network. As shown in Table 4, four centrality parameters have been identified in this study to evaluate the network of stakeholders who are linked to the integration process of biological hazard preparedness into the Disaster Risk Reduction (DRR) planning in the country.

Table 4. *Summary of centrality parameter interpretation (adapted from Landherr and Heidemann, 2010)*

Centrality parameter	Description
Degree centrality	Ability of a member in a network to contact the other directly (number of direct contacts)
Closeness centrality	Indicates how closely a member is connected to all other members in the network
Betweenness centrality	Indicates the degree of control a member has over the information flow based on his position in the network
Eigenvector centrality	Measures the node of influence in a network

Since these centrality parameters are used to quantify the interconnectedness of nodes in a network, based on the values obtained for each parameter and accordingly the most significant and powerful actors in the network of stakeholders related to preparedness and response planning for biological hazards can be identified. Furthermore, the values of the centrality parameters imply who are the actors that have more ability to control the flow of information in a network of stakeholders. The manner in which stakeholders are linked with each other needs to be mapped in order to model the network of stakeholders involved in emergency preparedness and response activities pertaining to epidemics. Accordingly, the links between stakeholders were identified using emergency operation procedures and inputs from key informants and the desk study. Actions that have been assigned at each stage of an epidemic were incorporated in identifying the interrelationship between the stakeholders/ units [see Table 5 for interrelationships].

Gephi software was used to model the network for stakeholders depending on the directional flow of information since it is an open-source software used for visualizing and analyzing large network graphs. In this model, stakeholders are represented by nodes, and relationship links have been denoted by edges.

4. RESULTS AND DISCUSSION

Results of the study are discussed under four areas namely, governance in preparedness planning for biological hazards, networks of stakeholders pertaining to preparedness and response in the event of an epidemic including cascading impacts, the role of public health authorities in this process, and involvement of the non-health sector stakeholders in preparedness and response planning. Details of findings under these three areas have been discussed in the following sub-sections.

4.1. Governance in preparedness planning for biological hazards

Currently, the Disaster Management Act No. 13 of 2005 is considered as the governing legal framework which makes provisions for Disaster Management (DM) mechanism in Sri Lanka. National Disaster Management Council (NDMC) as the supreme body of DM in Sri Lanka, and the Disaster Management Centre (DMC) as the executing agency of NDMC have been established under the said Act (Siriwardana et al., 2018). DMC has been vested with the power to coordinate and implement the DM mechanism countrywide, with the main Disaster Risk Management (DRM) activities being implemented by the mandated national technical agencies for

Table 5. Interrelationships between stakeholders

Before an epidemic			**During an epidemic**		
ID	**Label**	**Actors connected with**	**ID**	**Label**	**Actors connected with**
1	DMC	2, 4, 5,6,11,12,15,16	1	DMC	2, 5, 6, 11, 12, 15, 16, 17, 18
2	MOH	2, 3, 4, 5, 9, 8, 12	2	MOH	1, 3, 8,9, 11, 12, 17
3	HP	2	3	HP	2
4	DS	1, 2, 5, 13	4	DDS	5, 12, 13
5	DDMCU	1, 2, 4	5	DDMCU	1, 4
6	GP	1, 7, 9, 12, 13, 14, 15, 16	6	GP	1, 7, 9, 14, 15, 16, 17,
7	PMI	6	7	PMI	6
8	SLAAS	10	8	SLAAS	10
9	PHI	6	9	PHI	6
10	AP	8	10	AP	8
11	MMMI	7	11	MMMI	7
12	MLGPC	6, 13	12	MLGPC	4, 13, 18,
13	LA	14	13	LA	4, 12, 14,
14	GN	6	14	GN	6, 13
15	SLA	6	15	SLA	6
16	SLP	6	16	SLP	6
			17	NWS&DB	6
			18	NGO/INGO	1,12

twenty-one hazard types as listed in the said Act. Since epidemics have also been included in these hazards, DMC functions as the legal authority to coordinate DRM activities pertaining to epidemics. Ministry of Health, Sri Lanka (MOHSL) has been legally mandated to implement these DRM activities to mitigate the impacts of epidemics under the Disaster Management Plan which is developed as per the provisions of the said Act (Disaster Management Centre, 2014).

In addition to the Disaster Management Act, No. 13 of 2005, the Quarantine and Prevention of Diseases Ordinance chapter 222, No.3 of 1897 makes provisions for the prevention of the introduction of the plague and all other contagious and infectious diseases into Sri Lanka and the prevention of the spread of said diseases within and outside of Sri Lanka. In most regulations framed under this Ordinance, the Director-General of Health Services has been assigned as the proper authority for facilitating the prevention of the spread of these diseases. However, the Director-General of Health Services has delegated some of his powers to the Medical Officer of Health [MOH] and the Chairman of relevant local authority by way of the government Gazette Notification No. 7481 of 28-08-1925 & 10713 of 17-09-1954 (Epidemiology Unit, 2012; Ministry of Health, 2010) [see Figure 1 for the organizational structure of Ministry of Health, Sri Lanka].

Accordingly, the public health authorities in the country play a central role in preparedness and response planning pertaining to biological outbreaks such as pandemics and epidemics. Illustrating this, Sri Lankan public health authorities have been playing a key role in mitigating and preventing the risk of dengue, which is a frequent and widespread outbreak in the country (Thalagala et al., 2016). There are specialised units functioning under the purview of MOHSL that act as the focal points for specific aspects and functions related to preparedness planning for epidemics and pandemics which are detailed in. Table 6.

There are also several other health sector-related stakeholders who are either directly involved in decision-making related to preparedness planning for epidemics and pandemics or support the above-mentioned specialised units. They include the Department of Animal Health and Production, College of Community Physicians, and Government Medical Officers' Association. Furthermore, the findings of this study have highlighted that there is limited involvement of DRR authorities in preparedness and response planning for

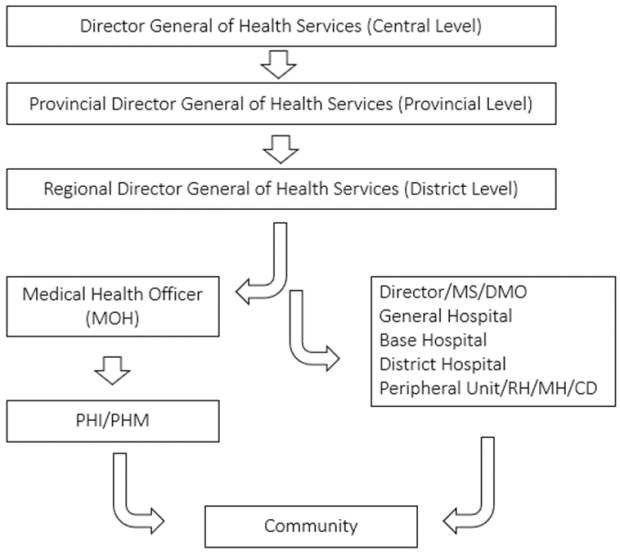

Figure 1. Organizational structure of Ministry of Health, Sri Lanka (adapted from Epidemiology Unit, 2012)

Table 6. *MOHSL units responsible for preparedness and response planning for epidemics and pandemics*

Specialised unit	Responsibility
Disaster Preparedness and Response Division [DPRD]	The central authority for coordinating health-related activities in disaster situations
Epidemiology Unit	Disease surveillance, risk assessment, and immunisation A co-focal point of IHR [2005] in Sri Lanka
Quarantine Unit	Responsible for border health security A co-focal point of IHR [2005] in Sri Lanka
Medical Research Institute [MRI]	Functioning as the main laboratory for testing and reporting
Health Promotion Bureau [HPB]	Responsible for risk communication related to health issues
Special Campaigns for Disease Surveillance	Ex; National Dengue Prevention Unit, Anti-Malaria Campaign

biological hazards in the country. Biological hazards are not adequately integrated into the disaster management plans developed by DRR authorities, especially at the local level. Therefore, it can be concluded that currently the preparedness planning for biological hazards, particularly epidemics and pandemics is a predominantly health sector-led process.

4.2. Network of stakeholders involved in preparedness and response mechanisms in the event of an epidemic

Figure 2 and Figure 3 represent the communication networks of stakeholders immediately before and during an epidemic that have been modelled using SNA. Stakeholders in the network are represented by nodes in these communication models and ranked based on the degree centrality value being represented by the varying node sizes. Furthermore, stakeholders in both models are ranked based on centrality parameters which have been detailed in Table 4. Further, Table 7 shows the top-ranked stakeholders for each centrality parameter immediately before and during the event of an epidemic.

According to the degree centrality and closeness centrality parameters, Disaster Management Centre [DMC] can be recognised as the key stakeholder being vested with the central role in coordinating and implementing emergency preparedness and response procedures in the event of an epidemic. The DMC has the highest ability to directly contact stakeholders in the network and communicate with stakeholders effectively. Furthermore,

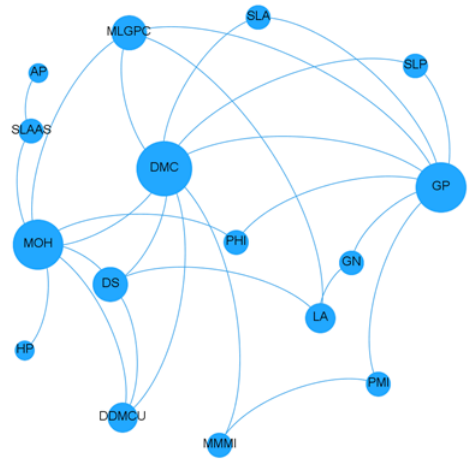

Figure 2. Communication network of stakeholders before an epidemic

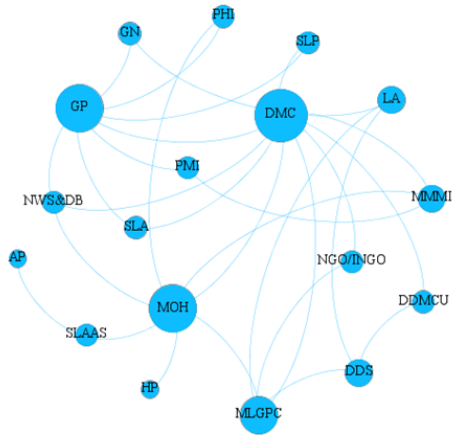

Figure 3. Communication network of stakeholders during an epidemic

Table 7. Top-ranked stakeholders for centrality parameters

Centrality parameter	Before an epidemic	During an epidemic
Degree centrality	Disaster Management Centre	Disaster Management Centre
Closeness centrality	Disaster Management Centre	Disaster Management Centre
Betweenness centrality	Ministry of Health	Ministry of Health
Eigenvector centrality	Disaster Management Centre	Disaster Management Centre

since the Ministry of Health [MOH] has the highest value in betweenness centrality, it implies that MOH has the highest control over the flow of information in the network of stakeholders. Therefore, it is evident that DMC and MOH are the most controlled actors in the network of stakeholders pertaining to emergency preparedness and response operations for epidemics in the country. Therefore, it can be concluded that public health authorities have been vested with a major responsibility in disaster management pertaining to biological hazards in Sri Lanka.

Developed communication network models for epidemics denote the focus on local government authorities and ING/NGOs too since these organizations have the potency of addressing possible cascading events of an epidemic. This highlights the importance of the engagement of relief organisations in the event of an epidemic. However, the exclusion of the National Disaster Relief Services Center (NDRSC) in these network models can be identified as a weakness. Furthermore, several key points can be identified when comparing network diagrams of stakeholders for epidemics with other hazards. Figure 4 shows the communication network model developed with references to emergency operations during tsunamis (Shehara et al., 2019). Shehara et al (2019) highlight that DMC has the highest rank in betweenness centrality parameter for all the selected hazards [Landslides, tsunamis, droughts, and floods]. This situation implies that DMC has a high level of control over the flow of information than the mandated technical agencies for particular hazards. In contrast, the mandated technical agency for epidemics [MOHSL] has the highest control over the flow of information during an event of an epidemic. It indicates that health authorities have become a predominant stakeholder in emergency preparedness and response

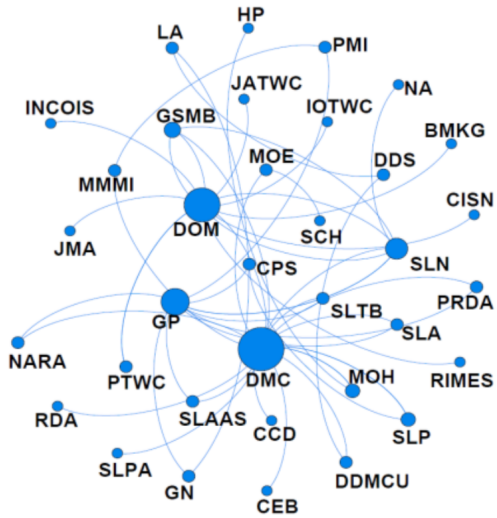

Figure 4. Communication Network for Tsunami Early Warning (Shehara et al., 2019)

planning pertaining to epidemics in Sri Lanka. Furthermore, Shehara et al (2019) have stressed the need for developing Standard Operation Procedures (SOPs) to minimise the complexity of communication networks developed based on emergency operation procedures which are applicable for epidemics as well.

4.3. Role of health authorities in preparedness planning for epidemics and pandemics

Results of the above analysis have highlighted that health authorities play a key role in preparedness and response mechanisms related to biological hazards. This has been further substantiated by the findings from key informant interviews and the review of secondary literature. Elaborating on the predominant role of health authorities in preparedness and response planning for biological hazards in most regulations framed under the Quarantine and Prevention of Disease Ordinance No. 13 of 1897, the Director-General of Health Services has been

assigned as the proper authority for facilitating the prevention of the spread of said diseases. Under the purview of the Director-General of Health Services, there are several agencies such as the Disaster Preparedness and Response Division, Epidemiology Unit, and Quarantine Unit which play key roles in preparedness and response planning for biological hazards. This section further elaborates the duties performed by public health authorities during the different phases of the disaster management cycle in this regard.

As mentioned earlier in section 4. 1 (Table 6) the Disaster Preparedness and Response Division (DPRD) acts as the central authority coordinating disaster preparedness activities in the event of an epidemic (DPRD, 2018). The Strategic Plan for Health Sector Disaster/ Emergency Preparedness which was published first in 2011 and adapted later in 2015 by DPRD, provides strategic guidance to the health sector in disaster/emergency management including biological hazards. Based on the guidance provided by this plan at national level, health sector preparedness and response plans have been developed at the district level. In most of these district-level plans, Dengue as an outbreak has been listed among the top five priority hazards (RDHS Matara & DPRD, 2018). Taking a step further, institutional disaster preparedness and response planning has been developed in major healthcare institutions under the supervision of the Ministry of Health. These plans include preparedness related to outbreaks since Dengue has become a frequent outbreak in Sri Lanka. Apart from the role of DPRD, the quarantine unit plays a key role in border health security. The Directorate of Quarantine of the Ministry of Health had developed the SOPs to be followed at PoEs for prevention, early warning, and response to public health events.

In the manual of Public Health Inspectors (PHIs), the Ministry of Health, Sri Lanka has recommended preventing the spread of diseases as one of the health interventions to be performed during the disaster response phase. This process involves activities such as providing safe water and food, immunization, disposal of human excreta, and other waste, burial of the dead, and disease vector control (Ministry of Health, 2010). Furthermore, the aforementioned manual has detailed three types of assessments named rapid reconnaissance, rapid health assessments, and surveys to prevent the spread of diseases (Ministry of Health, 2010). Illustrating the response mechanism of the public health sector during the COVID-19 outbreak, basic guidelines for health authorities have been issued by the central government. However, operational activities are carried out under provincial ministries other than the activities of agencies such as the Epidemiology Unit, Quarantine Unit and DPRD. In accordance with the provisions of the Quarantine and Prevention of Diseases Ordinance chapter 222, No.3 of 1897, the public health authorities in Sri Lanka play the central role in preventing and/or mitigating the risk of biological hazards. Dengue is a frequent outbreak where the Ministry of Health is in partnership with NGOs such as the Sri Lanka Red Cross Society [SLRCS] and World Vision Lanka is actively involved in controlling spread of the epidemic at the onset (International Federation of Red Cross and Red Crescent Societies, 2017).

Furthermore, the country's Disease Surveillance System which comprises of four functional elements namely, data collection, data compilation, analysis and taking action on reports, and feedback, is a key instrument in preventing and/or mitigating biological hazards (Ministry of Health, 2010). The surveillance of communicable diseases is supported by a Notification System designated to provide notifications on diseases identified in the list of Notifiable Diseases in Sri Lanka (Epidemiology Unit, 2020; Ministry of Health, 2010). The Quarantine and Prevention of Diseases Ordinance legally provides consent to the implementation of said Notification System (Ministry of Health, 2010). Furthermore, the National Immunisation Programme of Sri Lanka which functions under the purview of the Epidemiology Unit has achieved several milestones. Eliminating Malaria (2016) and mother-to-child transmission of STD/AIDS are the most prominent achievements. The

Epidemiology Unit has been able to provide 95% coverage of immunisation against thirteen deadly vaccine-preventable diseases (Key informant interviews, 2020),

4.4. Engagement of non-health sector stakeholders for preparedness and response planning for infectious diseases

Epidemics and pandemics need to be seen not as mere health crises and emulation of a multi-sectoral, whole of society approach is recommended for preparedness and response planning for infectious diseases. Limits cannot be imposed on the diversity of stakeholders involved in pandemic preparedness, ranging from macro-level stakeholders such as the Ministry of Health and micro-level stakeholders such as households and individuals. The involvement of local government authorities, tri forces, media institutions, private sector organisations, global development partners, NGOs, INGOs and community-based organisations in preparedness and response planning increases the effectiveness of the process.

As shown in the network diagrams of stakeholders (Figure 2 & Figure 3), the national action plans identify the importance of involving local government authorities, subnational level administrative officials, tri forces, media institutions, and NOGs/INGOs. In Sri Lanka, sub-national administrative officials have actively engaged in addressing cascading impacts of the crisis and activities carried out by these officials include, ensuring access to essential services, supplying food and dry rations to the community, recommendation of curfew passes, maintenance of social order, etc. Furthermore, Sri Lanka's private sector is considered a key provider of employment with about 5 million people being employed. Hence, the role of the private sector in preparedness planning for biological hazards, in particular, deserves more attention.

The private sector can incorporate pandemic and epidemic preparedness into the Business Continuity Plans [BCPs] of the respective organisations/ institutions. This can enhance the effectiveness of organisations responding proactively rather than reactively, to any future pandemic. Furthermore, there have been attempts to include Corporate Social Responsibility [CSR] and sustainability activities of private sector organisations towards epidemic and pandemic preparedness. Experts have highlighted the need for integrating pandemic and epidemic preparedness into occupational health and safety procedures in the private sector organisations. Currently the Construction Industry Development Authority [CIDA], Sri Lanka has published the Health and Immunity Enhancement guidelines for COVID-19 and Dengue to be followed in the construction field (CIDA, 2020). Furthermore, the Occupational Health Unit of the Directorate of Environmental and Occupational Health in the Ministry of Health, Sri Lanka has produced a set of guidelines for preparedness and response to COVID-19 in work settings.

Apart from the private sector, international development agencies such as the United Nations Development Programme [UNDP], the Asian Development Bank [ADB], and the World Bank play a vital role in the activities of preparedness planning for biological hazards in Sri Lanka. In addition to the private sector and international development agencies, community-based organisations at the grass-root level such as women's organisations, GN level disaster preparedness and response committees and youth organisations should also be involved in preparedness planning for pandemics and epidemics to facilitate a community-based approach to epidemic and pandemic preparedness. Accordingly, it is evident that there is a need for widening the scope of stakeholders involved in preparedness planning for pandemics and epidemics in the country, which will help to address the risks posed by such hazards in a holistic manner.

5. CONCLUSION

Findings of the study which is used as the basis for the development of this research has made it evident that currently the preparedness planning for biological hazards particularly

epidemics and pandemics is predominantly a health sector-led process. The DGHS has the authority to make independent decisions with regard to the mitigation and prevention of risks posed by infectious diseases as per the provisions of the Quarantine and Prevention of Diseases Ordinance chapter 222, No.3 of 1897. However, the provisions of the Sri Lanka Disaster Management (Amendment) Act No.13 of 2005 have confined the role of the DMC to the coordination and facilitation of DRM activities, related to the set of hazards mentioned in the Act, which includes epidemics as well. The provisions of the Disaster Management Act has vested the DMC with the authority to coordinate and implement DRM activities as opposed to the actual planning and implementation of DRM activities related to biological hazards, especially epidemics. Therefore, the absence of a unified legal framework and system of governance for disaster management in the country is evident thus paving the way for bureaucratic inefficiencies such as replication of procedures, limiting the ability to share expertise and resources in preparing for and responding to various hazards, and thereby weakening the overall mechanism in place for disaster management in the country.

Furthermore, while preparedness planning for epidemics and pandemics is a predominantly a health sector driven process in Sri Lanka, it is important to broaden the scope of stakeholders involved and to include the private sector, international development agencies, and community-based organizations so that the risks posed by epidemics and pandemics are addressed at the onset. In relation to the cascading effects of these biological disasters, the central government, sub-national level administrative authorities (e.g. District Secretaries, Divisional Secretaries, and GN officers) and INGOs have to play a leading role in providing relief services to address the unfavourable economic and social impacts of biological outbreaks, in the country. However, mere response measures such as provisions of emergency relief offer only short-term solutions to persistent problems. Therefore, it is important to shift the focus from response to building the resilience of both the economy and society to minimise the adverse economic and social implications of epidemics and pandemics. In conclusion, the existing gaps identified due to the impacts of the current COVID-19 pandemic accentuates the need for the emulation of a multi-sectoral approach in preparedness planning for pandemics and epidemics in Sri Lanka.

ACKNOWLEDGEMENT

This project is funded by UK Research and Innovation through the UK Government's Global Challenges Research Fund (GCRF) and the Newton Fund [grant number EP/V026038/1]. UK Research and Innovation accepts no liability, financial or otherwise, for expenditure or liability arising from the research funded by the grant except as set out in the Terms and Conditions, or otherwise agreed in writing.

6. REFERENCES

Business Standard News. (2020). *Covid-19 could cause economic loss up to $8.8 trn, 9.7% of global GDP: ADB* . https://www.business-standard.com/article/economy-policy/covid-19-could-cause-economic-loss-up-to-8-8-trn-9-7-of-global-gdp-adb-120051500319_1.html

CIDA. (2020). *Health and Immunity Enhancement Guidelines for COVID-19 and Dengue*. Construction Industry Development Authority. https://www.cida.gov.lk/newsevents/CIDA COVID and DEGUE Guidelines for Construction Industry Version 3(Revised).pdf

Das, K., Samanta, S., & Pal, M. (2018). Study on centrality measures in social networks: A survey. *Social Network Analysis and Mining*, *8*(1). https://doi.org/10.1007/s13278-018-0493-2

Dave, N., & Dave, R. (2020). Cascading Effects of COVID-19 Pandemic Across Economic and Social Sectors of India. *Liberal Studies*, *5*(1), 8–14.

Disaster Management Centre. (2014). *Sri Lanka National Disaster Management Plan 2013-2017*.

Disaster Management Centre. (2015). *National Emergency Operation Plan Volume 1 (NEOP)*. https://www.unlocked.lk/wp-content/uploads/2019/06/NEOP-Volume-1.pdf

DPRD. (2018). *Key Areas: Preparedness, Disaster Response and Relief Activities*. http://www.dprd.health.gov.lk/

Droogers, M., Ciotti, M., Kreidl, P., Melidou, A., Penttinen, P., Sellwood, C., Tsolova, S., & Snacken, R. (2019). European Pandemic Influenza Preparedness Planning: A Review of National Plans, July 2016. *Disaster Medicine and Public Health Preparedness*, *13*(3), 582–592. https://doi.org/10.1017/dmp.2018.60

Epidemiology Unit. (2012). *National Influenza Preparedness Plan*. http://www.epid.gov.lk/web/images/pdf/Influenza/completed_nipp_2013-03-20.pdf

Epidemiology Unit. (2020). *Weekly Epidemiological Report*. http://www.epid.gov.lk/web/index.php?option=com_content&view=article&id=148&Itemid=449&lang=en

International Federation of Red Cross and Red Crescent Societies. (2017). *DREF Operations Update Sri Lanka: Dengue*.

Jarus, O. (2020). 20 of the worst epidemics and pandemics in history. *Live Science*.

Kim, J., & Hastak, M. (2018). Social network analysis: Characteristics of online social networks after a disaster. *International Journal of Information Management*, *38*(1), 86–96. https://doi.org/10.1016/j.ijinfomgt.2017.08.003

Koivisto, J. E. (2014). A Stakeholder Analysis of the Disaster Risk Reduction Policy Subsystem in Mozambique. *Risk, Hazards & Crisis in Public Policy*, *5*(1), 38–58. https://doi.org/10.1002/rhc3.12048

Landherr, A., & Heidemann, J. (2010). A Critical Review of Centrality Measures in Social Networks. *Business & Information Systems Engineering*, *6*, 371–385. https://doi.org/DOI 10.1007/s12599-010-0127-3

Ministry of Health. (2010). *PHI Manual Chapter 05 – Disaster Management*.

National Research Council. (2009). *Applications of Social Network Analysis for Building Community Disaster Resilience: Workshop Summary*. https://doi.org/10.17226/12706

Oppenheim, B., Gallivan, M., Madhav, N. K., Brown, N., Serhiyenko, V., Wolfe, N. D., & Ayscue, P. (2018). Assessing global preparedness for the next pandemic: Development and application of an Epidemic Preparedness Index. *BMJ Global Health*, *4*(1), 1157. https://doi.org/10.1136/bmjgh-2018-001157

Ornstein, C., & Hixenbaugh, M. (2020). "All the Hospitals Are Full": In Houston, Overwhelmed ICUs Leave COVID-19 Patients Waiting in ERs—ProPublica. *ProPublica*.

PAHO, W. (2020). *COVID-19 has infected some 570,000 health workers and killed 2,500 in the Americas, PAHO Director says—PAHO/WHO | Pan American Health Organization*.

Parikh, S., & Desai, M. (2020). *The Coronavirus: What You Need to Know about the Global Pandemic*.

Perez, C., & Germon, R. (2016). Graph Creation and Analysis for Linking Actors: Application to Social Data. In R. Layton & Paul. A. Watters (Eds.), *Automating Open Source Intelligence*. https://doi.org/10.1016/C2014-0-02170-3

Rajput, A. A., Li, Q., Zhang, C., & Mostafavi, A. (2020). Temporal network analysis of inter-organizational communications on social media during disasters: A study of Hurricane Harvey in Houston. *International Journal of Disaster Risk Reduction*, *46*, 101622. https://doi.org/10.1016/j.ijdrr.2020.101622

RDHS Matara, & DPRD. (2018). *Health Sector Disaster Preparedness and Response Plan—Matara*. Minsitry of Health, Sri Lanka.

Schwartz, J., & Yen, M. (2016). Toward a collaborative model of pandemic preparedness and response: Taiwan's changing approach to pandemics. *Journal of Microbiology, Immunology and Infection*, *50*, 125–132.

Serrat, O. (2017). Social Network Analysis. In *Knowledge Solutions*. Springer. https://doi.org/10.1007/978-981-10-0983-9_9

Shehara, I., Siriwardana, C. S. A., Amaratunga, D., & Haigh, R. (2019). Application of Social Network Analysis (SNA) to Identify Communication Network Associated with Multi-Hazard Early Warning (MHEW) in Sri Lanka. *MERCon 2019 - Proceedings, 5th International Multidisciplinary Moratuwa Engineering Research Conference*, 141–146. https://doi.org/10.1109/MERCon.2019.8818902

Siriwardana, C. S. A., Jayasiri, G. P., & Hettiarachchi, S. S. L. (2018). Investigation of efficiency and effectiveness of the existing disaster management frameworks in Sri Lanka. *Procedia Engineering*, *212*, 1091–1098. https://doi.org/10.1016/j.proeng.2018.01.141

Suwanmolee, S. (2014). Social Network Analysis of Disaster Response in 2014 Chiangrai Province Earthquake. *International Conference Disaster Management: From Polar Region to the Local Communities*.

Thalagala, N., Tissera, H., Palihawadana, P., Amarasinghe, A., Ambagahawita, A., Wildersmith, A., Shepard, D., & Tozan, Y. (2016). Costs of Dengue Control Activities and Hospitalizations in the Public Health Sector during an Epidemic Year in Urban Sri Lanka. *PLOS Neglected Tropical Diseases*, *10*(2), 2–6.

The World Bank. (2020a). *COVID-19 to Add as Many as 150 Million Extreme Poor by 2021*. https://www.worldbank.org/en/news/press-

release/2020/10/07/covid-19-to-add-as-many-as-150-million-extreme-poor-by-2021

The World Bank. (2020b). *The Global Economic Outlook During the COVID-19 Pandemic: A Changed World*. https://www.worldbank.org/en/news/feature/2020/06/08/the-global-economic-outlook-during-the-covid-19-pandemic-a-changed-world

UNDRR. (2020). *UNDRR COVID-19 Engagement Strategy interim report*.

UNISDR. (2016). *Bangkok Principles for the implementation of the health aspects of the Sendai Framework for Disaster Risk Reduction 2015-2030*.

United Nations. (2020). *United Nations Comprehensive Response to COVID-19: Saving Lives, Protecting Societies, Recovering Better*.

WHO. (2005). *Health Service Planning and Policy Making; A toolkit for nurses and midwives*. World Health Organization, Western Pacific Region.

WHO. (2020). *COVID-19 Weekly Epidemiological Update—29*.

WHO. (2021). *Global Influenza Programme*. World Health Organization . https://www.who.int/teams/global-influenza-programme/public-health-preparedness/publications

World Health Organization. (2009). *Whole of Society Pandemic Readiness*.

World Health Organization. (2019). *Health Emergency and Disaster Risk Management Framework*.

Settling the ripples: An examination of Sri Lanka's approach to addressing cascading impacts of the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic in Sri Lanka has not only posed a severe threat to human health and longevity but also cascaded into a large scale economic downturn and bleak social effects signifying the systemic nature of risks. This study examines the major economic and social effects caused by the first wave of COVID-19 in the country and the manner in which these effects have been addressed with the aim of providing policy implications for systemic risk governance. This chapter is based on a number of secondary sources and primary data gathered from interviews conducted with key informants at both national and sub-national levels. Findings show that the pandemic has caused severe socio-economic impacts across the country which have been addressed with the main dominant involvement of the Presidential Task Forces, NGOs and INGOs at national level and Disaster Management and Public Health authorities at sub-national level. Effective collaboration among multiple-stakeholders and the emulation of a decentralised approach have been identified as the main strengths of Sri Lanka's approach to overcoming the cascading effects of the pandemic. However, response to these effects has been hampered due to inefficiencies caused with the establishment of new structures instead of leveraging the existing structures, difficulties faced in accurately identifying beneficiaries of relief services, inadequate allocations for stimulus packages and lack of focus on resilience building. Findings further demonstrate that effective and efficient mitigation of the cascading effects of hazards such as pandemics, calls for a shift in focus from short term response to building both economic and societal resilience.

Key words: Cascading effects, Systemic Risks, COVID-19, Sri Lanka

1. INTRODUCTION

1.1. Background

As of 31st December 2020, the COVID-19 pandemic has recorded over 1.8 million deaths and exceeding 83 million confirmed cases worldwide (Worldometer, 2020). By November 2020, many countries in Europe and other parts of the world have begun to experience the second wave of Coronavirus, with more cases being reported on a daily basis than during the first wave (Pollet, 2020; Africa Centres for Disease Control and Prevention, 2020; Jayasena & Chinthaka, 2020). The COVID-19 pandemic has certainly showcased the systemic nature of risks thus, calling for a paradigm shift

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in the approaches adopted for risk governance (UNDRR, 2020).

The term 'risk' describes a situation or an event that has damaging consequences but the outcome of which is uncertain (Rosa, 2008; Society for Risk Analysis Glossary, 2018). 'Risk' in the context of disasters indicate "the potential loss of life, injury or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity" (UNDRR, 2020). The concept of systemic risk seeks to elucidate the properties of risk from a systems perspective considering the fact that elements of a system are connected together and therefore a failure in one part may cause cascading effects on other parts of the system, which leads to the failure of the entire system (Kaufmann and Scott, 2003; Schwarcz, 2008). Systemic risks are highly complex, trans-boundary in nature and are characterised by stochastic and non-linear relationships (Schweizer and Renn, 2019).

Conforming to the description of 'systemic risks' stated above, the COVID-19 pandemic which started as a public health crisis soon transformed into a disaster causing grave and complex economic and social disruptions that extend beyond national boundaries (UNDRR, 2020). Consideinrg the effects of the COVID-19 pandemic, the World Bank (2020) has estimated a 5.2% contraction in global GDP and expects the severity of the pandemic to push tens of millions of people into extreme poverty across the world. According to World Bank records, advanced economies have contracted by 7% while developing economies have shrunk by approximately 2.5% (The World Bank, 2020). International and global food supply chains have been hampered owing to trade restrictions, confinement measures and border closures thereby posing a significant threat to food security (ILO, FAO, IFAD and WHO, 2020). Similarly, the psycho-social wellbeing of people is at stake as lockdowns and other containment measures imposed have caused separation from loved ones, feeling of helplessness, anxiety and uncertainty about their future and loss of freedom (Cao et al., 2020; Li and Wang, 2020; Saladino et al., 2020).

The complexity and magnitude of systemic risks are often underestimated in public policy arenas due to uncertainties of point of occurrence and the extent of damage caused (Schweizer and Renn, 2019). Nevertheless, effects of systemic risks associated with COVID-19 have spanned across almost all sectors and levels of the society, simultaneously exposing gaps in existing risk governance approaches. In Sri Lanka, the first confirmed case of COVID-19 was reported on 27th January 2020, i.e. almost a month after the outbreak was reported for the first time in Wuhan City in Hubei Province of China (Amaratunga et al., 2020). COVID-19 has caused disproportionate impacts on countries with existing vulnerabilities and risk factors (UNDRR, 2020; Alwazir, 2020). Sri Lankan economy relies heavily on the tourism industry and the country's foreign exchange earnings are largely dependent on its migrant labourers which has exposed the country to high vulnerability of COVID-19 (World Bank, 2020). The pandemic has also added to existing vulnerabilities caused by factors such as climatic shocks, poverty and the predominance of informality in the labour market (Hadad-Zervos, 2020; ADB, 2020; Michael, 2018). At the time of writing, Sri Lanka is combatting the 2nd wave of COVID-19 and as at 31st December 2020, 43,123 confirmed cases and 199 deaths have been reported (Health Promotion Bureau, 2020). In Sri Lanka the pandemic has not only posed a severe threat to human health and longevity but also cascaded into a massive economic downturn and bleak social effects. This study examines Sri Lanka's approach in addressing the cascading effects of the first wave of the pandemic under four sub-objectives : 1) To identify the major economic and social effects caused by the COVID-19 pandemic situation in the country; 2) To identify the main stakeholders and the roles played by them in addressing these cascading effects; 3) To identify the main strengths of the country's approach in addressing the cascading impacts of the COVID-19 pandemic situation and 4) To identify the main shortcomings of the country's approach in addressing the cascading

effects of the COVID-19 pandemic. In doing so this paper aims to provide policy implications for effective governance of systemic risks in Sri Lanka.

1.2. Systemic risk governance in addressing the cascading effects of COVID-19

The increasingly evident systemic nature of risk has called for significant improvements in risk governance approaches. The tendency of systemic risks such as COVID-19 to span beyond a single sector and cause cascading effects on a multitude of other sectors, eventually leading to the failure of the entire system invites multi-sectoral collaboration and coordination to manage and reduce disaster risks. It is necessary to create a platform where solutions are geared towards disaster risk management which are generated collectively and co-designed with the involvement of multiple stakeholders including [but are not limited to] public authorities, media, private sector and civil society (Kaufmann and Scott, 2003;UNDRR, 2020). Therefore, effective governance of systemic risks is built on inclusivity and participation of diverse stakeholders, transparency and collective accountability (UNDRR, 2020).

Furthermore, effectively responding to the cascading effects of COVID-19 requires a long-term approach that extends beyond the provision of short term relief to building whole of society 'resilience' (UNDRR, 2020). Moreover, the pandemic has posed disproportionate effects on certain population groups such as the poor, the elderly and informal sector workers, thus, exposing economic and social inequalities and highlighting gaps in social protection systems and lack of resilience (UNDP, 2020; Nicola et al., 2020; Ali et al., 2020). Investing in building resilience is conducive to saving lives and reducing the social and economic losses of disasters cum ensuring effective post-disaster recovery and rehabilitation. An inclination to strengthen whole of society resilience to disasters over the execution of emergency relief measures is crucial for protecting development gains from the complex and trans- boundary cascading impacts of disasters (UNDRR, 2020; Mitchell and Harris, 2012). Similarly, investing in building resilience is more cost effective than emergency relief and response (Combaz, 2014).Illustrating this, a UK funded study has shown that in Kenya, every US $1 spent on resilience could gain benefits worth US $2.9 over a period of 20 years(DFID, 2012) and in Southern Ethiopia every US US $ 1 invested in resilience could result in a US $ 2.8 gain as benefits. On the contrary, a humanitarian response would cost billions exceeding the cost of resilience building over a period of 20 years (DFID, 2012).

Strengthening disaster responsive social protection is paramount in an attempt to build whole of society resilience to disasters, whether natural, biological or technological (Kosec & Mo, 2017; Kuriakose et al., 2013; Singhe, 2014; Davies et al., 2012; Ulrichs, 2019; UNDRR, 2020). Referring to climate related shocks, Kuriakose et al. (2013) portrays how different social protection schemes contribute to long-term climate adaptation and building a society's resilience against such shocks. The authors claim that social protection instruments such as social insurance, social transfers and asset diversification reduce the vulnerability of households by enhancing their coping capacities in turn mitigating the impacts of climate related shocks (Kuriakose et al., 2013). Further, social protection measures that are aimed at the provision of relief [Eg: cash transfers and social pensions] facilitate improved coping among households immediately following a disaster (Kuriakose et al., 2013). On the other hand, measures such as support for diversification of livelihoods, facilitation of labour mobility and provision of micro-credit for livelihood promotion address underlying vulnerabilities of households and reduce a community's sensitivity to risk in the long run (Kuriakose et al., 2013). Complementing the arguments of Kuriakose et al. (2013), a recent study sources evidence from 2010 floods in Pakistan which depicts disaster responsive social protection schemes can attenuate the negative effects that shocks pose on the aspirations of people (Kosec & Mo, 2017).

Further, paying specific attention to COVID-19, Gerard et al. (2020) argue that effective recovery from the economic challenges posed by the pandemic, particularly in low and middle income countries require an emergency safety net with more extensive coverage accompanied by broader and more creative solutions. On 28th May 2020, a virtual webinar organised by UNESCAP, UNDRR and FAO examined how countries in the Asia Pacific had utilised social protection measures to manage and recover from the adverse effects of COVID-19 (UNDRR Asia-Pacific, 2020). This webinar also highlighted several policy recommendations on leveraging social protection schemes to reduce disaster related vulnerability and build whole of community resilience. Some of these recommendations call for investing in social protection before a disaster; promoting universal social protection while adopting a human rights based approach (UNDRR Asia-Pacific, 2020).

Furthermore, the risks posed by disasters on the private sector, particularly business enterprises, cannot be overlooked in an attempt to strengthen whole of society resilience given that the private sector makes a pivotal contribution to development in terms of generating employment opportunities, stimulating innovation and boosting economic growth (UNDRR, 2015; UNDRR, 2020; Sarmiento et al., 2014; Haraguchi et al., 2016). Moreover, private sector business enterprises operate in a networked society which has increased both the speed and the breath of chain failure during a disruptive event which further justifies the need for building private sector resilience to catastrophes (Haraguchi et al., 2016). Business continuity planning and disaster recovery planning are two of the most commonly used mechanisms for building resilience of a business against external shocks (Sahebjamnia et al., 2014). While business continuity planning entails the development of appropriate plans at the pre-disaster stage with the aim of resuming businesses operations to minimum acceptable level immediately following a disruptive event, disaster recovery planning is aimed at facilitating full recovery of disrupted operations to their original state during the post-disaster stage (Sahebjamnia et al., 2014). Apart from the above mentioned mechanisms, planning to seize post disaster opportunities, fostering employee resilience to have healthy levels of adaptive capacity cum building confidence during a disaster event and identification and designation of crisis leaders, have been considered as crucial for building business resilience to face disasters (Hatton et al., 2018).

1.3. Legal and institutional framework of addressing cascading effects of disasters in Sri Lanka

Sri Lanka Disaster Management Act No.13 of 2005 constitutes the legal framework for Disaster Management in Sri Lanka. The National Council for Disaster Management [NCDM] chaired by H.E. the President constitutes the supreme governing body for Disaster Management in the country and the Disaster Management Centre [DMC] functions as its executing agency (Amaratunga et al., 2020; Ministry of Disaster Management, 2013; Disaster Management Centre, 2020). All decisions pertaining to Disaster Management [DM] are taken by the Ministry of Disaster Management while decisions are implemented by the DMC which is the responsible authority for coordinating disaster risk management activities at national level (Disaster Management Centre, 2014; Amaratunga et al., 2020). Disaster management activities in Sri Lanka are carried out adopting a de-concentrated approach while at the sub-national level such activities are coordinated by the District Disaster Management Coordinating Units [DDMCUs]. Each DDMCU is manned by a District DM Coordinator, Assistant Coordinator and over 20 DM Assistants who report to the District Secretary and the DMC (Disaster Management Centre, 2014). Provincial, district, divisional and Grama Niladhari [GN] level DM committees also play a pivotal role in coordination and resource mobilisation in the event of a disaster (Disaster Management Centre, 2006). Disaster Management structures at national and sub-national levels have been outlined in Figure 1.

Sri Lanka's National Policy on Disaster Management accords high priority to (i) response, relief and immediate recover of essential services and (ii) medium and longer term reconstruction and rehabilitation to an improved standard than prior to the occurrence of a disaster(Disaster Management Centre, 2014). The National Disaster Relief Services Centre [NDRSC], which functions under the purview of the Ministry of Disaster Management, is the main institution responsible in providing immediate relief services for displaced persons in affected areas and making necessary arrangements for recovery. The NDRSC has a ware house established in 2005 under the Ministry of Social Services which maintains a readily available stock of emergency relief items. These items include dry rations, water, shelters/ tents, hygiene kits, health equipment, kitchen utensils, boat engines, clothes, water pumps, water tanks and water purification apparatus. These emergency relief items are distributed in the event of a disaster through the relevant District and Divisional Secretariats in the affected communities(NDRSC, 2020).

As mentioned prior, DM activities in Sri Lanka are carried out emulating a de-concentrated approach that corresponds with the administrative system in the country. Accordingly, while the NDRSC has been legally mandated to facilitate the provision of disaster relief services at national level, the authority to provide such services has been delegated to sub-national level administrative bodies, particularly the District Secretary at the district level, the Divisional Secretary at local level and the GN officer at community level. For instance, sanctioning the NDRSC to collaborate with sub-national level administrative bodies, the Sri Lanka Disaster Management (Amendment) Act No. 13 of 2005 vests the Divisional Secretary with the authority to provide disaster relief services as follows:

23A. During the period of a disaster, the Divisional Secretary of the Division having

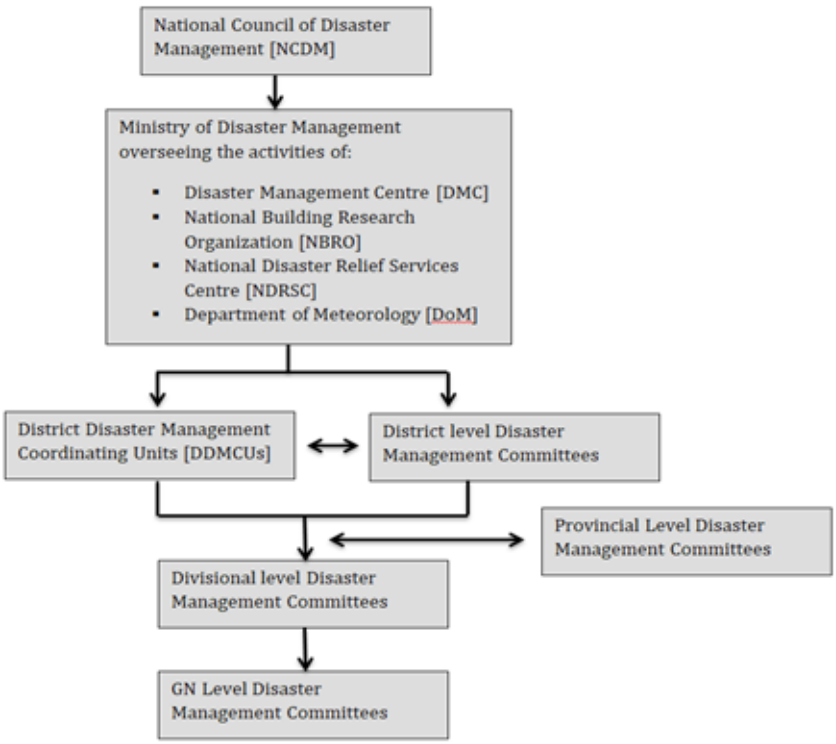

Figure 1. De-concentrated Aapproach to disaster management in Sri Lanka

Source: Adopted from Amaratunga et al. (2020)

jurisdiction over the affected area shall provide emergency relief in accordance with disaster management plans.

Similarly, the National Disaster Management Plan identifies District, Divisional and GN administrations as the "the main line of authority for disaster relief and other related aspects in post disaster situations" (Disaster Management Centre, 2014, p. 8). Accordingly, the Ministry of Home Affairs issued a circular based on a Cabinet decision made on 11th July 2017 to transfer powers to District Secretaries to respond immediately on emergency disaster situations. The circular was referred to both District Secretaries and Divisional Secretaries in August 2017 and it confers power on District Secretaries to carry out the following functions during a disaster situation:

1. Independent decision making with respect to emergency rescue operations and providing relief services.

2. In the event of a disaster, executing disaster management activities by obtaining the assistance of Divisional Secretariats and the officers of other Ministries attached to Divisional Secretariats.

3. On occurrences of disasters, transfer of powers to relevant Divisional Secretariats enabling them to make decisions and to organise necessary matters while declaring relevant disaster situations with the knowledge of the District Secretary in a way that the life of the community will be protected.

4. In case of an emergency disaster situation, obtaining information about voluntary rescue groups within the district for saving, rescuing and providing relief measures and obtaining their service in such situations.

5. In case of an emergency disaster situation, performing necessary activities for the purchase of essential items as may be necessary.

Therefore, it is evident that sub-national level administrative bodies, specifically District Secretaries and Divisional Secretaries have been given legal approval to take autonomous decisions and actions pertaining to the provision of disaster relief and mobilising search and rescue operations in the event of a disaster.

With regard to medium and long term reconstruction and rehabilitation following a disaster, the DMC coordinates with various responsible ministries and agencies including the Ministry of Economic Development and National Housing Development Authority while funding for such activities is provided by donors such as NGOs and INGOs (Disaster Management Centre, 2014). Further, various government agencies including [but are not limited to] the Central Environmental Authority [CEA], Department of Agriculture, Land Use Policy Planning Division, Ministry of Education, Ministry of Resettlement and the Social Services Department provide advisory support for reconstruction and rehabilitation activities. Accordingly, medium and long term plans for rehabilitation and reconstruction are prepared following a disaster in addition to which business entrepreneurs are encouraged to formulate business continuity plans (Disaster Management Centre, 2014).

In an evaluation of the current disaster response mechanisms in Sri Lanka, Bulancea (2018) points out that the Government of Sri Lanka [GoSL] is predominantly focused on the provision of short-term relief and assistance for immediate recovery in the form of cooked food; dry rations; non-food items; emergency cash grants; short-term house rental allowances and compensation for damaged property. However, attention paid to building households' resilience and long term post disaster assistance is minimal (Bulancea, 2018). Elaborating on this, Sri Lanka has an extensive social protection system which encompasses 36 welfare programs which can be broadly classified into: 1) social insurance; 2) social assistance and 3) active labour market programs. These programs are implemented by various government agencies at both the

national and sub-national levels (Institute of Policy Studies, 2018). Although disaster responsive social protection is paramount for strengthening the resilience of households, the effectiveness of social protection programmes in Sri Lanka is negated due to certain identified gaps such as (a) exclusion and inclusion targeting errors in entitlements where certain deserving households have not gained any benefits while some less deserving households have benefited; (b) inadequacy of benefits to meet a household's minimum requirements under normal conditions; (c) insufficient coverage of informal sector workers; (d) overlaps and duplications due to lack of institutional coordination and (e) lack of flexibility and scalability for inclusion of disaster affected non-beneficiary households and new requirements that arise following a disaster (Institute of Policy Studies, 2018).

This chapter outlines the cascading socio-economic impacts of the first wave of COVID-19 in Sri Lanka and examines how the Government of Sri Lanka [GoSL] responded to these impacts against the described legal and institutional framework. The chapter further highlights the strengths and limitations of GoSL's approach to addressing these cascading effects with the aim of providing policy recommendations on the governance of systemic risks.

2. METHODOLOGY

This chapter presents the findings of a larger study conducted on the integration of preparedness planning for biological hazards into Disaster Risk Reduction in Sri Lanka. It draws on a thorough review of secondary literature including scholarly articles, internet sources and reports published by national and international organisations pertaining to disaster management, public health and the COVID-19 pandemic situation in the country. Further, it has cited details from a case study conducted in the Polonnaruwa district, Thamankaduwa Divisional Secretariat Division. This particular study was based on in-depth interviews conducted with the District Secretary of the Polonnaruwa District, Divisional Secretary of the Thamakaduwa DSD and the Medical Officer of Health [MOH] of the Thamankaduwa DSD. In examining the cascading effects of the first wave of COVID-19 in Sri Lanka, the Polonnaruwa district is significant owing to two reasons. On one hand, the district of Polonnaruwa is a major rice producing area in Sri Lanka. Production and distribution of rice were categorised as essential services which thus, had to be uninterruptedly continued despite the pandemic situation in the country. On the other hand, the Kandakadu quarantine centre, one of the main quarantine centres established during the first wave of the pandemic was located in the same district.

Qualitative data was also gathered through in-depth interviews carried out with Assistant Directors of the DDMCUs in the Ratnapura, Badulla, Trincomalee and Kilinochchi districts. The districts of Ratnapura and Badulla stand significant in an analysis of COVID-19 as a systemic risk as with the advent of the Southwest monsoon said districts were faced with the risk of hazards such as floods and landslides occurring in parallel with the pandemic situation. The majority of the population in the district of Trincomalee constitutes of Muslims and Tamils, which are the largest ethnic minority groups in Sri Lanka. Hence these two districts were selected with the objective of obtaining a fair representation of all ethnic groups in the country. The questions posed during the interviews were aimed at capturing the role played by the sub-national level DM and health authorities in responding to the social and economic impacts of the first wave of COVID-19 and also the challenges faced by said authorities in this process.

Further, qualitative data was collected through in-depth interviews conducted with key informants including representatives from World Vision Lanka and Ceylon Chamber of Commerce in order to gain insights into the effects of the first wave of COVID-19 on the private sector and the role played by international organisations and the private sector in responding to cascading effects of the pandemic. Data was analysed using thematic analysis, a qualitative data analysis technique

where the data was coded and subsequently organised under the main and sub themes.

3. RESULTS AND DISCUSSION

This section of the chapter explains the findings of the study under two main themes: 1) the social and economic impact of the first wave of COVID-19 in Sri Lanka and 2) main stakeholders involved and the roles played by them in addressing the cascading effects of COVID-19. The latter has been sub-divided into three sub-themes as follows: (a) national level stakehodlers; (b) sub-national level stakeholders and (c) the strengths and limitations of Sri Lanka's approach to addressing the cascading effects of COVID-19.

3.1. The social and economic impact of the first wave of COVID-19 in Sri Lanka

The COVID-19 pandemic in the country called for the imposition of lockdown restrictions which in turn resulted in the closure of both government and private sector establishments. This posed a detrimental impact on Sri Lanka's key industrial sectors namely tourism, apparels, manufacturing and services. For instance, arrival of tourists in the country decreased by 71% in March 2020 and in the months following from April 2020 to June 2020 tourist arrivals were nil (Vithanage, 2020). Similarly, the Purchasing Manager's Index [PMI] of the manufacturing sector which was recorded at 54 in January, 2020 declined to 24.2 in April, 2020. This decline has been attributable to a fall in new orders, production and employment in the said sector (Central Bank of Sri Lanka, 2018). In addition to this, private remittances sent by migrant workers which contribute to around 63% of total export earnings in the country, decreased by 32% in April 2020 in turn posing a negative impact on Sri Lanka's foreign exchange earnings (International Labour Organization, 2020; Vithanage, 2020). This macro-economic downturn has inflicted economic suffering on individuals at a micro level causing loss of employment income. For instance, a recent labour market survey conducted among 2764 companies revealed that 1084 of these companies did not have the financial capacity to pay salaries to their employees due to the economic slump caused by the pandemic situation in the country (Wimalaweera, 2020).

It was emphasizsed by most key informants that Small and Medium Enterprises [SMEs] and the daily wage earners employed in the informal sector were the most vulnerable during and possibly as a resultant of the COVID-19 pandemic situation in the country (Key informant interviews, 2020). Confirming this statement, a recent survey conducted by UNDP and UNICEF (2020) among 2116 households in Sri Lanka, portrays the coping strategies employed by daily wage workers in the face of challenges posed by the first wave of COVID-19. The results indicated that out of the total number of daily wage earners who participated in the survey, 42% buorrowed money, 35% pawned and 51% sold their belongs to cope with the financial strains imposed by the pandemic (UNDP and UNICEF, 2020).

Apart from these adverse economic impacts, the pandemic situation in Sri Lanka created some bleak social implications as well. Lockdown restrictions accompanied by other social distancing measures disrupted the face to face educational services. In response, the Government of Sri Lanka encouraged educational services to be provided uninterruptedly via online (Kadirgamar & Thiruvarangan, 2020). This has widened inequalities in free access to education and fuelled social unrest (Kadirgamar & Thiruvarangan, 2020; Key informant interviews, 2020). Elaborating on this, a representative from the Ceylon Chamber of Commerce asserted that,

"*Education was disrupted for almost four months. The government took actions to continue the education uninterruptedly. See the social impact there. There are low income generating families who don't have access to computers and tabs and at the same time who don't have access to internet connections. Even if you have, who is going to pay for that cost? Only about 50% of the students participated. Later, in those places*

student unions are strong. So later on they have started a campaign boycotting lectures because some of their colleagues can't participate"

Further, certain social implications have stemmed from the adverse economic impacts itself. Such implications include anxiety caused by job losses or job insecurity and stress experienced by household heads as a result of not being able to adequately provide for the family (Key informant interviews, 2020).

3.2. Main stakeholders involved and the roles played by them in addressing the cascading effects of COVID-19

3.2.1. National level stakeholders

As mentioned earlier, NDRSC is the responsible authority for coordinating the provision of disaster relief in the country. Regardless of the capacity to utilise the services of the NDRSC in the context of the COVID 19 pandemic in Sri Lanka, a Presidential Task Force was established on the 26th of March 2020 by way of Gazette Extraordinary No. 2168/8. The Task Force was established to 'direct, coordinate and monitor the delivery of continuous services for the sustenance of overall community life, including the food provisions produced in rural areas being distributed to consumers giving priority to the Districts of Colombo, Kalutara, Gampaha, Puttlam, Jaffna, Mannar, Kilinochchi, Vavuniya and Mullaitivu which had greater vulnerability in the eradication of Coronavirus in Sri Lanka' (Centre for Policy Alternatives, 2020). With respect to the provision of disaster relief, the appointed Task Force was instructed to provide a grant of LKR 5000 to low income families and economically vulnerable populations such as daily wage earners as a single payment, for the purpose of easing their financial burden. Some of the economically vulnerable population groups entitled to this grant included teachers, private bus drivers and conductors, Ayurveda doctors not in government service but registered with the Ayurveda Medicine Council, handicraftsmen, women receiving maintenance, small scale tea estate owners and provincial reporters (The Department of Government Information, 2020). In addition to this, two other task forces were appointed namely, to foster economic revival and poverty alleviation and another to ensure the continuity of educational services during the pandemic (Centre for Policy Alternatives, 2020).

Considering the adverse effects posed by the pandemic situation on private enterprises, the GoSL introduced a stimulus package for SMEs for which the government allocated a fund of LKR 150 billion (Vithanage, 2020). The financial burden on SMEs was further lifted as the payment of income tax arrears was partially waived off (International Monetary Fund, 2020). Furthermore, the GoSL introduced a debt repayment moratorium which included a six month moratorium on interest payments of bank loans on tourism, garments, plantation and IT sectors and SMEs (International Monetary Fund, 2020).

In addition to this, INGOs such as World Vision Lanka played a crucial role in responding to the adverse economic and social impacts of the COVID-19 pandemic situation in Sri Lanka. For instance, it was revealed during the key informant interviews (2020) that World Vision Lanka targeted its emergency relief activities at families with children and households headed by females in sixteen (16) districts. The organisation identified suitable beneficiary households with the support of sub-national level authorities such as Divisional Secretaries and dry rations were provided to ensure food security. Apart from relief activities, the organisation was also committed in encouraging the families in these identified 16 districts to overcome the pandemic concerns via the execution of a livelihood development programme (Key informant interviews, 2020).

3.2.2. Sub-national level stakeholders

Activation of sub-national level Disaster Management Committees and DDMCUs

At sub-national level, the DDMCUs along with sub-national level Disaster Management committees including the district level, divisional level and Grama Niladhari level

committees played an important role in immediate response to the country's social and economic impacts due to the COVID-19 pandemic situation. The activities carried out by these sub-national level disaster management authorities have predominantly involved coordination and resource mobilisation.

In certain districts such as the districts of Badulla and Trincomalee, special District DM Committee meetings were held to discuss, as to how to organise programmes to respond to the pandemic situation at district level (Key informant interviews, 2020). The meetings were convened by the Assistant Director of the respective DDMCU and were attended by the Regional Director of Health Services [RDHS] of the relevant district who in turn briefed all other attendees on the current pandemic situation [i.e. the number of cases, the gravity of the risk, behavioural guidelines to be followed and actions to be taken] (Key informant interviews, 2020). In Trincomalee, the meetings were used to devise a joint action plan addressing the pandemic with the support of the health authorities. Informed by these discussions, the officials of DDMCUs coordinated with the relevant district level officers and mobilised personnel [eg: the police and tri-forces] and other resources [eg: financial support from NGOs and INGOs] to perform various activities such as the provision of relief services [particularly the LKR 5000 allowance] to vulnerable groups, provision of food supplies to families who were self-quarantined, ensuring undisrupted supply of vegetable production and distribution to markets and also ensuring that curfew or lockdown regulations and behavioural guidelines [eg: maintaining one metre distance and refraining from organizsing large gatherings] were followed. These activities were carried out in accordance with the specifications outlined in circulars that were referred to the District Secretary (Key informant interviews, 2020).

Establishment of separate committees to respond to the pandemic

In certain other districts such as the districts of Ratnapura and Polonnaruwa, separate committees were established to respond to the COVID-19 pandemic situation, instead of activating the Disaster Management committees. These committees were chaired by the District Secretaries of the respective districts and played a crucial role in the provision of emergency relief and short term response to the socio-economic effects of the first wave of COVID-19. The decisions taken at these committees were implemented at the divisional and Grama Niladhari levels. For instance in the district of Ratnapura, district level committee meetings were held every two (2) days and these meetings were represented by the public health authorities such as the Provincial Director of Health Services, Regional Epidemiologist, Deputy Provincial Health Director, Regional Director of Health Services and the Director of District General Hospital (Key informant interviews, 2020). The decisions taken at the district level committee meetings in consultation with the aforementioned health authorities were implemented by coordinating with relevant district level officers and other local and community level officers such as the Divisional Secretaries, Medical Officers of Health in collaboration with Public Health Inspectors [PHIs], Grama Niladhari [GN] officers and Public Health Midwives (Key informant interviews, 2020).

In the district of Polonnaruwa, the District level COVID-19 committee was represented by the Divisional Secretaries of the seven (7) Divisional Secretariat Divisions in the Polonnaruwa district. The committee met daily and at times twice a day, to discuss the progress of planned activities. The District Secretary who chaired the District committee played a significant role in ensuring that the quarantine centre established in the Kandakadu in the Polonnaruwa district had access to basic services such as water and other sanitation facilities (Key informant interviews, 2020). Furthermore, the District Secretary collaborated and coordinated with the seven (7) Divisional Secretaries to provide needed assistance in carrying out relief and surveillance activities at the divisional level. These activities involved coordinating with sub national level stakeholders [eg: GN officers, Development

officers, Samurdhi Development officers] in distributing the allowance of LKR 5000 among identified, economically vulnerable families in the division; ensuring that households which were isolated had access to essential services such as food; facilitating continuous supply of food to villages in the division and distributing dry rations to low income families and other vulnerable groups such as temples, children's orphanages and elders' homes (Key informant interview, 2020). Similarly, the Divisional Secretary had to ensure that necessary arrangements were made to pay the pension amounts to pension holders on due dates and the fuel stations were kept open while adhering to proper guidelines. The division has a garment factory which, stitched and provided masks to the public during the pandemic period and the Divisional Secretariat had to ensure that the factory continued to function during the lockdown period whilst adhering to proper health guidelines (Key informant interviews, 2020).

3.2.3. Sri Lanka's approach to addressing cascading effects: An analysis of strengths and limitations

In alignment with the recommendation of Kaufmann and Scott (2003) and UNDRR (2020) to emulate a multi-sectoral approach for effective governance of systemic risks, it is evident that there has been effective collaboration among various stakeholders ranging from DM authorities, health authorities, and private sector to international organisations in providing emergency relief services to affected groups during the first wave of COVID-19 in Sri Lanka. The DMC at the national level and the DDMCUs together with DM committees at the sub-national level have played a key role in facilitating such multi-sectoral collaboration which helped to improve both the efficiency and capacity of providing assistance and relief services. Another strength that was identified is the emulation of a decentralised approach where District and Divisional Secretaries have been able to make independent decisions pertaining to the provision of relief to impacted areas. This approach has enabled the cascading after effects to be addressed in a contextualised manner by resolving problems and also by leveraging resources which are localised to a particular area.

However, inefficiencies have been caused by the establishment of new structures where existing structures such as the NDRSC could have been utilised in providing relief services. For instance, the grant of LKR 5000 distributed during the COVID-19 pandemic situation by the newly established Presidential Task Force was a new system of relief introduced to address the economic concerns of the affected communities. Given the newness of this system, there were considerable delays in providing the grant which in turn disrupted the efficiency of relief services and aggravated the vulnerability of certain population groups. Illustrating this, an officer from DDMCU, Ratnapura said,

"*Under the Ministry of Disaster Management, when people are faced with a disaster and they are in relief camps or in the safety of their relatives'/ friends' homes, we provide them with food. We provide them with food parcels if they are in camps or dry rations if they are in a relative's house. However, this procedure that is carried out under the purview of the Ministry of Disaster Management was not able to be carried out during the COVID-19 pandemic situation. We proposed that this procedure be carried out at the committee meetings so that food supplies and dry rations can be provided to people who were self-quarantined. But this procedure was substituted by a LKR 5000 allowance that was given to vulnerable families. In our procedure, food supplies and dry rations are provided immediately following a disaster. However, in the provision of LKR 5000 there was a delay. So certain households that were self-quarantined may have been penalised during this time lapse*" (Key informant interviews, 2020).

Further, lack of updated information about the village population at local level posed a challenge in accurately identifying the "real" beneficiaries for the provision of the LKR 5000 allowance at sub-national level. The lists that were available with relevant GN officers [eg: lists of Samurdi beneficiaries,

people with chronic kidney disease and people with disabilities in the respective GN divisions] were neither up-to date nor inclusive of other economically vulnerable groups such as the daily wage earners in the informal sector who may have lost their means of income during the pandemic period. According to the key informants, the issue was aggravated due to the fact that, the GN officers appointed to relevant GN divisions were not from the same village and thus they were less familiar with the households of the particular community.

Additionally, there was lack of consistency in the circulars issued at national level with regard to the distribution of LKR 5000 grant. It was revealed during the key informant interviews that several revisions were made to the original circular issued to sub-national level authorities, particularly Divisional Secretaries, on the distribution of the LKR 5000 allowance among economically vulnerable population. This created confusion when defining the target beneficiaries. In addition, when addressing the cascading effects of COVID-19 in Sri Lanka, emphasis has been placed on the provision of emergency relief rather than building resilience, which is contrary to UNDRR's (2020) proposals of building whole of society resilience with a long term focus towards managing systemic risks. It is possible that, at this point some of the shortcomings discussed, particularly, lack of up-to date information regarding vulnerable population groups, inconsistency in circulars issued on deserving beneficiaries and inadequate focus on resilience building stem from certain deficiencies within Sri Lanka's social protection system such as targeting errors, inadequate coverage of informal sector workers, lack of institutional coordination and lack of scalability and flexibility to include disaster affected non-beneficiary households.

Apart from the limitations outlined, it was pointed out during the interviews that the stimulus packages offered for the SMEs were inadequate. Clarifying this, a representative from the Ceylon Chamber of Commerce stated:

"We analysed stimulus packages provided by 18 other countries. Some countries have even allocated 8-10% of the GDP for their stimulus packages. On an average it is about 3.5% of the GDP in most countries. But if you take into consideration the LKR 50 billion initially allocated, it is less than 0.5% of our GDP. So, it is something we can appreciate but it is not enough".

In light of the quoted statement, it is plausible to state that inadequacy of benefits provided to the private sector may slow down the overall economic recovery and hamper the resilience of the private sector to external shocks. The strengths and limitations discussed have been summarizsed in Table 1.

Table 1. Summary of Sri Lanka's approach, strengths and limitations in addressing the cascading effects of COVID-19

Stakeholders	Strengths	Limitations
National level stakeholders • Government of Sri Lanka (GoSL) • Presidential Task Forces • NGOs and INGOs Sub- national level stakeholders • District Disaster Management Coordinating Units (DDMCUs) • District Secretaries • Divisional Secretaries • Grama Niladhari Officers • Sub national level health authorities (eg: Medical Officers of Health [MoHs]; Regional Directors of Health Services [RDHS]; Public Health Inspectors [PHIs])	• Effective collaboration across sectors and levels • Emulation of a decentralised approach	• Inefficiencies caused by the establishment of new structures where existing structures could have been used • Lack of updated information on village level population • Inconsistency in the circulars issued at national level • Inadequate focus on resilience building • Benefits provided being inadequate [eg: stimulus packages]

4. CONCLUSION

The findings of this study show that pandemic situations are not mere health issues but hazards that create grave social and economic implications causing sustained vulnerabilities. However, mere response measures such as provision of emergency relief only offer short term solutions to persistent problems. Therefore, it is important to shift the focus from short term response to building economic and societal resilience with the aim of minimising the adverse economic and social implications arising due to disasters such as epidemics and pandemics. Adequate focus on building resilience coupled with an orientation for collective accountability is the cornerstone of effective and systemic governance of systemic risk. A resilience building approach calls for various policy initiatives such as the establishment of a systematic and an inclusive social protection system which is scalable and flexible in providing adequate assistance to non-beneficiaries affected by crises; strengthening the social protection of the informal sector; enhancing "state-citizen" interactivity at GN level to enhance the effectiveness of disaster recovery and resilience building programmes and establishing private-public partnerships to foster resilience of the private sector.

ACKNOWLEDGEMENT

This project is funded by the UK Research and Innovation through the UK Government's Global Challenges Research Fund (GCRF) and the Newton Fund [grant number EP/V026038/1]. UK Research and Innovation accept no liability, financial or otherwise, for expenditure or liability arising from the research funded by the grant, except as set out in the Terms and Conditions or otherwise agreed in writing.

REFERENCES

ADB. (2020). *Poverty: Sri Lanka*. Asian Development Bank. Retrieved 31 December 2020, from https://www.adb.org/countries/sri-lanka/poverty.

Africa Centres for Disease Control and Prevention. (2020). *Responding to the Second Wave of COVID-19 in Africa* (pp. 1-6). Addis Ababa: Africa Centres for Disease Control and Prevention. Retrieved from https://africacdc.org/download/responding-to-the-second-wave-of-covid-19-in-africa/

Ali, A., Ahmed, M., & Hassan, N. (2020). Socioeconomic impact of COVID-19 pandemic: Evidence from rural mountain community in Pakistan. *Journal of Public Affairs*. https://doi.org/10.1002/pa.2355

Alwazir, E. (2020). *World's Most Vulnerable Countries Lack the Capacity to Respond to a Global Pandemic*. Un.org. Retrieved 31 December 2020, from https://www.un.org/ohrlls/news/world%E2%80%99s-most-vulnerable-countries-lack-capacity-respond-global-pandemic-credit-mfdelyas-alwazir.

Amaratunga, D., Malalgoda, C., Haigh, R., & De Silva, A. (2020). *How do we Organise for DRR and Resilience? A Study on Disaster Reduction and Management Governance Profile of Sri Lanka*. Huddersfield, UK: University of Huddersfield.

Bulancea, P. (2018). Responding to Shocks through the Social Protection System: Opportunities for Sri Lanka. In *High-level Conference*. Colombo. Retrieved 2 January 2021, from http://pubdocs.worldbank.org/en/996001538412428837/6-Sri-Lanka-Safety-Nets-Paula-Bulancea.pdf.

Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., Dong, J., et al. (2020). The psychological impact of the COVID-19 epidemic on college students in China. *Psych. Res*. 287. https://doi.org/10.1016/j.psychres.2020.112934

Central Bank of Sri Lanka. (2018). *Purchasing Managers Index*. Retrieved 26 August 2020 from, https://www.cbsl.gov.lk/en/statistics/business-surveys/sl-purchasing-managers-index-survey%20.

Centre for Policy Alternatives. (2020). *Statement on the Presidential Task Forces*. Retrieved 27 August 2020 from, https://www.cpalanka.org/statement-on-the-presidential-task-forces/

Centre for Policy Alternatives. (2020). *Structures to Deal with COVID-19 in Sri Lanka: A Brief Comment on the Presidential Task Force*. Retrieved 26 August 2020 from, https://www.cpalanka.org/structures-to-deal-with-covid-19-in-sri-lanka-a-brief-comment-on-the-presidential-task-force/

Combaz, E. (2014*). Disaster resilience: Topic guide*. Birmingham, UK: GSDRC, University of Birmingham.

Davies, M., Bene, C., Arnall, A., Tanner, T., Newsham, A., and Coirolo, C. (2012). Promoting Resilient Livelihoods through Adaptive Social Protection: Lessons from 124

programmes in South Asia, *Development Policy Review*, 31(1), 27-58.

DFID. (2012). Multi-hazard Disaster Risk Assessment. Retrieved 31 December 2020, from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/204933/Multi-hazard_risk_assessment_guidance.pdf.

Disaster Management Centre (2006) Grama Niladhari Level Disaster Preparedness and Response Plan. Retrieved 2nd January 2020 from, https://www.preventionweb.net/files/2296_GNFormat.pdf. Accessed 30 June 2020.

Disaster Management Centre. (2006). Divisional Disaster Preparedness and Response Plan. Retrieved 2nd January 2020 from, https://www.preventionweb.net/files/2296_DivisionalFormat.pdf.

Hadad-Zervos, F. (2020). *Three ways Sri Lanka can deal with COVID-19 induced poverty*. World Bank Blogs. Retrieved 30 December 2020, from https://blogs.worldbank.org/endpovertyinsouthasia/three-ways-sri-lanka-can-deal-covid-19-induced-poverty.

Haraguchi, M., Lall, U. and Watanabe, K. (2016). Building Private Sector Resilience: Directions After the 2015 Sendai Framework, *Journal of Disaster Research*, 11(3), 535-543.

Hatton, T., Grimshaw, E., Vargo, J., and Seville, E. (2018). Lessons from disaster - creating a business continuity plan that really works, *Journal of Business Continuity & Emergency Planning*, 10 (1), 84-92.

Health Promotion Bureau. (2020). *COVID-19 Situation Report*. Retrieved 31 December 2020, from https://www.hpb.health.gov.lk/en.

ILO, FAO, IFAD, & WHO. (2020). *Impact of COVID-19 on people's livelihoods, their health and our food systems*. Who.int. Retrieved 20 December 2020, from https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people's-livelihoods-their-health-and-our-food-systems.

Institute of Policy Studies. (2018). *Social Protection and Disaster Risk Management in Sri Lanka*. Colombo, Sri Lanka: Institute of Policy Studies. Retrieved 2nd January 2020 from, https://www.ips.lk/wp-content/uploads/2018/10/13-Social-Protection-and-Disaster-Risk-Management-in-Sri-Lanka.pdf

International Labour Organization. (2020). *Labour migration in Sri Lanka and the Maldives*. Retrieved 30 August 2020 from, https://www.ilo.org/colombo/areasofwork/labour-migration/lang--en/index.htm#banner

Jayasena, H., & Chinthaka, W. (2020). COVID-19 and developing countries: lessons learnt from the Sri Lankan experience. *Journal Of The Royal Society Of Medicine*, *113*(11), 464-465. https://doi.org/10.1177/0141076820947367

Kadirgamar, N. & Thiruvarangan, M. (2020). *Learning lessons: The COVID-19 challenge to education*. Retrieved 27 Augusts 2020 from, http://www.ft.lk/columns/Learning-lessons-The-COVID-19-challenge-to-education/4-700218

Kaufmann, G. and K.E. Scott. (2003). What is Systemic Risk, and Do Bank Regulators Retard or Contribute to it? *The Independent Review*, 7(3), 371-391.

Kosec, K. and Mo, C. (2017). Aspirations and the Role of Social Protection: Evidence from a Natural Disaster in Rural Pakistan. *World Development*, 97, 49-66.

Kuriakose, A., Helyberg, R., Wiseman, W., Costella, C., Cipryk, R, Cornelius, S. (2013). Cliamte-Responsive Social Protection. *Development Policy Review*, 31(2), 19-34.

Li, L. Z., and Wang, S. (2020). Prevalence and predictors of general psychiatric disorders and loneliness during COVID-19 in the United Kingdom. Psych. Res. 291, 0165–1781. https://dx.doi.org/10.1016%2Fj.psychres.2020.113267

Michael, D. (2020). *Lanka's informal sector: A rare gem awaiting polish*. Sunday Observer. Retrieved 31 December 2020, from http://sundayobserver.lk/2018/10/21/business/lanka%E2%80%99s-informal-sector-rare-gem-awaiting-polish.

Ministry of Disaster Management.(2013). *National Policy on Disaster Management*. Colombo, Sri Lanka: Ministry of Disaster Management.

Mitchell, T. & Harris, K. (2012). *Resilience: A risk management approach*. Retrieved 31 December 2020, from https://www.odi.org/publications/6271-resilience-risk-management-climate-change .

NDRSC. (2020). *Emergency Relief*. Retrieved 2nd January 2020 from, http://www.ndrsc.gov.lk/web/index.php? option=com_content&view=article&id=60&Itemid=67&lang=en

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Losifidis, C., Agha, M., & Agha, R. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *International Journal of Surgery*. 78, 185-193. https://doi.org/10.1016/j.ijsu.2020.04.018 .

Pollet, M. (2021). *Which countries in Europe are experiencing a second wave of COVID-19?*. euronews. Retrieved 20 December 2020, from https://www.euronews.com/2020/11/18/

is-europe-having-a-covid-19-second-wave-country-by-country-breakdown.

Rosa, E. A. (2008). White, black, and gray: critical dialogue with the International Risk Governance Council's Framework for Risk Governance. In: Renn, O. and K. Walker (eds.). Global Risk Governance: Concepts and Practice Using the IRGC Framework. Dordrecht. Springer. 101-118

Sahebjamnia, N., Torabi, S. and Mansouri, S. (2014). Integrated business continuity and disaster recovery planning: Towards organizational resiliency, *European Journal of Operational Research*, doi: 10.1016/j.ejor.2014.09.055

Saladino, V., Algeri, D., & Auriemma, V. (2020). The Psychological and Social Impact of Covid-19: New Perspectives of Well-Being. *Frontiers In Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.577684

Sarmiento,J., Hoberman, G., Ilcheva, M., Asgary, A., Majano, A., Poggione, S., Duran, L., (2014). Private sector and disaster risk reduction: The Cases of Bogota, Miami, Kingston, San Jose, Santiago, and Vancouver, *International Journal of Disaster Risk Reduction*, http://dx.doi.org/10.1016/j.ijdrr.2014.09.008

Schwarcz, S.L. (2008). Systemic Risk. *The Georgetown Law Journal*, 97(1), 93–249.

Schweizer, P. & Renn, O. (2019) Governance of Systemic Risks for Disaster Prevention and Mitigation. Contributing Paper to GAR.

Singh, S., Eghdami, M. and Singh, S. (2014). The Concept of Social Vulnerability: A Review from Disasters Perspectives, *International Journal of Interdisciplinary and Multidisciplinary Studies* (IJIMS), 1 (6), 71-82.

Society for Risk Analysis. 2018. *Society for Risk Analysis Glossary*. Retrieved 31 December 2020, from http://sra.org/sites/default/files/pdf/SRA%20Glossary%20-%20FINAL.pdf.

Sri Lanka Disaster Management (Amendment) Act, No.13 of 2005. Retrieved 25 May 2020 from, https://www.preventionweb.net/english/policies/v.php?id=60321&cid=162

The Department of Government Information. (2020). Many material, financial assistance for those affected by the Coronavirus. Retrieved 25 September 2020 from, https://www.news.lk/news/political-current-affairs/item/29919-many-material-financial-assistance-for-those-affected-by-the-coronavirus

The Disaster Management Centre (2014) *Sri Lanka National Disaster Management Plan 2013-2017*. Colombo, Sri Lanka: The Disaster Management Centre.

Ulrichs, M., Slater, R., and Costella, C. (2019). Building resilience to climate risks through social protection: from individualised models to systemic transformation, *Disasters*, 43(3), 368-387.

UNDP. (2020). *COVID-19 Socio-economic Impact.* Retrieved 31 December 2020, from https://www.undp.org/content/undp/en/home/coronavirus/socio-economic-impact-of-covid-19.html.

UNDRR Asia-Pacific. (2020). *Disaster Responsive Social Protection: Lessons from COVID-19*. Retrieved 2nd January 2021, from https://www.undrr.org/publication/undrr-asia-pacific-covid-19-brief-disaster-responsive-social-protection.

UNDRR. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030*. Geneva: United Nations Office for Disaster Risk Reduction.

UNDRR. (2020). *COVID-19 Engagement Strategy Interim Report*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNDRR).

UNDRR. (2020). *Resilience*. Retrieved 31 December 2020, from https://www.undrr.org/terminology/resilience.

UNICEF & UNDP. (2020). COVID-19 Crisis Household Impact: Sri Lanka Telephone Surveys. Retrieved 2 January 2021 from, https://www.unicef.org/srilanka/media/1611/file/UNICEF%20UNDP%20Covid%20Impact%20Telephone%20Survey%20Round%203.pdf

Vithanage, C. (2020). *Impact of COVID-19 on the Sri Lankan Economy*. Retrieved 25 August 2020 from, https://www.youtube.com/watch?v=7JIzQUXlIM0.

Wimalaweera, A. (2020). Covid 19 & Beyond- The impact on the Labour Market of Sri Lanka SURVEY REPORT OF THE E-SURVEY CONDUCTED ON PRIVATE SECTOR ESTABLISHMENTS –MAY 2020. Colombo: Department of Labour Sri Lanka. Retrieved 30 August 2020 from, http://www.labourdept.gov.lk/images/PDF_upload/notices/survey%20report%202020.pdf

World Bank. (2020). *Sri Lanka's COVID-19 Response: Saving Lives Today, Preparing for Tomorrow*. Retrieved 31 December 2020, from https://reliefweb.int/report/sri-lanka/sri-lanka-s-covid-19-response-saving-lives-today-preparing-tomorrow#:~:text=Sri%20Lanka%20was%20extremely%20vulnerable,19%20on%20March%2010%2C%202020.

World Bank. (2020). *The Global Economic Outlook During the COVID-19 Pandemic:*

A Changed World. World Bank. Retrieved 30 December 2020, from https://www.worldbank.org/en/news/feature/2020/06/08/the-global-economic-outlook-during-the-covid-19-pandemic-a-changed-world#:~:text=Businesses%20might%20find%20it%20hard,by%20almost%208%25%20in%202020.

Worldometer. (2020). *Coronavirus Update (Live): 86,900,891 Cases and 1,877,450 Deaths from COVID-19 Virus Pandemic - Worldometer*. Retrieved 31 December 2020, from https://www.worldometers.info/coronavirus/.

A more decentralized governance framework for pandemic response: A multi-stakeholder approach for COVID-19 preparedness and planning in Sri Lanka

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ABSTRACT

The entire world is in an unprecedented dysfunction since 11th March 2020 when the WHO declared a global pandemic as unprecedented health and socio-economic issues emerged with the outbreak of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and its associated 53 coronavirus diseases (COVID-19). This challenging pandemic has created a greater shock on regular activities of every social strata resulting in a significant decline in economic growth and health sector progression. A serious wearing down of infrastructure, human resources and emergency response in the public health sector was visible in many countries, irrespective of the level of economic and social development. In this backdrop, many scholars are exploring appropriate and effective resilient systems to govern pandemic risks in varied settings. It is observed that Sri Lanka's pandemic response is not properly embedded with the country's Disaster Risk Reduction (DRR) framework and in many aspects, it is heavily reliant on the public health sector authority. In further elaborating the identified gap, this study explored many possible policy amalgamations that can be considered to improve the effectiveness of pandemic response activities at sub-national levels in Sri Lanka. Many government authorities, universities, volunteer agencies including NGOs, private sector organisations and the community can be efficiently integrated into pandemic response activities, vesting necessary responsibilities and authority for contingency and financial decision making at sub-national level. This system further ensures the unique and contextual approach in pandemic response at Divisional Secretariat level of each sub-region, which consists of diverse cultures. A large number of public officers are employed at District Secretary (DS) level in different areas of work such as finance, statistic and information, development, public health, livelihood, legal, police, child protection and probation, social welfare, elderly care, poverty alleviation, etc. within the public administration protocol adopted in Sri Lanka. These official positions can also be effectively integrated with the pandemic preparedness and response mechanisms at sub-national level.

Key words: COVID-19, Pandemic response, Disaster risk reduction, Public health emergencies in Sri Lanka

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1. INTRODUCTION

The COVID-19 pandemic is the most devastating health concern which has significantly impacted the global community in the recent past. By the first week of February 2021, a total of 2,312,278 deaths have been reported all over the world, while 105,805,951 people have been identified as confirmed cases since the first incident reported in 2019 (WHO, 2021c). Therefore, the COVID-19 pandemic can be considered as the most severe biological hazard of its kind, which happened during recent times in terms of the systemic nature of the cascading risks of this infectious disease around the world. The Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and its associated 53 coronavirus diseases, commonly known as COVID-19 was initially found in China, in December 2019 and spread across other regions rapidly within a short time span (Quigley et al., 2020; WHO, 2020). Considering the alarming outbreak of this virus and its greater repercussions impacting the social, economic and political spheres and in particular the public health sector, the World Health Organization (WHO) declared the epidemic as a global pandemic on 11th March 2020 (WHO, 2020).

The severity of the pandemic outbreak is significant and alarming due to the sudden emergence of two variants of SARS-COV-2 known as the VOC-202012/01 variant, which was initially detected in the United Kingdom and the 501Y.V2 variant originally found in South Africa (WHO, 2021b). Further, the mutated variant, which is commonly known as Kent strain or technically as B117, has been detected across UK and in more than 50 other countries. The outbreak of this pandemic worsened with the rapid spreading of new variants in certain regions and the accelerated outbreak of the root virus (SARS-COV-2) in many other regions, which shows the devastating and uncontrollable nature of the current pandemic. This unexpected and unprecedented global challenge has stressed the need for scaling up sustainable and effective resilience policies and mechanisms to eradicate the present pandemic and face similar or more challenging occurrences in the future. Experiencing devastating socio-cultural, economic, and political impacts arising due to global outbreaks and pandemics is not a new incidence. The human evolution has been through hundreds of pandemics caused by infectious diseases or pathogens or zoonotic diseases which have been frequent occurrences throughout the world history (Briand et al., 2011; Georgalakis, 2020; WHO, 2018). Severe acute respiratory syndrome or commonly known as SARS hit several regions in 2003, predominantly Asia and the threat to the public health sector was severe, resulting in more than 8000 confirmed cases. The H1N1, a novel influenza virus in 2009 and another pneumonic disease called Middle East Respiratory Syndrome (MERS) started to spread across the Middle Eastern countries during 2012-2013. The Ebola epidemic in 2014 badly impacted the West African region including Guinea, Liberia and Sierra Leone and then spread out to three other continents by sparking global alert for pandemic preparedness and response as a public health concern. A recent severe epidemic which was experienced in many parts of the world was the Zika virus outbreak in 2015, firstly emerged in Brazil and then started spreading across more than 70 countries. The most recent was a severe outbreak of Plague in Madagascar in 2017, which lasted a longer time period with 2,417 confirmed cases being reported and over 200 verified deaths. This was also a transmissible disease among humans and nine countries and territorials were declared as restricted travel destinations due to it being a significant case of bubonic plague. Serious consideration should be given in understanding the magnitude of the damages caused due to 1307 epidemic events that have occurred due to 20 transmissible diseases only during 2011 to 2017, as reported by the WHO (Briand et al., 2011; WHO, 2018).

Accordingly, lessons learnt from the past pandemic and epidemics also should be positively used for mitigating risks of present and future pandemics as many of these diseases or other new variations could possibly re-emerge in the near future. Addressing the grave loss of human lives, economic stability, social

order and integrity, political stability and health resources in the countries and overall global health resilience is yet to be fast tracked. Concept of 'global health security' was being identified by international health experts for governing relevant global and national agencies including national governments as a collaborative body in order to strengthen policies and activities in pandemic preparedness and response. (WHO, 2018).

Sri Lanka showed a satisfactory level of progress in terms of pandemic response especially during the first outbreak by reporting the lowest number of infected persons and deaths in the region and when compared with many of the other countries, up until October 2019. Even though, the second wave which started in the second half of October 2019, recorded an increasing and alarming number of both infected persons and deaths, Sri Lanka is yet identified by the WHO as a nation which is coping well, with cluster transmission in terms of the nature of the pandemic outbreak (WHO, 2021a). However, several recent studies suggest that Sri Lanka's pandemic preparedness and response should be further optimised as current pandemic response has not yet adequately been embedded with the disaster risk reduction framework of the country and heavily rely on the public health sector authority in many aspects (Amaratunga et al., 2020; Ranaweera et al., 2020). In this context, this chapter aims to explore the potential of developing a more comprehensive and multi stakeholder approach for pandemic response in Sri Lanka. Suggestions proposed by above studies provide an insight for developing a more decentralised and professionally engaged pandemic response framework rather, than adopting a more public health-oriented and bureaucratically top-down approach in terms of decision making and involvement in any public health emergency.

2. METHODOLOGY AND PROCEDURES

The objective of the study is to identify the gaps in pandemic response activities with specific focus on the divisional secretariat level and to propose suggestions to enhance the current response mechanism which should be more decentralised and engaged. Therefore, the study focuses its approach based on the qualitative descriptive research design and the collection of data was done in two stages. A desk study was conducted using existing research literature to accumulate both conceptual and secondary data, as the first part of the research. As the second step, eight (8) key informant interviews were conducted to gain a deeper insight, by selecting several respondents who represented decision making and implementation activities in disaster risk governance at the national level, provincial level and also involved in disaster management operations at divisional secretariat level.

Literature mining process was carried out using three well reputed electronic data bases known as ScienceDirect, PubMed and Scopus. Research literature mining process was initiated using the keywords which were derived from the research objectives: COVID-19 pandemic, pandemic preparedness and response, multi-stakeholder approach, pandemic governance in Sri Lanka.

The literature mining was restricted only for published peer-review research articles and excluded unpublished works, working papers, abstracts, books, chapters, reports, thesis and meta-analysis to filter comprehensive research papers. Finally, eight (8) research articles and several grey literature published on pandemic response and governance in Sri Lanka were used for the analysis by synchronising interview data, based on synthesis and thematic analysis approach.

3. COVID-19 PANDEMIC RESPONSE IN SRI LANKA

There is no debate on the effectiveness of the COVID-19 response in Sri Lanka, during the first pandemic outbreak as the performance of the authorities and relevant officials was reasonably satisfied. Sri Lanka was able to manage the first outbreak of COVID-19 quite successfully, thus exemplifying as an efficient model to many of its neighbouring

countries in the region, in terms of minimising the infected and death rates which were reported as 3346 infected and 13 deaths as at 4th October 2020. The first confirmed case of Coronavirus infected person was reported in Sri Lanka on 27th January 2020, who was a Chinese national who arrived in Sri Lanka on 19.1.2020 as a tourist. She was admitted to the National Institute of Infectious Diseases (NIID) and fully recovered by 10th February 2020. Meantime, a Sri Lankan citizen who is a tourist guide, was diagnosed positive as the first local patient and 14 suspected persons were identified by 7th February 2020. With this minor outbreak,14 hospitals around the country have been identified and prepared as treatment centres for suspected persons which were NHSL, LRH, NIID, TH *Ragama*, DGH Gampaha, DGH Negombo, National Hospital Kandy, TH *Karapitiya,* TH Anuradhapura, TH Jaffna, TH Kurunegala and PGH (MoH, 2020). The institutional preparedness during the first outbreak strengthened the pandemic response very effectively.

However, the second outbreak resulted in more than 69,000 infected persons while 64,000 recovered and discharged by the hospitals, and 356 deaths (up to 08/02/2021) (MoH, 2021a). Yet, in terms of deaths and infected cases, Sri Lanka's performance is considerably better than several other countries in the South Asia region except Bhutan (861 infected and 1 death) and Maldives Islands (17101 infected and 56 deaths) up to 10/02/2021 (WHO, 2021a). Similarly, curtailing the second outbreak also shows a satisfactory achievement when compared with many other countries that are out of the region. The following table (Table 1) shows a comparison of COVID-19 outbreak in terms of infected and death rates, calculated to the one million population for a few countries.

Nevertheless, Sri Lanka's pandemic mitigation efforts and strategies in the first Covid-19 wave were considerably effective in terms of controlling deaths and infected cases when compared with other regional countries such as India, Bangladesh, Pakistan and Afghanistan, where the outbreak is severe (Sarkar et al., 2020). As shown in the above table, comparatively Sri Lanka has been able to maintain a low Covid-19 death rate as a percentage of the total population when compared with many other developed nations. However, the optimum output which can be generated within the existing Disaster Risk Reduction (DRR) policies and mechanisms is yet to be enhanced, to strengthen the disaster responsiveness in Sri Lanka, especially with regard to biological hazards. Recent studies explored indicate that there are several loopholes and concerns within the current DRR framework, in responding to public health emergencies with the notable monopoly of public health and a few other sectors in governing pandemic responses (Amaratunga et al., 2020; Dissanayake, 2020).

Table 1. COVID-19 data of selected countries

Country	*Cumulative cases per 1 million population*	*Deaths per 1 million population*
Sri Lanka	3181	15
India	7787	112
Singapore	10172	5
Australia	1130	36
South Africa	6360	98

Source: (MoH, 2021b)

Findings of the desk study suggests that existing pandemic response in Sri Lanka is disproportionately public health and military oriented, which is a major criticism with regard to the response strategies often adopted by the country to face the current pandemic (Amaratunga et al., 2020; Dissanayake, 2020; Ranaweera et al., 2020). Moreover, this discourages, unfolding of new paradigms to pandemic response in the context of biological hazards and/or public health emergencies. On the other hand, monopoly in decision making during a critical crisis where none of the sectors in the country are safeguarded in terms of the regular functionalities, tends to dissuade the involvement of all necessary stake holders, which is much needed to regain the 'build back better'.

The COVID-19 task force in Sri Lanka comprises with epidemiologists, medical administrators, infectious disease specialists, military teams, police, politicians and media

under the leadership of the head of state (Hettiarachchi et al., 2020). In terms of short-term responses in public health emergencies, involvement of only key stakeholders or a smaller number of important authorities might be notably feasible in order to ensure time bound effectiveness in decision making, implementation and effective coordination, among different sectors. However, as per the field data, in the long run Sri Lanka needs comprehensive pandemic response strategies and mechanisms which reflect considerable involvement of all key stakeholders and inter-sectorial networking from top level to grass root level, which is considerably lacking in the existing policy making and practices. For instance, frequent involvement of military personnel in pandemic response for certain purposes such as contact tracing, government intelligence service, maintaining social security and safety during a pandemic are acceptable and valued with their training and professional capacities. Nevertheless, the involvement of military personnel in carrying out certain tasks or duties for which they have not gained any proper training, seems to be questionable in terms of ethical consideration (Dissanayake, 2020). Sri Lanka has extensively obtained the services of the military forces to combat the COVID-19 pandemic during the first outbreak and that strategy was an institutional arrangements of the state, for emergency response and as a developing nation the optimal use of available human and physical resources, to face an unexpected disaster (Hettiarachchi et al., 2020). However, current strategies on pandemic preparedness and response activities can be integrated with the involvement of essential stakeholders in the field of nonmilitary and nonhealthy sector, whose involvements and activities are highly professional. For an example, there is a need for more psychologists, social workers, community mobilizers and counsellors to be involved in the quarantine centres to harness peoples' mental health and safeguard social and cultural stability. Further, quarantine places must be equipped with an effective grievance redress mechanism as these centres are utilised by diverse groups such as children, females, differently abled, elderly persons of different ethnic groups.

It is also suggested that effectiveness of the pandemic response to a greater extent is determined by the response models that are developed by the state and based on the knowledge of the practitioners on strategies and measurements they administrate. As an example, the police involved in mobility monitoring, should be aware of the optimum extent of mobility to control cross sectional travel, in order to make the efforts a success (Erandi et al., 2020). In addition, peoples' psychological issues have largely been under estimated in the context of a pandemic, by disproportionately recruiting mental health professionals to provide necessary counselling to families with infants and young children, pregnant women and other mentally vulnerable population (Patabendige et al., 2020). In this context, this study proposes that pandemic response and governance framework in the country should be more elaborate and decentralised.

4. NEED FOR AN INTER SECTORAL APPROACH AND EFFECTIVE COORDINATION BETWEEN SECTORS

This challenging pandemic has generated a greater socio-economic shock and has resulted in a serious decline of cumulative progress in every sector in Sri Lanka, including public health. Many scholars are exploring appropriate resilient systems for different social contexts, which would be useful to govern pandemic risks effectively, as COVID-19 has become an unprecedented public health emergency, faced by the entire world. The reaction to COVID-19 outbreak highlights the need of rethinking and restructuring of traditional policies and practices of DRR, crisis management and emergency response adaptations as everyone had to deal with 'the unknown of unknowns'. Several governments have already developed complementary approaches to alter the orthodox emergency management procedures and protocols, which were led by the centre of governments (CoGs) based on the political

intentions (OECD, 2020). In many countries, all approaches relevant to this emerging field are mainly focused on short-term specific issues and therefore, the involvement of stakeholders representing different sectors and professions is very limited (Ogie & Perez, 2020; Pereno & Eriksson, 2020). This was very common in many countries, especially during the first pandemic outbreak as the nature of outbreak was novel. Sri Lanka, being a tropical country has been exposed to several biological hazards or epidemics including dengue, malaria, and other seasonal infectious diseases. Hence, each year with the monsoon, the relevant authorities maintain a high scale of public health interventions based on the free public health policy. What is required is a strong incorporation of pandemic governance to the existing epidemic control framework with an holistic approach (Ranaweera et al., 2020).

From another perspective, the COVID-19 pandemic exemplifies the systemic nature of effects, creating a variety of cascading social and economic impacts due to complexly interconnected structures. This unavoidable crisis sparks the need for fragmented institutions to be more integrated and synergised and shift from fever stakeholders to more stakeholders ranging from the private sector to local governments and civil societies. This new paradigm requires daring policy actions to regularise functions in the healthcare systems, education, safeguard employability and businesses and maintain the stability of economy. Further, trusted political will and leadership must be comprehended with the faith and expectations of the citizens and the role of governments. This is necessary to promote national resilience and preserve well-being with agile and innovative responses at the highest level, while co-ordinating and collaborating with lower levels of government and a large array of stakeholders (OECD, 2020).

High-level institutional arrangements and commitments are paramount in governing and managing policy responses to the pandemic or any other biological hazards, disregarding the context. It is suggested that there should be a strong focus and integration between three main dimensions in the institutional arrangement, for combating pandemics or epidemics.

1. Coordination and strategic planning

2. Use of evidence for informed decision-making

3. Communicating decisions to the public (OECD, 2020).

To enhance the effectiveness and sustainability of pandemic responses, all necessary institutions, organisations, groups, and individuals must have an opportunity to involve and integrate with diverse task loads, particular to their own capacities and professions. Nevertheless, in many countries, health institutions, healthcare providers, managing authorities, universities, research centres, welfare clusters, non-government organizations (NGOs), healthcare networks and professional consortiums, play a significant collaborative role in pandemic response, to shift or make a smooth transition from short term plans to long-term strategies (Pereno & Eriksson, 2020).

Ludvigsson (2020) emphasises that the success of COVID-19 response in Switzerland has been doubled up in an effective manner by gathering a range of stakeholders during the first outbreak. Interestingly, Swedish universities and education institutes have been encouraged to engage in COVID-19 research as key stakeholders, who were in the outer circle of the central government, in order to provide scientific insights for timely decision making. Therefore, it is apparent that, further decentralising of necessary decision-making powers and authority within the national resilience framework is required, to promote active involvement of different stakeholders. This will provide more effective and efficient approaches to the existing DRR policies and practices in the country.

5. EMBODYING BIOLOGICAL HAZARDS ADEQUATELY IN TO DRR POLICIES AND PRACTICES

Sri Lanka has several strengths to develop its pandemic preparedness and response activities very effectively using the existing DRR framework and human and institutional capacities. It is obvious that, free public health and education policies established in the country about nine decades ago have navigated a considerable improvement of human and social development in Sri Lanka. Increase of several social development indexes over the decades such as Human Development Index (HDI) (0.780) and average life expectancy (76.8 years) shows the positive impacts of education and health policies in the country. Literacy rate recorded at 92.5% is the second highest in the region next to Maldives. Many of the public health indicators of the country, outperform such indicators of several other nations in South Asia and East Asia (CBSL, 2020). These social indicators prove that the existing public health, education and welfare policies and approaches in the country have positively impacted the current social development. Moreover, these rates speculate that the existing public health and education mechanisms in the country also have its rigor to perform extraordinary standards as a developing nation, which has been socially and economically damaged by a thirty-year separatist war.

National Council for Disaster Management (NCDM) established under the Sri Lanka Disaster Management Act No. 13 of 2005 is the apex body concerning disaster management (DMC, 2014). NCDM is comprised of the Ministry of Disaster Management (MDM), Department of Meteorology (DOM), Disaster Management Centre (DMC), National Building Research Organisation (NBRO), and National Disaster Relief Services Centre (NDRSC). Apart from this body, a set of national and international humanitarian agencies also operate in several disaster-prone areas in the country, in line with the mission of NCDM in policy making and handling ground operations. The disaster management institutional structure has been designed by the NCDM which is chaired by the President and vice-chaired by the Prime Minister of the country and it extends to the level of Village Disaster Management Committee which represents the grass root level affected community (CEDMHA, 2017). Decentralisation of the DRR activities has been effectively integrated with District Disaster Management Coordinating Units (DDMCUs) and sub-national level disaster management committees. Furthermore, de-concentration of policy structures of DRR sub-national level disaster management plans and village level plans have also been developed (DMC, 2014). However, the existing DRR framework reflects less emphasis on pandemic and epidemic preparedness and response, which is paramount for the current situation in the country. As revealed by the key informant interviews, village level committees are frequently established in disaster-prone areas and many other villages have not been adequately integrated with these grass root programmes. Even though this is logical for natural hazards, all villages must have committees for biological hazards especially in pandemic and epidemic context. The most feasible approach to sustain these village level committees, is vesting the decision making and financial powers to the DSs to function as independent response units.

In this context, several studies suggest that the existing policy framework can be further improved and integrated with public health emergencies for combatting biological hazards within the current DRR framework, particularly to pandemic and epidemic response in the country. What is required is an effective inter sectoral and multi stakeholder approach to strengthen the public health resilience. An example to back this analysis, is the lack of integration between the anti-malaria campaign (AMC) and COVID-19 mitigation programmes in the country, even though both are operating under an umbrella of pathogens or infectious diseases of the public health sector in Sri Lanka (Amaratunga et al., 2020; Ranaweera et al., 2020). Ranaweera et al., (2020) suggests that expertise and resources of the AMC have not been directly utilised for programmes to combat COVID-19

and coordination between multiple sectors and departments is highly unsatisfactory. It was further highlighted, that there should be sound public health infrastructure with adequate and trained field staff, to facilitate contact tracing and expedite scientific testing protocols, as these are the two most significant elements in both COVID-19 and malaria combatting programmes in the country. The lack of coordination between departments and institutions as reflected in the programmes being carried out, is a significant gap in terms of intersectoral coordination during health emergencies. Conversely, preparedness for lowering the risks and vulnerability of biological hazards and mitigating compound impacts, have not been adequately grasped by the existing infectious disease control activities in Sri Lanka.

6. DIVISIONAL SECRETARIATS AS PANDEMIC GOVERNING FOCAL POINT: MORE DECENTRALIZED APPROACH

Governance of pandemic is a very critical component in pandemic response as there are several stakeholders involved in the process including centre of governments (CoGs), responsible institutions, departments, external organisations, and partners, civil societies, and the community. In Sri Lankan pandemic governance context basically, decentralisation up to the DS level has been concentrated for decision making during a disaster under the provisions of emergency relief and post-disaster management. The Disaster Management Act No. 5 of 2013 of Sri Lanka, vests powers to district secretaries and divisional secretaries to function in an emergency. However, a greater number of divergences such as limitations of financial powers, relying on certain upper bureaucratic approvals etc. could be observed especially, in the implementation of DRR activities and programmes in a health emergency, at the divisional secretariat level. Further, lack of updated information on village population at local level in terms of identifying beneficiaries for relief services and other state facilitations and also inconsistency in circulars and regulations issued at sub-national level with regard to the relief services, are some of the common concerns that have been identified. (Amaratunga et al., 2020). Hence, pandemic response is yet to be enhanced, especially with regard to the coordination gap between top level and sub-national levels, lack of decision-making power for immediate implementations and also to implement emergency response activities, that are to be carried out in different grass root clusters, etc.

Analysis suggests that there are many potential policy amalgamations that can be done to increase the effectiveness of pandemic response activities at sub-national level. One such aspect is effective networking and coordination between essential stakeholders. Many public departments, universities, volunteer agencies, private sector organisations and the community can be efficiently integrated into pandemic response activities, vesting necessary powers for contingency and financial decisions at sub-national level. This system further ensures the unique and contextual approach for each divisional secretariat/ village/community which could also consist of notable cultural diversity prevalent in the area. Nature of issues related to the livelihoods of people, social problems, level of poverty, psychological issues, relief needs, and overall grass root involvement firmly depend on the specific culture of the community, which are attributed to a prolonged period based on the ethnicity, religion, believes, language, attitudes, etc. Therefore, governing a pandemic and an epidemic at sub-national level, as a specific cluster is very effective, since a national level blanket approach for pandemic response is less effective, in many aspects. Results of the key informant interviews highlight that with the national authority, vesting direct powers to the Divisional Secretariats (DSs), these authorities can be empowered as independent governing bodies to engage in pandemic response based on own decision making and implementation rights and having the capacity to formulate regulatory and advisory committees, by assigning necessary stakeholders. As noted, what is needed is the full potential of decision-making powers and necessary infrastructure capacities to function as a complete self-

regulatory body. This system further ensures the unique and contextual approach, known as 'cluster-based approach' for sub-regions which reflect considerable cultural diversity and requirements.

The following figure (Figure 1) shows the structure of the presidential task force appointed for dengue control in Sri Lanka. As indicated, the protocol flow of the process is from the president to the village dengue committees. The task force is of the view that, village committees should be the more actively involved in dengue prevention activities. This committee must implement the action plan, under the technical guidance of the relevant Medical Officer of Health/ Public Health Inspector and with the assistance of respective Grama Niladaris (village admin officers) in the area. These committees are mostly headed by the Divisional Secretary and the chairperson of the local government authority (MoH, 2017). This process and the programmes are also heavily depended on the public health

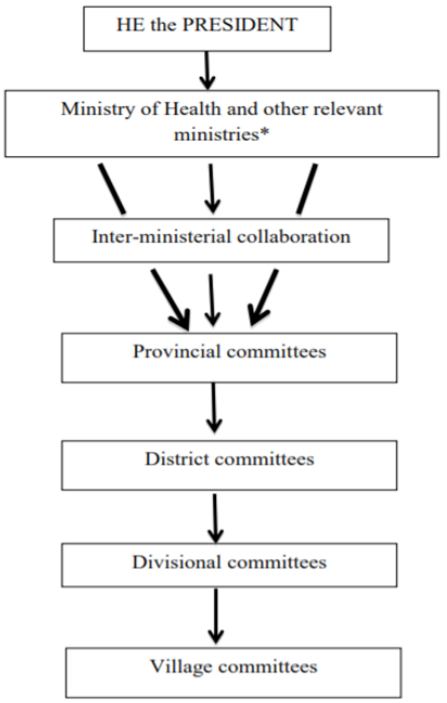

Figure 1. Structure of the presidential task force on dengue control

Source: (MoH, 2017)

authorities and involvement of other relevant stakeholders is very much needed.

Another potential at sub-national level (DSs level) is, involvement of a larger number of public officers at divisional secretariat level in areas such as finance, statistics, information gathering, development, public health, livelihood development, legal, police, child protection, probationary, social welfare, elderly caring, poverty alleviation etc., within the public administration system in Sri Lanka. This institution set up can be certainly elevated as an independent body with decision making powers and financial authority for different aspects of pandemic preparedness and response and also to develop case-based expert committees, propose strategies and work routines, to collect data for effective reporting (Amaratunga et al., 2020), and to proceed with necessary implementations without overly depending on top-level decision making. This body can act as a local or sub-national level agent for data management, emergency communication, contact tracing, relief activities, creating awareness, progress monitoring and post-pandemic coordination when required.

7. A MORE INVOLVED AND COMPROMISED APPROACH FOR PARTICIPATION OF STAKEHOLDERS IN PANDEMIC PREPAREDNESS AND RESPONSE

Lack of participation and collaboration of different stakeholders and inefficient coordination among the different sectors, is identified as a main drawback in pandemic response, in Sri Lanka even within the public health sector (Ranaweera et al., 2020). This is even very common in the national DRR framework. For instance, several departments and ministries such as DMC, Meteorology, Health, local government an provincial councils, Sri Lanka Army, Police, hospitals, National Water Supply and Drainage Board, public media, airports and Civil Aviation have been exclusively entrenched with the current DRR activities while certain potential sectors such as education, higher education including

universities, research institutes as well as social work and mental health programmes are less reflected (DMC, 2014). According to the DMC (2014), anticipated stakeholders for health hazards such as epidemics, communicable diseases, bird flu, AIDS, SARS, poisoning etc. and possible biological and other health hazards, are mentioned as the Ministry of Health, Epidemiology Unit, Department of Health Services, Medical Research Institute, and others as relevant. This explains that, identifying non-health sector stakeholders in the involvement of responding to biological hazards, is seriously misunderstood and inadequate.

Decentralised pandemic response body at sub-national level, can effectively be integrated and involved as a unit of operation for public health emergencies since it has enough potential to develop multi-stakeholder appraisal. Further, this can promote adequate and proportionate involvement of different stakeholders including public departments, universities, research institutions, volunteer agencies, NGOs, private sector organisations, sociologists, anthropologists, social workers, psychologists and volunteers at community level who are available and willing to cooperate at each sub-national level.

Many countries such as Canada, Singapore, and Korea, which have been effectively mitigating this challenging COVID-19 pandemic are better prepared in terms of pandemic response and, particularly regarding pandemic governance. One strong policy that these countries have been adopting in fighting many biological hazards, is the multi-stakeholder and multi-sectoral approach which has been developed based on the lessons learnt from the SARS epidemic. For example, networking scholar associations, universities and research institutions are empowered to be involved with detection and screening infectious diseases, real time data sharing with national and international agencies and collaborations and developing professional alliances to address specific technical, social and economic issues faced in the context of a pandemic (Jang & Choi, 2020; Kim & Ashihara, 2020; OECD, 2020). Further, many countries which have performed successfully and effectively responded to COVID-19 outbreaks are permitting the relevant pandemic and epidemic response bodies, to function very independently having minimal interference. Accordingly, many members who are involved with the relevant countries' pandemic and epidemic response bodies are completely released from their primary duties assigned in government offices, committees, departments, and other missions assigned by the CoGs. These tactical committees and governing bodies have been assigned to respond to the COVID-19 pandemic as independent bodies, without any political and other external interference (OECD, 2020).

8. CONCLUSION

There are several improvements to be done as discussed below to enhance the effectiveness of the existing pandemic preparedness and response framework in Sri Lanka. It is observed that even though the current DRR framework has certain strengths in advocating and implementing effective preparedness and response activities from national level to community level, the pandemic or epidemic governance is less integrated and inadequately incorporated. Therefore, a strong integration between the current DRR framework and biological hazards is required. Furthermore, many lessons can be learnt from countries which have successfully responded to the COVID-19 pandemic and other pathogens such as SARS, Ebola and H1N1 to enhance current DRR policies and practices in Sri Lanka. It is noted that, many countries which have satisfactorily administered the 'build back better' concept have adopted a multi-stakeholder and decentralised governing mechanism. Moreover, regulatory bodies that are established for pandemic response must be independent governing agencies without having any political or other external interferences or influences. All members of such regulatory bodies should not be permitted to be engaged in their primary duties, if they represent any state or non-state organisation, institution or department in order to utilise

their optimum potential and obtain the maximum commitment. Considering the above suggestions, pandemic response in Sri Lanka can be more decentralised to include the DS level within the existing DRR framework and promoted as 'cluster-based' or 'case-based' response approach, in line with national DRR protocols. Furthermore, the pandemic response needs to be more multi-stakeholder oriented, and a coordinated effort is needed to ensure a new paradigm of sustainable healthcare and professionally led process is adopted towards a smooth transition and a resilient public health system in Sri Lanka.

REFERENCES

Amaratunga, D., Fernando, N., Haigh, R., & Jayasinghe, N. (2020, 2020/12/01/). The COVID-19 outbreak in Sri Lanka: A synoptic analysis focusing on trends, impacts, risks and science-policy interaction processes. *Progress in Disaster Science, 8*, 100133. https://doi.org/https://doi.org/10.1016/j.pdisas.2020.100133

Briand, S., Mounts, A., & Chamberland, M. (2011, 2011/05/01/). Challenges of global surveillance during an influenza pandemic. *Public Health, 125*(5), 247-256. https://doi.org/https://doi.org/10.1016/j.puhe.2010.12.007

CBSL. (2020). *Economic and Social Statistics of Sri Lanka 2020, Statistics Department, Central Bank of Sri Lanka*. https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/statistics/otherpub/ess_2020_e1.pdf

CEDMHA. (2017). *Sri Lanka Disaster Management Reference Handbook, Center for Excellence in Disaster Management & Humanitarian Assistance (CEDMHA)*. https://reliefweb.int/report/sri-lanka/sri-lanka-disaster-management-reference-handbook-december-2017

Dissanayake, U. (2020). *Technocratic Populism and the Pandemic State: Performative Governance in Post-COVID Sri Lanka, Discussion paper, Centre for Policy Alternatives*.

DMC. (2014). *Sri Lanka National Disaster Management Plan 2013-2017, The Disaster Managment Centre, Colombo*.

Erandi, K. K. W. H., Mahasinghe, A. C., Perera, S. S. N., & Jayasinghe, S. (2020). Effectiveness of the Strategies Implemented in Sri Lanka for Controlling the COVID-19 Outbreak . *Journal of Applied Mathematics, 2020*, Article 2954519. https://doi.org/10.1155/2020/2954519

Georgalakis, J. (2020, 2020/04/01/). A disconnected policy network: The UK's response to the Sierra Leone Ebola epidemic. *Social Science & Medicine, 250*, 112851. https://doi.org/https://doi.org/10.1016/j.socscimed.2020.112851

Hettiarachchi, D., Noordeen, N., Gamakaranage, C., Somarathne, E. A. R. B. D., & Jayasinghe, S. (2020). Ethical Responses to the COVID-19 Pandemic—Lessons from Sri Lanka [Article]. *Asian Bioethics Review*. https://doi.org/10.1007/s41649-020-00153-z

Jang, I. C., & Choi, L. J. (2020). Staying connected during COVID-19: The social and communicative role of an ethnic online community of Chinese international students in South Korea [Article]. *Multilingua*. https://doi.org/10.1515/multi-2020-0097

Kim, J., & Ashihara, K. (2020). National disaster management system: COVID-19 case in Korea [Article]. *International Journal of Environmental Research and Public Health, 17*(18), 1-18, Article 6691. https://doi.org/10.3390/ijerph17186691

Ludvigsson, J. F. (2020, Dec). The first eight months of Sweden's COVID-19 strategy and the key actions and actors that were involved. *Acta Paediatr, 109*(12), 2459-2471. https://doi.org/10.1111/apa.15582

MoH. (2017). *INTENSIVE INTER SECTORAL PROGRAMME FOR THE PREVENTION AND CONTROL OF DENGUE, National Dengue Control Unit: Ministry of Health, Nutrition & Indigenous, Presidential Task Force on Dengue Control.* https://www.epid.gov.lk/web/images/pdf/DHF/Action_Plan/action_plan_for_dengue_prevention_english.pdf

MoH. (2020). *2019-nCoV Acute Respiratory Disease - Situation Report - 2020.02.07 – 10.00am, Epidemiology Unit, Ministry of Health: Sri Lanka.* https://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-07-02_10.pdf

MoH. (2021a). Coronavirus disease 2019 (COVID-19) - Situation Report – 08.02.2021–10 a.m. Epidemiology Unit, Ministry of Health, Sri Lanka. http://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-08-02_10_21.pdf

OECD. (2020). *Building Resilience to the Covid-19 Pandemic: The Role of Centres of Governments*. www.oecd/coronavirus

Ogie, R. I., & Perez, P. (2020, 2020/11/01/). Collaborative translation of emergency messages (Co-TEM): An Australian case study. *International Journal of Disaster Risk*

Reduction, 50, 101920. https://doi.org/https://doi.org/10.1016/j.ijdrr.2020.101920

Patabendige, M., Gamage, M. M., Weerasinghe, M., & Jayawardane, A. (2020). Psychological impact of the COVID-19 pandemic among pregnant women in Sri Lanka. *International Journal of Gynecology and Obstetrics, 151*(1), 150-153. https://doi.org/10.1002/ijgo.13335

Pereno, A., & Eriksson, D. (2020, 2020/09/01/). A multi-stakeholder perspective on sustainable healthcare: From 2030 onwards. *Futures, 122*, 102605. https://doi.org/https://doi.org/10.1016/j.futures.2020.102605

Quigley, M. C., Attanayake, J., King, A., & Prideaux, F. (2020, 2020/06/01). A multi-hazards earth science perspective on the COVID-19 pandemic: the potential for concurrent and cascading crises. *Environment Systems and Decisions, 40*(2), 199-215. https://doi.org/10.1007/s10669-020-09772-1

Ranaweera, P., Wickremasinghe, R., & Mendis, K. (2020). Preventing the re-establishment of malaria in Sri Lanka amidst the COVID-19 pandemic [Article]. *Malaria Journal, 19*(1), Article 386. https://doi.org/10.1186/s12936-020-03465-5

Sarkar, A., Liu, G., Jin, Y., Xie, Z., & Zheng, Z.-J. (2020). Public health preparedness and responses to the coronavirus disease 2019 (COVID-19) pandemic in South Asia: a situation and policy analysis. *Global health journal (Amsterdam, Netherlands), 4*(4), 121-132. https://doi.org/10.1016/j.glohj.2020.11.003

WHO. (2018). Managing epidemics: Key facts about major deadly diseases. https://www.who.int/emergencies/diseases/managing-epidemics-interactive.pdf?ua=1

WHO. (2020). Critical preparedness, readiness and response actions for COVID-19. https://www.who.int/publications/i/item/critical-preparedness-readiness-and-response-actions-for-covid-19

WHO. (2021a). *Covid-19 dashboard, 10/02/2021*. https://covid19.who.int/table

WHO. (2021b). COVID-19 Weekly Epidemiological Update. https://www.who.int/publications/m/item/weekly-epidemiological-update---5-january-2021

WHO. (2021c). *WHO Coronavirus Disease (COVID-19) Dashboard*. https://covid19.who.int/

Preparing, responding and re-opening: Lessons from the UK to emerge during the COVID-19 pandemic

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ABSTRACT

A year after the first human cases of Covid-19 were identified in late 2019, the global Covid-19 pandemic had already killed more than 2.25 million people and infected more than 103 million people. By late 2020, the disease caused by this novel coronavirus had resulted in devastating health, economic, social and environmental impacts on countries across the world. In attempting to reduce these impacts, governments have introduced a wide range of different measures and with varying levels of success. The novel coronavirus has hit Europe especially hard, and the UK has had one of the continent's worst Covid-19 outbreaks, recording among the highest Covid-19 deaths per million people. The UK Government has taken numerous measures to minimise the virus's impacts across three stages of the pandemic: preparedness, responding, and re-opening. This study evaluates the UK pandemic risk governance approach by examining the strengths, weaknesses and challenges across these three stages. The study is based on a systematic desk review of publications in the Science Direct, Emerald and Google Scholar databases. A literature review protocol was developed in carrying out the study. After applying inclusion and exclusion criteria, forty-six papers were selected from the three databases for the review. The analysis revealed several best practices within the UK pandemic risk governance system but also exposed shortcomings and challenges related to each of the preparedness, response and re-opening stages. Further analysis of this literature also revealed potential strategies to overcome these challenges. These included strengthening pandemic preparedness measures, strengthening social and economic support systems and assuring risk governance mechanisms. The study provides valuable insights on areas to be strengthened for future pandemic preparedness and response measures.

Key words: Covid-19, Pandemics, Risk governance, Preparedness, United Kingdom

1. INTRODUCTION

Covid-19 was first identified in Wuhan, China, in December 2019. The World Health Organisation (WHO) declared a public health emergency on the 30th of January and later declared a pandemic on the 11th of March 2020 (Schindler et al., 2020; Shaw et al., 2020). As of the first week of February 2021, across the world, there were more than 2.25 million deaths and more than 103 million infections attributed to Covid-19 (WHO, 2021). It has become evident that the virus is highly contagious, making the elderly and people with underlying health conditions more vulnerable (Shaw et al., 2020).

Covid-19 has had a significant impact on the health, economic, social and environmental sectors (Collins et al., 2020; Fu & Zhu, 2020; Leach et al., 2020; Oldekop et al., 2020). It is too early to understand the full extent of its

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economic impact. However, some estimates suggest that Covid-19 will have initiated the worst economic downturn since the 1930s. The World Bank suggests that as a result of Covid-19, the global economy is undergoing the most profound economic recession in history (World Bank, 2021a) and estimates that extreme poverty will increase from 88 million to 115 million people globally, the most significant increase during the last two decades (World Bank, 2021b).

Although it is too early to make full judgments about the effectiveness of different countries' preparedness and response, it is also apparent that it will be difficult to prevent, manage, and avoid new viruses in a globalised world. (Connolly, 2015; Oldekop et al., 2020). Countries have introduced different measures to reduce and stop the virus's spread within their territories (Flynn et al., 2020; Murphy et al., 2020; Shaw et al., 2020). For example, several East Asian countries, including China and South Korea, adopted an early containment strategy at the beginning of the pandemic and soon returned to normality after the first wave of infections. In contrast, the USA and many European countries introduced these measures later. This delay appears to have resulted in higher death rates and significant damages to these countries' health systems, economies and people (Ahmad, 2020; Schindler et al., 2020; Shaw et al., 2020). The situation in the Western world appears to challenge the pre-assumption that the global north has the strength and expertise to face any challenge (Oldekop et al., 2020), although the development of the vaccine within a short period partially offsets this perception.

Europe is one of the hardest-hit regions from the Covid-19 pandemic. Among European countries, the UK was badly affected by the pandemic, specifically the economic and health sectors (Flynn et al., 2020). According to the UK's Office for National Statistics, the country has recorded the largest economic contraction among the G7 countries in terms of Gross Domestic Product, (Dey-Chowdhury et al., 2021). The UK faced two waves of the Covid-19 pandemic during the spring of 2020 and the autumn and winter of 2020 and 2021. These two waves resulted in reporting an unprecedented level of excess mortality in the UK.

The excess mortalities are expressed as relative age-standardised mortality rates (rASMRs). By the end of June 2020, the UK reported the second-highest rASMR for people of all ages and the highest rASMR among people aged under 65years in Europe (Campbell & Ward, 2021). During the summer, most countries in the region recorded average mortality rates below five-year average mortality rates. The UK and its constituent countries, England, Scotland, Northern Ireland and Wales, showed similar weekly fluctuations but within the five-year average level (Campbell & Ward, 2021). Again, during the autumn, a sharp rise in mortality rates was reported from central and eastern European countries compared to western Europe. The rASMR for Poland was reported as 104.6%, the highest excess mortality rates reported during the autumn and early winter period. Nevertheless, several western European countries also showed a rise in excess deaths. Among these countries, Spain, France, the UK and Netherlands reported rASMRs between 24% to 28%. The UK's rASMR was 26.6% during November and December. Similar to this, all four constituent countries in the UK experienced a sharp rise in weekly rASMRs.

Since the beginning of the pandemic, the UK Government has taken several measures to control the spread of the virus and reduce its devastating effects (Bronka et al., 2020; Flynn et al., 2020). For example, following the WHO's warning, the UK Government published their four-phase coronavirus action plan on the 3rd of March 2020 (ONS, 2020; Scally et al., 2020). Nevertheless, the previously described rASMR for the UK, compared with other countries, suggests that there may have been some flaws in the UK's pandemic risk governance approach.

This paper presents the results of an initial study to evaluate the UK's pandemic risk governance approach during the preparedness, response and re-opening stages of the

COVID-19 pandemic. A series of research questions were identified to guide the study:

1. What are the policy and legislative background relevant to pandemic risk governance in the UK?

2. What actions have been taken during the pandemic preparedness, response and re-opening stages in the UK?

3. What are the best practices and challenges within the pandemic preparedness, response and re-opening stages in the UK?

4. What could be done to improve the UK's pandemic risk governance strategy?

2. METHODS

A systematic literature review was carried out to answer the research questions. According to Laufs and Waseem (2020), a systematic review comprises four different elements: identifying a research question, determining selection criteria and data sources, setting filtering measures, and synthesising and analysing the findings. Khankeh et al. (2019) presented a more systematic methodology for developing the literature review protocol, which this study has adopted.

Several databases were used for the study, including Emerald, Science Direct, Google Scholar and some websites directly linked to the UK Government and Covid-19. The databases were searched using pre-determined keywords based on the study scope and the research questions.

The keywords and the synonyms were searched in the following combinations within the titles and abstracts in the databases.

Emerald syntax

(Pandemic OR Covid-19) AND (Governance OR Risk Governance) AND (United Kingdom OR UK)

Science Direct syntax

(Pandemics OR Covid-19) AND (Governance OR Risk Governance) AND (Preparedness OR Pandemic preparedness) AND (United Kingdom OR UK)

Google Scholar

All in the title: the United Kingdom "Pandemic" OR "Covid 19" OR "Governance" OR "Risk governance" OR "United Kingdom" OR "UK"

Eligibility criteria were applied, covering the type of the study and based on inclusion and exclusion criteria. The study's inclusion criteria were studies that were written in English and published between 2010-2020. For Google Scholar, criteria were narrowed to include only those within 2020 due to the much larger volume of available papers. Only research papers that were accessible to the research team are included in this analysis. Studies that were not related to the study's scope and questions were excluded. Editorials, discussion papers and any papers not written in English were also removed.

After applying the inclusion and exclusion criteria, the articles selected for the study were exported to EndNote software. Duplications were found manually and removed from the EndNote library. Furthermore, some reference materials and legal documents were searched to answer the research question around the legal and policy background for pandemic risk governance in the UK. Accordingly, 53 documents were finally selected for the systematic literature review.

Analysis was based on the research questions and using thematic analysis. According to Braun and Clarke (2006), a thematic analysis is a valuable research tool for providing a rich and detailed account of data in studies. This method identifies, analyses and reports patterns among data gathered. Data obtained from the literature were classified into themes based on the pandemic stages. The themes used in the study are preparedness, response and re-opening and recovery.

3. FINDINGS

3.1. Policy and legislative background for epidemic/ pandemic risk governance

This section presents an overview of the applicable policy and legislative background for pandemic preparedness and response mechanisms in the UK while identifying gaps within the present legislative and policy environment.

Of the available legislation, the Civil Contingency Act (CCA) of 2004 is predominant since it governs the UK's overall disaster management system (GOV UK, 2004). One of the Act's strengths is that it identifies biological hazards as an emergency under Section 19 and 22. For example, provisions on coordinating the Regional Civil Contingency Committees and the Central Government during a pandemic are covered in the Act (Blick & Walker, 2020). The CCA also identifies the NHS, police and local authorities as front-line emergency responders working in partnerships for effective emergency response.

The UK Influenza Pandemic Preparedness Strategy (2011) is another essential legislative provision relevant to planning for and responding to an influenza pandemic. This strategy was further developed based on the lessons learned in the H1N1 (2009) influenza pandemic and the latest scientific evidence (Department of Health, 2011). Early detection and assessment, promotion of individual responsibilities, developing vaccinations, rolling out vaccinations among high-risk groups and provision of health and social care systems have all been emphasised in the strategy as actions during an influenza pandemic.

The Pandemic Influenza Response Plan (PIRP) was introduced in 2014 for preparing and responding to a pandemic situation in the UK. The plan set out the roles and responsibilities within 10 Public Health England (PHE) directorates during the five pandemic phases. This plan emphasises the necessity of all types of advisors. These include surveillance and epidemiological, specialist diagnostics, microbiology, statistics and modelling, clinical and infection control advice, communications, managing the national countermeasures, developing and validating new diagnostic tests, conducting research, and procuring vaccines (Public Health England, 2014a). However, the PIRP was not implemented as intended. For example, during Covid-19, scientific experts were limited to epidemiological experts without public health experts (Scally et al., 2020).

The Pandemic Influenza Strategic Framework (2014) complements the other legislation during an influenza pandemic. It guides various divisions/centres within PHE to update and develop their operational plans to minimise the potential impact of a future pandemic, minimise the potential impact of a pandemic on society and the economy, and maintain trust and confidence (Public Health England, 2014b). Another related legislation to pandemic risk governance in the UK is the Health and Social Care Influenza Pandemic Preparedness and Response (2012) (DH / HIP/ PIP, 2012). This legislation emphasises the necessity of reporting and collating surveillance data, contact tracing, swabbing and testing samples, and antivirals, in particular during a pandemic outbreak. Besides, the Emergency Preparedness, Resilience and Response Framework (EPPR) facilitates the performance of NHS funded organisations fulfilling the duties assigned by the CCA. The framework describes how the NHS and its related organisations are required to perform their duties in an emergency.

The Government introduced the latest Coronavirus Act (CA) 2020 on the 25th of March 2020 (GOV.UK, 2020c). Initially, the Act is valid for two years and will be renewed if necessary, depending on medical advice. The Act delegates additional powers to the Government to slow down the spread of the virus, reduce the resourcing and administrative burden on public bodies, and limit the impact of potential staffing shortages on public services delivery. The CA grants the Government emergency powers to restrict or suspend public gatherings, detain individuals suspected of being infected, and intervene or relax regulations in various sectors. The Act further

specifies all lock-down measures with respect to every industry in the economy. For example, the operation of ports and airports, educational institutions and childcare premises. Another significant provision included in the Act is death management in particular local areas.

Similarly, the CA allows provisions to cover the pandemic's economic impact and enables the Government to reimburse the cost of statutory sick pay for employees affected by Covid-19 (GOV.UK, 2020b; Marshall et al., 2020). However, some criticise the Government's effort to introduce new legislations instead of implementing the provisions specified in the existing legislation (Blick & Walker, 2020; Scally et al., 2020).

3.2. Pandemic preparedness measures introduced in the UK

Across the world, countries have introduced a range of pandemic preparedness measures. The most common appear to be risk assessment, early warning, provision of infrastructure facilities, scientific inputs for policymaking and selection of response measures (Horton, 2020; Mellish et al., 2020). This study uses these measures as a framework to evaluate the UK's pandemic preparedness measures.

3.2.1. Risk identification and risk assessment

Several risk assessments were undertaken in the UK for identifying emergencies. For example, the National Risk Assessment (NRA) assesses the most significant emergencies which the UK and its citizens could face over the next five years. The risks are classified into: accidents, natural events (hazards) and malicious attacks (threats) (GOV.UK, 2020a). Besides this, the Natural Hazard Partnership (NHP) provides authoritative information, research and analysis on natural hazards for developing effective policies, communications and services for civil contingencies, governments and the responder communities in the UK (MET, 2020). The partnership oversees and assesses natural hazards and potential natural hazards daily, and assesses the health implications that could result from these over the subsequent five days (Hemingway & Gunawan, 2018). Both the NRA and NHP identified the potential impact of the pandemic in the UK. In addition, some researchers highlighted the influenza outbreak in 2014/15 to illustrate the potential risk of a pandemic outbreak as the top health risk in the UK (Connolly, 2015).

Irrespective of these, several researchers highlighted some weaknesses related to Covid-19 risk assessment in the UK. For example, Scally et al. (2020) queried how the Government elected to downgrade the risk level from four to three during the initial stage of Covid-19 in the UK. The Government justified its decision as a strategy to handle inadequate infrastructures. Even though a medical director at the PHE asserted the high likeliness of the pandemic's widespread transmission, UK Government disregarded the risk (Colfer, 2020; Sibony, 2020). Also, Imperial College London estimated that the possible number of deaths due to Covid-19 would be 250,000, but the Government overlooked their assessment at the beginning (Collins et al., 2020).

In addition, the Exercise Cygnus report (2016) revealed that the UK's pandemic preparedness was weak and proposed several recommendations (Atkinson et al., 2020; Scally et al., 2020). However, little attempt was made to implement those recommendations (Horton, 2020). Despite this, the Government and the advisers demonstrated their confidence in pandemic preparedness (Scally et al., 2020). Another issue related to risk assessment was not sharing risk assessment data, which undermined efforts to understand the pandemic's potential impact (Atkinson et al., 2020).

3.2.2. Receiving and communicating early warning

Early warning (EW) and communication are vital in disaster preparedness as part of a range of non-pharmaceutical measures (Atkinson et al., 2020; Connolly, 2015; Dame Deirdre Hine, 2010). During the Covid-19 pandemic, the Government received EW from the WHO at the global level. These EWs

escalated the UK's response measures, for example, activation of the Scientific Advisory Group for Emergencies (SAGE) (Atkinson et al., 2020). Similarly, PHE experts and Imperial College London issued EW nationally while the European Early Warning and Response System (EWRS) provided EW regionally, before BREXIT (Rankin, 2020).

Timely and clear EW communication to health and social care staff and the public are essential (Atkinson et al., 2020). The Government's daily press briefings at the Prime Minister's office became a feature in the UK. At the meetings, the PM is supported by the Government Chief Scientific Advisor (GCSA) and the Chief Medical Officer (CMO), demonstrating that policies are supported by scientific evidence (Atkinson et al., 2020). In addition to daily briefings, a traffic light system was used for communicating EW to the public (Fearnley & Dixon, 2020).

Several experts claimed that the Government either downplayed the EW received or delayed EW communication to the public (Hunter, 2020; Scally et al., 2020). According to Lapsley (2020), with differentiated interest among the leadership, the Government ignored the pandemic's early warnings. For example, in the early stages, the Government appeared to be more focused on the Brexit deal than preparing for the pandemic. Another issue related to EW communication was clarity. Atkinson et al. (2020) suggest that EWs issued at the beginning of the pandemic were confused and unclear to healthcare personnel and the public. They also expressed concern at how frequently the EW messages changed, which undermined trust among the people.

3.2.3. Provision of infrastructure

The provision of infrastructure is a crucial preparedness measure during an emergency. During the Swine flu outbreak, the UK Government purchased the antiviral drug *Tamiflu* to cover 100 per cent of the population as soon as the WHO declared a pandemic (Bell et al., 2012; Connolly & Elliott, 2020). Similarly, during the Covid-19 outbreak, the Government built Nightingale Hospitals, established Lighthouse testing centres, introduced test and tracing systems, and made arrangements to purchase ventilator machines (Atkinson et al., 2020).

However, the use of additional hospital facilities was limited due to inadequate staff in the NHS service. The inadequacy of trained staff in the NHS system was highlighted as a challenge facing a future pandemic situation in the UK (Renn, 2020; Welby-Everard et al., 2020). According to Scally et al. (2020) and Mellish et al. (2020), trained staff's inadequacy and other limited resource availability, such as hospital beds, resulted from a continuous budget cut for the NHS (Collins et al., 2020; Hunter, 2020). Inadequate PPE was another example where limited infrastructure threatened the public health system in the UK. For example, though infectious disease experts recommended gowns as essential for carrying out testing and treating Covid-19 patients (Atkinson et al., 2020; Scally et al., 2020), the Government was late purchasing PPEs and ventilators (Hunter, 2020). Inadequate PPE exposed the NHS and social care staff and the patients to higher levels of risk (Atkinson et al., 2020; Scally et al., 2020; Welby-Everard et al., 2020). The situation resulted in attempts to speed up the supply of PPE, but procurement and delivery were found to be inefficient in overcoming the shortfall (Atkinson et al., 2020).

3.2.4. Use of scientific input into policymaking

Another emergency preparedness measure identified from the literature was the use of scientific advice to inform policymaking. According to Vallejo Jr and Ong (2020), the UK was the first to introduce scientific advice to the Government, Cabinet Departments and the Prime Minister. SAGE was established to coordinate with the Cabinet Office Briefing Room (COBR) for advising the cabinet. The committee is chaired by the Government Chief Scientific Advisor (GCSA). Scientific advice is vital when responding to pandemic outbreaks (Atkinson et al., 2020; Rajan et al., 2020; Sibony, 2020), and SAGE has been instrumental in this

capacity, providing scientific advice to the UK Government during Covid-19 (Atkinson et al., 2020; Rajan et al., 2020; Scally et al., 2020; Vallejo Jr & Ong, 2020).

Nevertheless, some criticise the scientific advice given by SAGE. For example, SAGE was reluctant to recommend immediate lock-down measures during the pandemic's early stages. It allowed businesses to operate as usual (Scally et al., 2020; Vallejo Jr & Ong, 2020). Another example was that the CMO did not show great interest in identifying every new case unless there was a significant regional variation in cases (Scally et al., 2020). The scientific advice was further criticised for not being transparent. Vallejo Jr and Ong (2020) highlighted that some early SAGE meetings were conducted behind closed doors during the early stages of the pandemic.

Walters, 2020 as cited in Lapsley (2020), expresses concern that the Government disbanded the Threats, Hazards, Resilience and Contingency Committee (THRCC), which was established to address any emergencies related to national security in the UK. Moreover, Chambers et al. (2012) identified a conflict of interest between scientific experts and political parties that created issues when deciding the best options. For example, the decision to wear a mask was an issue between the two groups. Further concern was the composition of the stakeholders represented in the scientific advisory groups to the UK government. The scientific advisory committees were dominated mainly by epidemiologists with minimal representation from public health experts and communities. Besides, some reforms introduced into the PHE affected independence. As a result, the CMO has not become a public health leader (Scally et al., 2020).

The Scientific Pandemic Influenza Group on Modelling (SPI-M) models the future of an epidemic outbreak and provides input into SAGE in the UK. According to Rajan et al. (2020) and Scally et al. (2020), the composition of SPI-M and SAGE were dominated by modellers and epidemiologists, and lacked public health experts, communicable disease experts, women, and ethnic minorities. The unbalanced stakeholder representation led to ignoring valuable inputs from key stakeholders in the community.

Communication plays a significant role in the preparedness stage. Specifically, clear communication between the scientific community and policymakers is essential. Nevertheless, according to Atkinson et al. (2020), scientific and technical advisers have sometimes been unable to communicate effectively to policymakers during the pandemic. As a result, politicians took several decisions without scientific evidence. For example, the ministers were interested in wearing masks, when the scientific advice was bit confined about giving their scientific opinion on the efficacy of wearing masks. By mid of April, however, the ministers announced the decision in favour of wearing masks, supported by scientific advice. This incident demonstrated where the advisers advise and minsters decide approach worked in the UK (Atkinson et al., 2020). Due to unclear communication between science and policy, policymakers could not accept the scientific community's advice. Lapsley (2020) suggests this was due to a lack of clarity. For example, as a consequence of this poor communication, the Government used their emergency powers to transfer elderly patients to care homes without testing for Covid-19. Atkinson et al. (2020) and Horton (2020) further criticised policymakers and the scientific community for not incorporating previous pandemic experience into the present pandemic situation.

3.2.5. Selection of the response strategy

Another preparedness strategy identified from the literature review is the selection of a response strategy. A correct response strategy is critical for dealing with a novel virus because little is known about its features, transmission pattern and speed (Sibony, 2020). At the beginning of the pandemic, the UK strategy relied on a herd immunity approach similar to the Swedish system (Colfer, 2020; Scally et al., 2020). The Government followed several

voluntary measures until the countrywide lock-down was announced on the 23rd of March 2020 (Colfer, 2020). Later, a containment phase was followed through contract tracing and antiviral treatments (Connolly & Elliott, 2020). When taking such decisions, sometimes trade-offs are common between economic and logistical constraints (Sibony, 2020).

However, several concerns have been expressed regarding the UK's response strategy. For example, this includes the decision to use the influenza response strategy to deal with a pandemic (Hunter, 2020) and the herd immunity approach Scally et al. (2020), which were widely deemed not to be suitable for dealing with a highly contagious and poorly understood virus.

3.3. Response measures

Countries adopted different response measures, for example, national or local level lock-down, self-quarantine, social distancing, and public health measures, to stop the spread of the virus (Flynn et al., 2020; Laufs & Waseem, 2020; Murphy et al., 2020; Shaw et al., 2020). Based on their origin, the response measures are classified into legislative, scientific, and socio-economic categories, as presented below.

3.3.1. Legislative responses

Similar to previous epidemics and pandemics, the UK Government introduced several legislative responses. These included a countrywide lock-down, school and university closures, restrictions on non-essential business and border control measures (Colfer, 2020; Fisayo & Tsukagoshi, 2020; Murphy et al., 2020).

Even though immediate responses are vital for slowing down the virus's spread (Atkinson et al., 2020), most response measures were introduced late (Hunter, 2020; Murphy et al., 2020). The delayed responses missed a considerable time, which could be used to prepare and prevent the virus (Atkinson et al., 2020; Colfer, 2020; Scally et al., 2020). However, the Government justified their late responses highlighting possible behavioural fatigue among people because of the lock-down decision (Hunter, 2020; Sibony, 2020). Some criticise the Government's responses as irresponsible. For example, the decision to discharge older patients from hospitals to care homes without testing led to a rise in the number of deaths among care home residents (Scally et al., 2020). Several others criticise the Government's decision to continue business as usual (Hunter, 2020; Lapsley, 2020). For example, Hunter (2020) queries the Government's decision to continue major sporting events in the UK, a time of peak virus spread in other parts of the world.

Several researchers identified limited political support as a challenge within legislative responses during the pandemic's early stage. For example, the National Security Council (NSC) was not convened at the beginning of the pandemic due to divergent political interests (Atkinson et al., 2020; Parker, 2020). Besides, several transparency issues were identified during the response stage. Lack of transparency and accountability has become a significant concern during the pandemic leading to a weakening of public trust (Atkinson et al., 2020). Another legislative issue identified by Colfer (2020) was that the devolved governments in the UK adopted divergent political judgements even when it appeared the threat to each devolved part of the UK was similar.

3.3.2. Scientific response

During a pandemic outbreak, legislative responses must be supported by scientific responses. For example, this may include conducting test and trace, conducting scientific research, and developing and approving vaccines (AlHinai, 2020; Lapsley, 2020). During the Swine Flu outbreak, the UK's health authorities influenced the decision to invest in Tamiflu (the antiviral medication) for its population's safety (Chambers et al., 2012; Connolly, 2015). Similarly, during the Covid-19 outbreak, the UK Government contributed to conducting novel pathogen research, collecting a large amount of data at an unprecedented

speed for developing the vaccines (Atkinson et al., 2020).

Nevertheless, several challenges were identified, irrespective of the strengths presented earlier. For example, several researchers considered the digital contact tracing system a waste of public funds. According to Lapsley (2020) and Collins et al. (2020), the digital test and tracing system was operated until the 14th of September 2020. The decision to suspend the use of the contact tracing app was due to civil rights legislations available in European countries. Scally et al. (2020) considered the test and tracing system in the UK as confused, overwhelmed and inaccessible to the public. Lapsley (2020) highlighted that most testing centres were also not convenient for public access.

Another weak scientific response was the selection of herd immunity. According to Hunter (2020), herd immunity was chosen rather than strengthening preparedness measures in the UK. Furthermore, several stakeholder related issues were identified within scientific responses. For example, similar to the Swine flu outbreak in the UK, during the Coivd-19 pandemic, there were limited inputs from local public health agencies, local authorities, or public health directors (Leach et al., 2020; MET, 2020). Another scientific response was expanding the hospital capacities by building Nightingale hospitals and buying ventilators in record time. Nevertheless, such measures were criticised due to poor efficiency and effectiveness. For example, Nightingale hospitals' use was undermined by limited human resources (Lapsley, 2020).

3.3.3. Socio-economical response

In addition to legislative and scientific responses, socio-economic responses are vital during an emergency because vulnerable communities have been disproportionately affected (Flynn et al., 2020; Renn, 2020). Due to socio-economic damages caused by the pandemic, a significant level of health inequalities also emerged (Fisayo & Tsukagoshi, 2020). Hence, more social support systems have been advocated as a way to prevent future crises. Covid-19 is a socially constructed risk in societies, and thus additional social measures are required for future pandemics. Within these socio-economic measures, access to health care facilities in the UK during the Covid-19 has been highlighted as remarkable compared to some other developed countries (Flynn et al., 2020; Hunter, 2020).

Similarly, the UK Government's generous financial package given during the Covid-19 outbreak also contributed significantly to most of the communities affected by the pandemic (Bronka et al., 2020; Flynn et al., 2020; Scally et al., 2020). On the 17th of March, the Exchequer's Chancellor introduced an extensive emergency package worth £330 billion. According to Colfer (2020), this is the most significant financial package given in the UK to the businesses sector since the 2008 financial crisis. Bronka et al. (2020) highlighted how these financial measures could support communities and business affected during the pandemic, reduce income inequalities, and reduce poverty by one per cent compared to the pre-pandemic situation.

Some weaknesses in the socio-economic response measures have also been highlighted. For example, Watts (2020) found that access to health services had been constrained by the digital divide, which limited some groups' access to digital technologies. The virus is also expected to worsen health inequalities through severe economic injury. The sectors that rely on low-paid staff – often women, young people and Black, Asian and Minority Ethnic (BAME) people, will take the longest to recover from the predicted deep economic recession (Fisayo & Tsukagoshi, 2020). Many ethnic minority communities suffered from high social deprivation irrespective of the Government financial support (Iob et al., 2020). Another primary concern was the emergence of violence, domestic abuse, self-harm, suicidal thoughts and high mental health issues during the pandemic (Iob et al., 2020).

3.4. Recovery and re-opening measures

The easing of lock-down in the UK shows a divergent approach across the devolved governments. For example, school re-opening took place on the 15th of June in England and the 29th of June in Wales. The schools in Scotland opened on the 11th of August, but for Northern Ireland it was September (Colfer, 2020). This demonstrates a divergent political judgement among leaders of the devolved governments, who appear to have assessed similar data but sometimes reached different conclusions.

Several researchers have identified the development of a novel vaccination as the way forward for re-opening the economy. For example, Salali and Uysal (2020) explained the necessity of developing the new vaccine and promoting people to be vaccinated for widespread immunity. Sherman et al. (2020) describe developing the vaccine and vaccination as the UK's primary recovery strategy.

As of 31st of January 2021, more than 8 million people have received the 1st dose, and more than 0.5 million people received the 2nd dose in the UK (NHS, 2021). However, some have expressed concerns that there would be public hesitancy to the vaccine, which could undermine the recovery and re-opening strategy in the UK (Salali & Uysal, 2020; Sherman et al., 2020).

3.5. Suggestions to strengthen pandemic risk governance in the UK

The review found a number of challenges and weaknesses across each of the three pandemic stages, but also revealed some recommendations that could help to strengthen pandemic risk governance in the UK.

Scally et al. (2020) suggest to integrate the communicable disease control measures into pandemic preparedness measures, linking local preparedness strategies into pandemic situations. For this purpose, a supportive government is necessary for securing the country's public health and well-being. For example, Atkinson et al. (2020) and Scally et al. (2020) suggest increasing public finance to public health in the UK, reversing the continuous financial cuts that have occurred over recent decades. Collins et al. (2020) also explained how such public finance could help expand the UK's health sector capacity for future emergencies. They stress that the short term-financial cuts to address economic deficits emerging from the pandemic must not be allowed sacrifice long-term resilience in the health sector. Provisioning more funding could address current limitations related to staff shortages, hospital beds, and a lack of senior experts in the public health system in the UK.

Similarly, Collins et al. (2020) further emphasised the necessity of introducing relevant institutional and regulatory changes for more sustainable practices in the country. For example, public money could be invested in resilience measures, which could avoid future crises. Mellish et al. (2020) suggested introducing policies to integrate market-oriented and national sovereignty to promote manufacturing and agriculture-based economies. Such policies are recommended to strengthen the weakened preparedness system for facing future crises in the UK. For example, these could help to address the issues related to the supply-chain system in the UK, which created the short supply of PPEs. This could be addressed by an industrial strategy that better considers pandemic and other crisis situations that may close borders and disrupt international supply chains.

Lapsley (2020) recommended developing the governance system through a responsive learning approach to avoid future mistakes. A balanced decision-making approach is vital for securing governance. For example, an equal representation of public health experts, epidemiologists, virologists, and politicians recommended for SAGE (Scally et al., 2020). Such expert committees should also be supported through scientific data towards evidence-based policymaking, as suggested by Chambers et al. (2012) and Collins et al. (2020). Fearnley and Dixon (2020) also highlighted the importance of equal participation of experts when developing early warnings for future emergencies. Governance can be further

assured by making policymakers accountable for policy outcomes instead of shifting their responsibilities to experts, as happened in the early stage of the pandemic in the UK. Scally et al. (2020) emphasised the necessity of policymakers to take correct, perhaps, unpopular policy decisions during a crisis. Connolly and Elliott (2020) and Lapsley (2020) explained the benefit of securing public policy accountability, which could avoid blame games.

Atkinson et al. (2020) and Collins et al. (2020) suggested clear, timely, accurate, and uniform guidance and communication to health and social care workers and the public for strengthening pandemic preparedness. Clear communication prevents information overload and confusion during an emergency. According to Collins et al. (2020), clear communication between policymakers and the public is essential for the long-term application of crisis management practices. Fearnley and Dixon (2020) suggest this is because early warnings are critical in preparedness for future pandemics and until a vaccine is found to greatly reduce the threat posed by a biological hazard.

An effective pandemic response requires speedy responses than delayed responses (Hunter, 2020; Mellish et al., 2020; Scally et al., 2020). Among such measures, strengthening rapid test and trace systems were encouraged to avoid future pandemic risks in the UK (Mellish et al., 2020; Scally et al., 2020). Scally et al. (2020) further elaborated on how local public health teams could be integrated into effective test and trace system within localities. In addition, a robust surveillance system could benefit from identifying and stopping the spread of the virus (Chambers et al., 2012). Thus, Collins et al. (2020) recommend the use of technology for surveillance systems.

Activation of necessary agencies during emergencies was also suggested. For example, Parker (2020) propose the activation of the National Security Council, which was established to oversee national security threats and act upon an emergency. Strong political support is essential to activate the NSC and to avoid an intelligence failure in the country. Another necessary agency to be strengthened is the Police Department. During pandemics, public unrest and conflicts between police and public are to be expected. Laufs and Waseem (2020) suggest more studies need to be undertaken for future pandemic situations to decide the type of policing organisations to be established for future emergencies. They also emphasise a need to allocate more resources to such institutions in order to maintain law and order in a pandemic situation.

Pandemics also have severe short- and long-term socio-economic impacts on communities. Thus, several researchers suggested introducing community-based measures to avoid any harmful consequences of the pandemic, especially on minority and underrepresented groups in society. For example, Fisayo and Tsukagoshi (2020) suggested that opening libraries and community centres will heal the damages left by the pandemic. Besides this, a greater understanding is necessary to reflect the impact of the pandemic on different communities. Accordingly, Iob et al. (2020) suggested introducing new ways of identifying and evaluating individuals at risk of abuse and self-harm to help to allocate additional support to people at risk. Flynn et al. (2020) emphasised that such measures should be taken before easing lock-down and social distancing measures. Another suggestion was to reflect on current societal disruptions or changes in lifestyles during the pandemic. The pandemic has made significant changes to people's daily lives, such as working from home and using online services. Examining such changes and what practices would be good to continue or change for the best social interactions in the future, needs to be determined (Collins et al., 2020). Shaw et al. (2020) and Watts (2020) suggested providing long-term technical support to acquire digital know-how, equipment and access to the internet to avoid health inequalities caused by the pandemic.

Similarly, long-term economic support is vital to reduce the impact created by the pandemic because the present support schemes are available for a limited time

(Bronka et al., 2020). Long term support should also be extended to industries, like the hospitality and travel sectors. Collins et al. (2020) explained how a global emergency fund could be established to provide immediate compensation to heavily affected sectors in the economy.

Another recommendation was to rebuild lost public trust in the government. For that, Scally et al. (2020) suggested sharing science-based information and using scientific data when communicating with the public. Similarly, it is essential to assure multi-stakeholders in decision-making, especially those who have been left behind in decision-making, to reflect their issues into policymaking (Rajan et al., 2020).

In addition to practising social measures, pharmaceutical interventions are vital for recovering and re-opening economies after the pandemic. Vaccination for the virus is a critical strategy for re-opening economies but can be undermined if there is public mistrust in the vaccine programme. In order to counter such threats, Chambers et al. (2012) stress the need to raise awareness and education among all communities as this mistrust is likely to have been pre-determined by prior experiences. Further, wider communication of scientific evidence, emphasising the benefit of vaccination, has also been suggested. For example, Salali and Uysal (2020) and Sherman et al. (2020) suggest using the media to explain the significance of the vaccine reducing the spread of the virus.

In addition to pharmaceutical interventions, social measures have also been identified to improve the effectiveness of returning strategies. Scally et al. (2020) propose an explicit population strategy based on case finding, testing, contact tracing, and isolation for the four devolved governments to inform and justify how the lock-down can be safely relaxed.

4. CONCLUSIONS

Figure 1 summarises the measures, strengths and weaknesses of the UK's pandemic risk governance approach across the three stages and sets out some key recommendations to inform future pandemic governance efforts.

A pandemic alone does not paralyse a country, but the pandemic risk governance system can do if it is not effective. This study has attempted to evaluate the UK pandemic risk governance system during the Covid-19 pandemic. Similar to other countries, the UK government has introduced several measures during the preparedness, response and re-opening stages. Key success factors identified are contributing to vaccine research, early approval of the vaccine, vaccine roll-out, and the government generous financial package. In addition to strengths, several weaknesses were found related to weak preparedness measures, delayed and transparency-related issues in the governance system and some gaps in the socio-economic response mechanisms.

Even though it is too early for a complete evaluation, this initial analysis provides some valuable input for policymakers and researchers. The review has revealed a range of approaches that could be adopted to strengthen UK governance and preparedness for future pandemic threats. These include strengthening preparedness measures through an effective test and trace system, investing more in public health and raising awareness among authorities and communities. The review also revealed a need to improve risk governance, especially to enable transparent and accountable policymaking with the support of relevant stakeholders, to strengthen evidence-based policymaking, and to assign clear roles and responsibilities among stakeholders. Strengthening short-term and long-term socio-economic support mechanisms was also suggested to reduce the socio-economic damages caused by the pandemic.

As the recovery continues, further studies will be necessary, especially to collect and analyse ground-level data that can be used to

Figure 1. Summary of the UK pandemic risk governance during preparedness, response and recovery stages

PREPAREDNESS	RESPONSE	RECOVERY
MEASURES		
Risk assessments by NRA, NHP & experts EW communication using traffic light system Developed additional hospitals & ventilators Activate SAGE Choice of herd immunity approach	Country wide lock-down Introduced test & trace system Conduct scientific research Continue health care facilities Introduced financial package	Easing of lock-down Contribute to vaccine development Vaccination rollout
STRENGTHS		
Sound legal & policy background Capacity to conduct risk assessment Access to EW systems Financial stability to invest in emergencies Scientific expertise	Contributing to novel research Developing & rapid approval of vaccine Provision of free health care Government generous financial package	Early approval of vaccine High vaccination rate
WEAKNESSES		
Risk assessments-disregarded/ downgraded EW communication-delayed & unclear Long-term resource constraint- PHS Science-policy conflict Transparent, accountability & stakeholder issues in scientific advice Inappropriate strategy selection	Delayed lock-down Divergent & limited political support Ineffective contact tracing system Waste of public funds on hospitals/PPE Emergence of health inequalities due to digital divide	Possible public hesitancy to vaccination Divergent political decisions across DGs
RECOMMENDATIONS		
Link local preparedness with pandemics Strengthen public health systems Introduce institutional/ regulatory systems to support sustainable practices - resilience Strengthen governance system with multi-stakeholders, evidenced based policies, accountability & transparency Clear, accurate & timely EW communication	Speedy response Expand test & trace strategy with local public health teams Activate necessary agencies More community support systems Promote research on pandemic impact Long term financial/ social support Rebuild lost public trust on government	Raise awareness on vaccination through media & scientific experts Explicit population strategy to support lock-down easing

explore the impact of the pandemic on different sectors. There will also be a need for more comparative studies to examine how different governance approaches across the world have been able to prepare for and mitigate the threat posed by COVID-19.

ACKNOWLEDGEMENT

This project is funded by the UK Research and Innovation through the UK Government's Global Challenges Research Fund (GCRF) and the Newton Fund [grant number EP/V026038/1]. UK Research and Innovation accept no liability, financial or otherwise, for expenditure or liability arising from the research funded by the grant, except as set out in the Terms and Conditions or otherwise agreed in writing.

REFERENCES

Ahmad, E. (2020). Multilevel responses to risks, shocks and pandemics: lessons from the evolving Chinese governance model. *Journal of Chinese Governance*, 1-29.

AlHinai, Y. S. (2020). Disaster management digitally transformed: Exploring the impact and key determinants from the UK national disaster management experience. *International journal of disaster risk reduction*, *51*, 101851.

Atkinson, P., Gobat, N., Lant, S., Mableson, H., Pilbeam, C., Solomon, T., Tonkin-Crine, S., & Sheard, S. (2020). Understanding the policy dynamics of COVID-19 in the UK: Early

findings from interviews with policy makers and health care professionals. *Social Science & Medicine*, *266*, 113423.

Bell, M., Warren, A., & Budd, L. (2012). Scales of governance: the role of surveillance in facilitating new diplomacy during the 2009–2010 H1N1 pandemic. *Health & place*, *18*(6), 1404-1411.

Blick, A., & Walker, C. (2020). Why Did Government Not Use the Civil Contingencies Act? *The Law Society Gazette*.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Bronka, P., Collado, D., & Richiardi, M. (2020). *The Covid-19 crisis response helps the poor: The distributional and budgetary consequences of the UK lock-down*.

Campbell, A., & Ward, S. (2021, 19 03 2021). *Comparisons of all-cause mortality between European countries and regions: 2020*. Office for National Statistics. Retrieved 22 03 2021 from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/articles/comparisonsofallcausemortalitybetweeneuropeancountriesandregions/2020

Chambers, J., Barker, K., & Rouse, A. (2012). Reflections on the UK's approach to the 2009 swine flu pandemic: conflicts between national government and the local management of the public health response. *Health & place*, *18*(4), 737-745.

Colfer, B. (2020). Herd-immunity across intangible borders: Public policy responses to COVID-19 in Ireland and the UK. *European Policy Analysis*, *6*(2), 203-225.

Collins, A., Florin, M.-V., & Renn, O. (2020). COVID-19 risk governance: drivers, responses and lessons to be learned. *Journal of Risk Research*, 1-10.

Connolly, J. (2015). The "wicked problems" of governing UK health security disaster prevention. *Disaster Prevention and Management*.

Connolly, J., & Elliott, D. (2020). British Crisis Management in a European and Regional Context. In *Oxford Research Encyclopedia of Politics*.

Dame Deirdre Hine. (2010). *The 2009 Influenza Pandemic: An independent review of the UK response to the 2009 influenza pandemic* C. Office. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/61252/the2009influenzapandemic-review.pdf

Department of Health. (2011). *UK Influenza Pandemic Preparedness Strategy 2011*. D. o. Health.

Dey-Chowdhury, S., McAuley, N., & Walton, A. (2021). *International comparisons of GDP during the coronavirus (COVID-19) pandemic* Office for National Statistics Retrieved 22 03 2021 from https://www.ons.gov.uk/economy/grossdomesticproductgdp/articles/internationalcomparisonsofgdpduringthecoronaviruscovid19pandemic/2021-02-01

DH / HIP/ PIP. (2012). *Health and Social Care Influenza Pandemic Preparedness and Response*. D. o. Health. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/213696/dh_133656.pdf

Fearnley, C. J., & Dixon, D. (2020). Early Warning Systems for Pandemics: Lessons Learned from Natural Hazards. *International journal of disaster risk reduction*.

Fisayo, T., & Tsukagoshi, S. (2020). Three waves of the COVID-19 pandemic. *Postgraduate Medical Journal*.

Flynn, D., Moloney, E., Bhattarai, N., Scott, J., Breckons, M., Avery, L., & Moy, N. (2020). COVID-19 pandemic in the United Kingdom. *Health Policy and Technology*, *9*(4), 673-691.

Fu, K.-w., & Zhu, Y. (2020). Did the world overlook the media's early warning of COVID-19? *Journal of Risk Research*, 1-5.

Civil Contingencies Act 2004, (2004).

GOV.UK. (2020a). The Government UK. Retrieved 20 July 2020 from https://www.gov.uk/government

GOV.UK. (2020b). *Coronavirus (COvid-19) in the UK- UK Summary*. Government of the UK. Retrieved 06 07 2020 from https://coronavirus.data.gov.uk/

GOV.UK. (2020c). *Guidance Coronavirus Act 2020: Status Table*. Department of Health and Social Care Retrieved 14 08 2020 from https://www.gov.uk/government/publications/coronavirus-act-2020-status/coronavirus-act-2020-status-table

Hemingway, R., & Gunawan, O. (2018). The Natural Hazards Partnership: A public-sector collaboration across the UK for natural hazard disaster risk reduction. *International journal of disaster risk reduction*, *27*, 499-511.

Horton, R. (2020). *The COVID-19 Catastrophe: What's Gone Wrong and How to Stop It Happening Again*. John Wiley & Sons.

Hunter, D. J. (2020). Covid-19 and the stiff upper lip—The pandemic response in the United

Kingdom. *New England Journal of Medicine*, *382*(16), e31.

Iob, E., Steptoe, A., & Fancourt, D. (2020). Abuse, self-harm and suicidal ideation in the UK during the COVID-19 pandemic. *The British Journal of Psychiatry*, *217*(4), 543-546.

Khankeh, H. R., Hosseini, S. H., Farrokhi, M., Hosseini, M. A., & Amanat, N. (2019). Early warning system models and components in emergency and disaster: a systematic literature review protocol. *Systematic reviews*, *8*(1), 1-4.

Lapsley, I. (2020). An uncertain, erratic story: the pandemic in the UK. *Journal of Accounting & Organizational Change*.

Laufs, J., & Waseem, Z. (2020). Policing in pandemics: A systematic review and best practices for police response to COVID-19. *International journal of disaster risk reduction*, 101812.

Leach, M., MacGregor, H., Scoones, I., & Wilkinson, A. (2020). Post-pandemic transformations: How and why COVID-19 requires us to rethink development. *World development*, 105233.

Marshall, J., Nice, A., Haddon, C., & Hogarth, R. (2020). *Coronavirus Act 2020*. Institute for Government Retrieved 14 08 2020 from https://www.instituteforgovernment.org.uk/explainers/coronavirus-act

Mellish, T. I., Luzmore, N. J., & Shahbaz, A. A. (2020). Why were the UK and USA unprepared for the COVID-19 pandemic? The systemic weaknesses of neoliberalism: a comparison between the UK, USA, Germany, and South Korea. *Journal of Global Faultlines*, *7*(1), 9-45.

MET. (2020). *Natural Hazards Partnership*. Met Office Retrieved 15 08 2020 from https://www.metoffice.gov.uk/services/government/environmental-hazard-resilience/natural-hazards-partnership

Murphy, M. M., Jeyaseelan, S. M., Howitt, C., Greaves, N., Harewood, H., Quimby, K. R., Sobers, N., Landis, R. C., Rocke, K., & Hambleton, I. R. (2020). COVID-19 containment in the Caribbean: the experience of Small Island Developing States. *medRxiv*.

NHS. (2021). *COVID-19 Vaccinations By Region of Residence*. NHS, England https://www.england.nhs.uk/statistics/statistical-work-areas/covid-19-vaccinations/covid-19-vaccinations-archive/

Oldekop, J. A., Horner, R., Hulme, D., Adhikari, R., Agarwal, B., Alford, M., Bakewell, O., Banks, N., Barrientos, S., & Bastia, T. (2020). COVID-19 and the case for global development. *World development*, *134*, 105044.

ONS. (2020). *Deaths involving COVID-19, England and Wales: deaths occurring in April 2020: Number of deaths registered each month in England and Wales, including deaths involving the coronavirus (COVID-19), by age, sex and region.* Office for National Statistics Retrieved 28 05 2020 from https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsinvolvingcovid19englandandwales/deathsoccurringinapril2020

Parker, C. G. (2020). The UK national security council and misuse of intelligence by policy makers: reducing the risk? *Intelligence and National Security*, 1-17.

Public Health England. (2014a). *Pandemic Influenza Response Plan2014*. P. H. England.

Public Health England. (2014b). *Pandemic Influenza Styrategic Framework-2014*. (2014256). London: Public Health England Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/344696/PI_Strategic_Framework_13_Aug.pdf

Rajan, D., Koch, K., Rohrer, K., Bajnoczki, C., Socha, A., Voss, M., Nicod, M., Ridde, V., & Koonin, J. (2020). Governance of the Covid-19 response: a call for more inclusive and transparent decision-making. *BMJ global health*, *5*(5), e002655.

Rankin, J. (2020). *UK seeks access to EU health cooperation in light of coronavirus* The Guardian. Retrieved 20 05 2020 from https://www.theguardian.com/politics/2020/may/02/uk-seeks-access-to-eu-health-cooperation-in-light-of-coronavirus

Renn, O. (2020). The Call for Sustainable and Resilient Policies in the COVID-19 Crisis: How Can They Be Interpreted and Implemented? *Sustainability*, *12*(16), 6466.

Salali, G. D., & Uysal, M. S. (2020). COVID-19 vaccine hesitancy is associated with beliefs on the origin of the novel coronavirus in the UK and Turkey. *Psychological medicine*, 1-3.

Scally, G., Jacobson, B., & Abbasi, K. (2020). The UK's public health response to covid-19. In: British Medical Journal Publishing Group.

Schindler, S., Jepson, N., & Cui, W. (2020). Covid-19, China and the future of global development. *Research in Globalization*, *2*, 100020.

Shaw, R., Kim, Y.-k., & Hua, J. (2020). Governance, technology and citizen behavior in pandemic: Lessons from COVID-19 in East Asia. *Progress in Disaster Science*, 100090.

Sherman, S. M., Smith, L. E., Sim, J., Amlôt, R., Cutts, M., Dasch, H., Rubin, G. J., & Sevdalis, N.

(2020). COVID-19 vaccination intention in the UK: results from the COVID-19 vaccination acceptability study (CoVAccS), a nationally representative cross-sectional survey. *Human vaccines & immunotherapeutics*, 1-10.

Sibony, A.-L. (2020). The UK COVID-19 response: A behavioural irony? *European Journal of Risk Regulation*, *11*(2), 350-357.

Vallejo Jr, B. M., & Ong, R. A. C. (2020). Policy responses and government science advice for the COVID 19 pandemic in the Philippines: January to April 2020. *Progress in Disaster Science*, *7*, 100115.

Watts, G. (2020). COVID-19 and the digital divide in the UK. *The Lancet Digital Health*, *2*(8), e395-e396.

Welby-Everard, P., Quantick, O., & Green, A. (2020). Emergency preparedness, resilience and response to a biological outbreak. *BMJ military health*, *166*(1), 37-41.

WHO. (2021, 30 06 2020). *Coronavirus disease (COVID-19) pandemic*. World Health Organization. Retrieved 12 01 2021 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019

World Bank. (2021a). *Global Economic Prospects* (A World Bank Group Flagship Report Issue.

World Bank. (2021b). *Updated estimates of the impact of COVID-19 on global poverty: Looking back at 2020 and the outlook for 2021*. The World Bank. Retrieved 31 03 2021 from https://blogs.worldbank.org/opendata/updated-estimates-impact-covid-19-global-poverty-looking-back-2020-and-outlook-2021

COVID-19 nexus with food security and sustainable growth: Impacts, implications and road to resilience in Sri Lanka

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ABSTRACT

Covid-19 pandemic, one of the most significant humanitarian and development setbacks faced by humankind in the known history, imposes immeasurable risks to the progress of sustainable development and human wellbeing. It is a health crisis that went beyond anyone's control, leading to a global pandemic, but on the other end, it is an economic catastrophe that might takes years, if not decades, for a full recovery. Impacts vary from region to region, country to country and district to district, depending on how resilient, lean, agile the systems are. However, impacts are undoubtedly immense. Developed, developing, and least developed countries are battling to regain social, cultural and economic progress. Due to the pandemic, Sustainable Development Goals, commonly known as SDGs, the global blueprint with clearly set development targets to be achieved by 2030, has faced enormous strain as never before. Among 17 goals of the SDGs, Goal 1: No Poverty, Goal 2: Zero Hunger, Goal 03: Good Health and Well-being, Goal 4: Quality Education, and Goal 8: Decent Work and Economic Growth have been pushed back by the pandemic. While the pandemic has significant impacts on all the goals and targets, this chapter specifically discusses the impacts of Covid-19 on goals 1 and 2 and their overall impacts on food security and sustainable growth, with particular emphasis on Sri Lanka. The chapter also discusses potential recovery options to regain the path to SDG, prosperity and splendour in the island nation.

Key words: Sustainable development goals, Covid-19, Recovery, Resilient, Food security

1. COVID 19 PANDEMIC IN SRI LANKA

Covid-19, a zoonotic disease that handcuffed the whole world, is caused by Severe Acute Respiratory Syndrome Coronavirus 2, commonly known as SARS-CoV-2. The disease was first detected and identified in December 2019 in the city of Wuhan in Hubei province of the People's Republic of China (Santos-Sanchez & Salas-Coronado, 2020). As of 12 May 2021, according to the World Health Organization (WHO), confirmed cases of COVID-29 are 159,319,384, while 3,311,780 deaths have been reported globally (WHO, 2021a). The pandemic is not yet over. As of 12 May 2021, Sri Lanka has reported 131,098 confirmed cases of COVID-19 with 850 deaths (WHO, 2021a). With robust contact tracing and surveillance in place, Sri Lanka detected its first local case of COVID-19 on 11 March 2020 (Ediriweera et al., 2020). The first wave of COVID-19 in Sri Lanka resulted in swift and urgent actions by the government, public health authorities, and the general public with lockdown and restricted movements to control the spread of the disease. While effective disease control measures were in place, their impacts on the economy, trade, tourism, education, livelihoods and food security, among others,

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were significant. According to the world bank, Sri Lanka economy contracted by 3.6 per cent in 2020, which is the lowest growth on record (World Bank, 2021a). Global demand for the textile industry impacted drastically, reducing the trade and jobs market. Uncertainty on the investment was very high as the pandemic continued to diminish the investors' confidence and interests. Due to the pandemic, jobs lost and earnings reduced, impacting livelihoods and food security.

Sri Lanka was praised for its successful control of the first wave of the pandemic, with about 3,000 confirmed cases and 11 deaths by the end of September 2020. However, the second wave was much wider, with sharp spikes emerging across the country with 43,000 infections and 204 deaths towards the end of 2020 (Weerakoon, 2021) and almost double this number by the end of February 2021. The approach to managing the second and third waves is different to that of the first wave, and the country did not go through country-wide lockdown as it may affect the production, supply and value chain, livelihoods, food security, unemployment and the overall economic performance, which was already in the declining path. The growth rate could be less than what is reported as 2.3% in 2019. As Covid-19 has evidently impacted the progress of achieving sustainable growth, the next two sections of the chapter discuss about the Sustainable Development Goals and the economic footprint in general and in particular to the context of Sri Lanka.

2. SUSTAINABLE DEVELOPMENT GOALS (SDGS)

Sustainable Development Goals, commonly known as SDGs, defines the 2030 development agenda and its targets. It calls upon all member countries to enhance prosperity while protecting the planet (UN, 2021). This global blueprint is being implemented to transform the development discourse while keeping sustainability at the core. It supports an integrated approach for ending poverty, economic growth and addressing other social needs such as education, health, job opportunities, climate change, and environmental protection. Seventeen goals of the SDG are presented in Figure 1.

The SDG goal 1, "No Poverty", aims in ending extreme poverty for all people in all its forms everywhere by 2030. It also aims to ensure nationally appropriate social protection systems, the poor and vulnerable have equal rights to economic resources and reduce their exposure and vulnerability to climate-related extreme events and disasters. It also focuses on resource mobilization and

Figure 1. UN Sustainable Development Goals: Source (UN, 2021)

creating sound policy frameworks at the national, regional and international levels. Goal 2, "Zero Hunger", aims to end hunger and ensure access to safe, sufficient and nutritious food by all people, in particular poor and vulnerable people, throughout the year. It also focuses on ending malnutrition, increasing agricultural productivity and income of small-scale food producers, ensuring sustainable food production systems through resilient agricultural practices. Goal 3 focuses on ensuring healthy lives and promote wellbeing for all ages. Goal 4 aims at inclusive, equitable and quality education and promoting lifelong learning opportunities for all. Goal 8 focuses on promoting inclusive and sustainable economic growth, full and productive employment and decent work for all. Goal 12 aims at ensuring sustainable consumption and production patterns, while goal 13 focuses on urgent action to combat climate change and its impacts, including climate-related hazards and disasters. All other goals are also vital instruments to pave the path for sustainable development, achieving lasting peace, economic growth and ecosystem resilience.

2.1. Sustainable Development Goals and Sri Lanka

After ending the three-decade-long internal conflict, Sri Lanka was on its path to a sustainable and more resilient society before Covid-19 struck. Having set high standards in the human development index, Sri Lanka was able to keep the unemployment rate below 5 per cent, a high literacy rate of 98.7 per cent and life expectancy over 75 years (UNESCAP, 2019). According to UNESCAP, some of the critical challenges of achieving SDGs in Sri Lanka were improving the quality and relevance of education, providing affordable treatments and care facilities for the ageing population and fighting climate change and disasters which requires further policy support and financial resources while strengthening existing partnerships and forming new ones. One of the key milestones in achieving SDGs in Sri Lanka is the enactment of the "SRI LANKA SUSTAINABLE DEVELOPMENT ACT, No. 19 OF 2017," which was certified on 03 October 2017. The Act provides the legal framework to implement the SDGs and the establishment of the Sustainable Development Council to formulate national policies, guidelines and promote institutional and policy coherence (UNESCAP, 2019). Financing SDG implementation and improving investment efficiency in key sectors such as Education, Healthcare, Agriculture, Climate Resilience and Gender Equality remained priorities before the Covid-19 pandemic. Furthermore, engaging through multi-sectoral partnerships, including the private sector, and enhancing regional cooperation within the South Asian economy can bring Sri Lanka to new heights in its SDGs endeavour. As the country is just nine years away from the 2030 milestone of achieving Sustainable Development Goals, sound macroeconomic and fiscal policies supported by measured approaches must be followed if the goals to be a reality. Among 17 goals of the SDGs, Goal 1: No Poverty, Goal 2: Zero Hunger, Goal 03: Good Health and Well-being, Goal 4: Quality Education, Goal 8: Decent Work and Economic Growth have been challenged as never before due to the recession caused by the pandemic. Therefore, the next section of the chapter discusses specific Covid-19 impacts on the progress of achieving SDGs.

2.2. COVID-19 Impacts on Sustainable Development Goals

Although countries had spent one-third of the 2030 agenda timeframe before Covid-19 struck the world, they were not on track to achieve set targets by 2030. It was recognized that the speed and progress were not up to the mark; therefore, world leaders renewed their commitments during the SDG summit held in September 2019, pledged to achieve transformational progress by 2030. This decade from 2020-2030 was recognized as the decade of actions to achieve SDGs; however, Covid-19 has devasting impacts on all 17 goals of SDGs and threatening to derail the progress made in multiple areas (UN, 2020). Impacts are not uniform across countries, sectors and communities. The poorest and most vulnerable countries have impacted disproportionately

by the pandemic. According to the United Nations Development Program (UNDP), SDGs progress will be adversely impacted, leaving more than 1 billion people living in extreme poverty by 2030 (UNDP, 2020). It is evident that continued Covid-19 spread will delay the recovery process.

While Covid-19 has impacted all the goals, Goal 1: No Poverty, Goal 2: Zero Hunger, Goal 3: Good Health and Wellbeing, and Goal 4: Quality Education were the most affected goals. Global poverty has escalated as Covid-19 has hit the poorest most and widen inequalities. Half of the global workforce, 1.6 billion workers, are in the informal sector, and they were pushed towards unemployment or underemployment resulting in 60-80 per cent income lost due to Covid-19 (UN, 2020). Loss of livelihoods will immensely contribute to poverty, keeping countries away from their reach in the SDG 1.

On the other hand, food production, supply chain, and prices have been affected due to Covid-19. Impacts on food availability, access, utilization, and stability will keep countries away from SDG 2. Health care systems are already over-stretched globally, impacting the SDG 3. Remote learning remains out of reach for more than 500 million students globally, resulting in a substantial setback to the progress of SDG 4. All in all, SDGs have gone beyond our reach as economic recovery is yet to be seen. As Covid-19 has caused substantial impacts on SDG goals related to food security, the next section of the chapter discusses about the covid impacts on the food security sector with special emphasis on Sri Lanka.

3. COVID-19 IMPACTS ON THE FOOD SECURITY SECTOR

Covid-19 is not only having health impacts but also severe economic impacts across the world. Impacts on the food and agriculture sector, among others, are significant. Affected countries had to rethink their existing and future food and agriculture policies to ensure food availability and affordability to all (Ma et al., 2021). Economic impacts, including food insecurity, will be much more challenging than the disease itself for the poor and developing countries (WFP, 2020a). Food insecurity was already on the rise before Covid-19 struck the world (UN, 2020). Six hundred ninety million people were unable to meet their nutritional requirements in 2019, 60 million higher than in 2014. Furthermore, more than 2 billion people suffered from moderate or severe food insecurity in 2019. It had gone up from 22.4% in 2014 to 25.9% of the global population in 2019. According to the world bank, chronic and acute hunger was on the rise due to conflicts, natural hazards, climate change, pests etc., even before covid-19 struck the world. Covid-19 has led to severe food insecurity globally across all countries, and it will continue in 2021 and 2022 (World Bank, 2021b). Due to Covid-19, global food prices have risen by 38%, causing severe strain on food access, especially by poor and vulnerable communities in developing countries. Increased retail prices and loss of income have led to a compromise in quality and quantity of food consumption by covid-19 hit communities in lower- and middle-income countries.

Covid-19 restrictions and unavailability or lack of workforce during the pandemic affected domestic and international food trade and the supply chain. In 2020, more than 821 million people did not have access to safe and nutritious food, and they regularly suffer from hunger, out of which 100 plus million people endured acute hunger (WFP, 2020a). Global hunger is mainly due to conflicts, climate change and economic recessions. Covid-19 has imposed unimaginable economic and supply chain challenges increasing the severity and magnitude of hunger globally (WFP, 2020a). United Nations has identified undernutrition as a high-risk factor for the Covid-19 (UNOHCA, 2020). According to the United Nations World Food Program, the Covid-19 pandemic can contribute to more than a quarter of a billion people suffering from acute hunger by the end of 2020. The figure may go as high as 265 million people from low and middle-income countries by the end of 2020 (Anthem, 2020). This doubles the global acute hunger estimate due to the pandemic, a significant setback

to decades of investments made to enhance food security globally. It is evident that the pandemic and its control measures, including the social distancing, have disturbed the food production, distribution and economies, leaving food security at risk (Mardones et al., 2020). Impacts of the Covid-19 pandemic on poverty and food security are visible and directly related due to shocks on household income and thereby limited access (Laborde et al., 2021). The authors further predicted that global GDP might be declined by 5% due to Covid-19 with a similar range in South Asia and a higher decline (-9%) in Africa.

As the food security of Sri Lanka has been impacted by the Covid-19 pandemic as the rest of the world, the next section of the chapter discusses the food security context of Sri Lanka.

3.1. Food Security Context in Sri Lanka

Food security can be defined as a "condition when all people, at all times, have physical, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). From the outset, the COVID-19 pandemic has affected all the key dimensions of the definition resulting in significant challenges to food and nutrition security as the pandemic impacted the physical and economic access to food. Based on the Economist Group, Sri Lanka ranked 75 in the Global Food Security Index. One of the main challenges is the volatility of agriculture production (Economist, 2020).

As stated in Figure 2 and Figure 3, Sri Lanka food security performances in the year 2020 is relatively weak compared to other countries in the Asia Pacific region. Sri Lanka food security index of 2020 deteriorated two places from 73 to 75 in the global food security index compared to 2019. Developing countries in South Asia, including Sri Lanka, will face hunger, poverty and food insecurity due to climate change impacts. Achieving Sustainable Development Goals, especially the goal 1 and 2 (no poverty and zero hunger) by 2030 in a changing climate, will be a major challenge for the country (Herath & Poon, 2021).

The president of Sri Lanka declared 2017 as a key milestone for alleviating poverty to realize the SDG 1. In 2016, the "National Strategic Review on Food and Nutrition: Towards Zero Hunger" was launched by the government to accelerate the progress of achieving SDG 2, Zero Hunger (WFP, 2017). Despite substantial progress over the last 20 years, food insecurity and poverty remain high in low income and certain social strata of the country. According to the WFP, 80 per cent of Sri Lanka's annual food demand is produced domestically, while 20 per cent is imported from international markets. Rice, Sri Lanka's staple food, was nearly self-sufficient before the covid-19 struck. However, the availability of adequate food at the domestic markets does

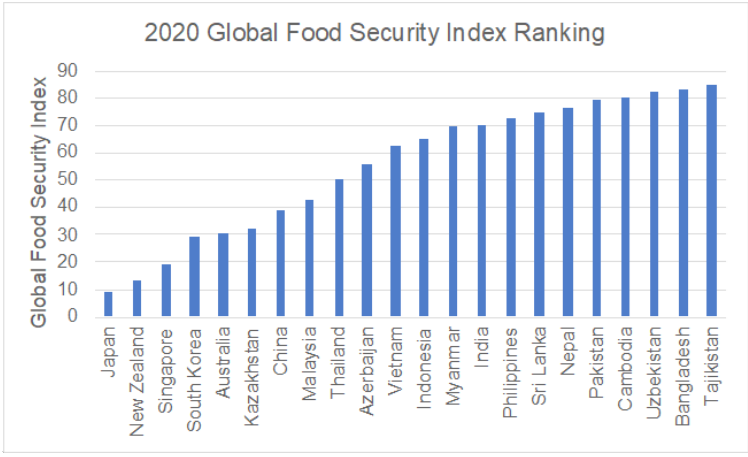

Figure 2. Global Food Security Index -2020 [Data Source (Economist, 2020)]

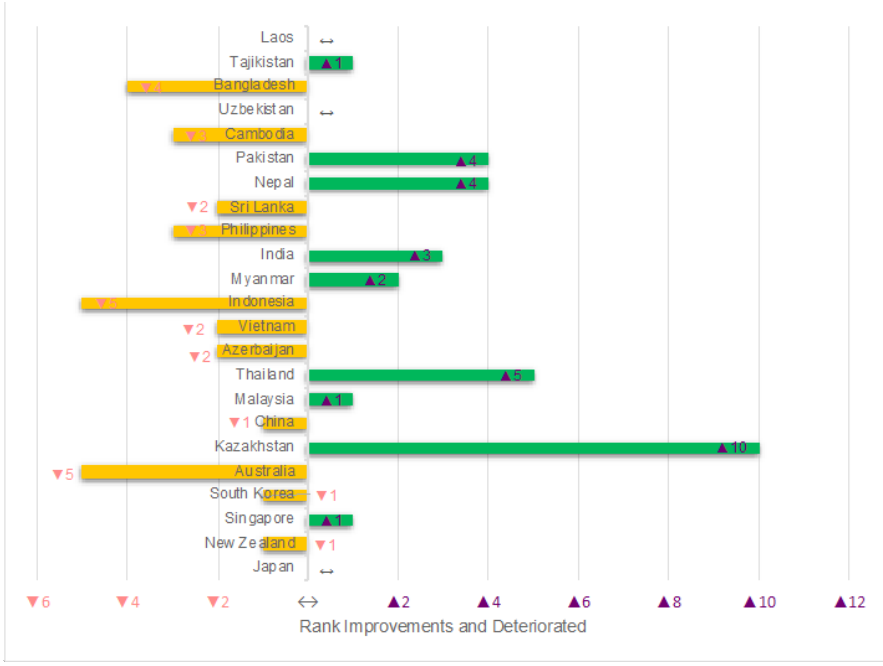

Figure 3. Global Food Security Index Changes in 2020 compared to 2019 [Data Source: (Economist, 2020)]

not guarantee economic and physical access to food at the household level in Sri Lanka (WFP, 2017). The nutrition status of children and mothers have shown some progress over the years. However, food and nutrition insecurity are still a major concern. Some of the main reasons are due to yield stagnation, food prices, income inequalities, high informal labour force, land degradation, and climate change. As it is evident that the food security of the country has impacted due to the Covid-19 pandemic, as the rest of the world, the next section of the chapter discusses Covid-19 impacts on the food security sector in Sri Lanka.

3.2. Covid-19 Impacts on Food Security Sector in Sri Lanka

The first Covid-19 case of Sri Lanka was a Chinese tourist reported on 27 January 2020. The second confirmed case was reported on 11 March 2020, and it climbed 122 cases with two deaths by 31 March 2020 (Amaratunga et al., 2020). By 31 July 2020, total confirmed cases escalated to 2,814 and by 12 May 2021, confirmed cases had rocketed high as 131,098 with 850 deaths (WHO, 2021b). The Impact of Covid-19 in Sri Lanka is multi-faceted. While it directly impacts the SDG Goal 03: Good Health and Well-being due to motilities and morbidities caused by SARS-CoV-2, other direct and indirect long-lasting socio-economic impacts cannot be underestimated. State and development partners' priorities on poverty alleviation had to be reprogrammed, allowing sufficient resources available for the pandemic response. On the other hand, zero hunger may no longer be a reality during the pandemic and post-pandemic era unless sound planning, strategies and program are designed across the systems and sectors. According to the World Food Program, restricted movements and lockdown have impacted income-generating opportunities, especially for low- and middle-income families, impacting their food and nutrition security (WFP, 2021). According to the International Monetary Fund (IMF), the country had reported a negative real GDP growth rate of - 4.6% for 2020 (IMF, 2021).

Further, average consumer price inflation has been reported as 4.7 %. Food and nutrition security has been impacted due to the loss of income and livelihoods, negative GDP growth rate, price fluctuation and inflation of agricultural and food products.

In Sri Lanka, the food supply chain was interrupted due to more stringent lock-down measures coupled with the closure of ports and airports. Economic hardships were enormous in the first phase of lock-down from March-May 2020 (Hettiarachchi et al., 2020). Loss of economic opportunities and interruptions to livelihoods have caused significant impacts, especially among the daily wage labours. Emergency food supply and financial assistance worth Sri Lankan rupees 5,000 were given to the needy people. However, there were initial setbacks in reaching the at-risk communities in time. Local charities and well-wishers collaborated with local authorities in providing dry rations to the food-unsecured and at-risk communities who have lost their livelihoods (Hettiarachchi et al., 2020). While Covid-19 has caused food insecurity globally, a balanced and safer diet is one of the main concerns. Protein intakes such as fish and meat and fruits and vegetable intakes have gone down across the world while instant foods and sugary drinks consumptions have increased, affecting immunity against communicable diseases (Jayawardena & Misra, 2020). Peliyagoda fish market Covid-19 cluster had led to several sub-clusters and district level spreads of the pandemic across the country by the end of December 2020 (WHO, 2020). The closure of the Paliyagoda wholesale fish market, the only wholesale fish market on this scale, had created public panic and refusal to buy and consume seafood due to misconception (Piyasiri, 2020). While it has caused economic hardships and livelihood impacts to the fishery industry, food insecurity implications to the general public were immense, especially from the nutrition lens as fish and seafood are primary protein sources of Sri Lankan meals. Import restrictions and supply chain disruptions had halted the production of "Thriposha", a supplementary food given to children and lactating mothers, due to the unavailability of imported maize. Furthermore, the national school feeding program has been halted since 12 March, resulting in the loss of daily in-school meals, a key component of food security in Sri Lanka (WFP, 2020b). Heavy dependency on retailed-based food security, especially from urban and peri-urban poor communities, have paid the price during the lock-down period.

On the other hand, impacts on livestock, especially the poultry sector, was significant. Lack of animal feeds, labour shortage, the closure of processing and storage facilities, and diminished demand due to reduced disposable income are the main setbacks (Netherlands and You, 2020). Furthermore, post-harvest food loss due to the closure of wholesale and retail markets was a heavy blow to farmers. The foreign exchange stabilization policy of the Government also took a toll on the food sector. Import restrictions imposed on 156 products, including food items such as rice, grains, pasta, and bakery products, impacted the food security of people, especially in the urban and peri-urban settings.

Similar to the global trend, the impacts of covid-19 on the food security of Sri Lanka are multi-faceted. It has affected all SDG goals to varying degrees contributing to increased poverty, loss of livelihoods, increased unemployment and declined disposable income and purchasing power, especially among the poorest districts and communities. Urban poor is one of the hardest-hit segments of the society as most of them are part of the informal workforce.

Covid-19 has shown how a pandemic in this scale can derail decades of investments and progress achieved in the food security sector. Covid-19 impacts on the food security sector is a complex spiral without a visible end. It is connected with poverty, health and wellbeing, education, and nutrition security, just to name a few; hence an integrated approach is needed if the country is to reinvigorate for a speedy and sustainable recovery to make the 2030 agenda straight. Therefore, the next section of the chapter discusses some possible interventions to pave the path forward for prosperity and splendour, a vision that the Government embarked before covid-19 struct the country. These recommendations were derived from extensive literature reviews and speaking to food security and disaster risk management experts in Sri Lanka and in the region to design

strategies and options for regaining resilience and prosperity in the post-covid development phase.

4. PATH TO SPLENDOUR: REGAINING RESILIENCE AND PROSPERITY

Although Covid-19 has caused substantial setbacks to Sri Lanka and its socio-economic development, it can also provide an opportunity to reassess vulnerabilities, regain resilience and prosperity through process re-engineering to meet current and future challenges. Some of the possible interventions to achieve food and nutrition security are stated below, which eventually contribute to sustainable development.

4.1. Coherence Approach to Food Security

Coherence is the key to achieve faster, equitable and sustainable recovery from Covid-19. It has proven beyond doubt that covid-19 is a multi-sectoral issue than just a public health emergency; therefore, solutions also depend on multi-sector, multi-disciplinary approaches. Policies, programs and interventions can be designed in an integrated manner keeping the sustainable development goals at the centre of the policymaking and implementation, while disaster risk reduction, food security, climate change adaption and all other sectoral policies and strategies supporting the SDGs targets. The sustainable development act of 2017 and the sustainable development council of Sri Lanka can play a leading role to establish nexus and synergy across the sectors and actors. Empowerment of the sustainable development council with necessary technical, operational, leadership and tactical skills will decide how quick Sri Lanka can recover from the pandemic.

4.2. Data-driven Food and Nutrition Security

During Covid-19, it was proven that data and evidence are critical to formulating informed policies and programs. However, reliable and timely data is one of the most significant development challenges in Sri Lanka. Furthermore, data access is a perineal issue. Data analytics and utilization to make informed and inclusive policies and programs are limited. Nevertheless, Covid-19 has presented all sectors and actors an opportunity to bring this long-lasting issue to order. Integrated data management protocols, decisions support system (DSS), data visualization and food and nutrition intelligence supported by crowdsourcing, big data and artificial intelligence (AI), digitization of markets, demands and supply chains could be potential tools to regain the food and nutrition security in Sri Lanka.

4.3. Re-engineering Market Access

Access to food is one of the main dimensions of food security. However, Covid-19 restrictions and lockdowns showed us that access to food could be disrupted during a disaster. As most of the markets, wholesaler and retailer outlets closed down their operations, people did not have sufficient consumer tools to access vendors. Although some limited online vendors and mobile retail stalls were in operation, especially in the urban and peri-urban areas, it was not sufficient to meet the demand and reach specifically in the rural areas. Capitalizing on the high literacy rate, mobile phone penetration and internet access in Sri Lanka, market access re-engineering is a priority. Learning how consumer markets and the e-commerce industry work in other countries during the pandemic, such as in Southeast Asia, Sri Lanka needs to expand and invest in the e-commerce industry allowing farmers, consumers and vendors to interact through e-commerce platform to select their preferred food and nutrition options. Such a system will not only improve food access but also will provide analytics, food intelligence and tools for policymakers and the private sector.

4.4. Self-reliance through Regenerative Agriculture

Traditionally, Sri Lanka's food security relied on the home gardening system, where nutrition and food diversity were inherent.

However, modern monoculture has dominated most parts of the country in the recent past diminishing food and nutrition diversity. Furthermore, urbanization has reduced the arable land availability for home gardening. Food insecurity was apparent during the Covid-19 lock-down, and communities could not meet their minimum nutritional and food preferences. The Government initiated distributing seeds for home gardening, which created a positive trend for resuming the home gardening system across the country. Capitalizing on the new trend and willingness by the public, Regenerative Agriculture can be a viable option, which promotes organic and ecosystem-based home gardening. It will not only avoid the highly toxic Agro-chemicals usage but also increase the quality of food and nutrition diversity that Sri Lankans cherished and known for centuries.

4.5. Climate-Smart Agriculture

Agriculture is one of the most sensitive sectors to climate change and variability. Hydro-met disasters such as droughts and floods can affect food availability, access, stability and utilization. Food security will adversely be impacted if climate-induced disasters strike during the post-recovery phase. Therefore climate-informed agriculture planning and climate-smart agriculture practices should be scaled up across the country. Developing appropriate strategies supported by actionable programs by the government, private sector, and farming communities, including farmer associations, can be a critical component of reviving food security in Sri Lanka. Forecasts based agriculture through the annual and seasonal climate outlooks, Agri-early warning systems coupled with Agri-extension network and supporting progressive farmers to invest in Climate Smart Agriculture is a timely need in the post-covid-19 recovery phase.

4.6. Alternative Farming Techniques to boost Food Security

Covid-19 revealed the food vulnerability of the urban and peri-urban settings, especially during the lock-down restrictions. Alternative farming techniques such as vertical farming, hydroponics, and aquaponics, can be vital practices to face food insecurity and demands, especially in a resource-constrained setting like urban settlements (FAO, 2021b). Such practices will be essential to meet the food and nutrition needs and achieve SDG targets in the post-covid-19 recovery phase.

4.7. Social Safety Nets for Food Security

"Social Safety Net" (SSN) can be defined as the private and public mechanisms designed to support individuals and families to maintain minimum consumption standards (Paitoonpong et al., 2008). SSN is critical during economic and disaster shocks for people to meet their daily food and nutritional needs. Some of the SSN programs in Sri Lanka include the Samurdhi program, school feeding program, cash for work program and work for food programs, among others. However, the development and social welfare objectives of such programs should be reviewed to assess the level of impacts on the ground. If planned and programmed well, these SSN programs can be the lifeline for the country's most impoverished communities to bounce back from Covid-19 and other future shocks. According to the World Bank Group, the SSN programs have supported addressing chronic poverty, shocks and food insecurity, especially in low and middle-income countries (World Bank, 2011). Revitalization of SSN programs in Sri Lanka is a must, going beyond the current system, which has not yielded developmental and social welfare benefits as anticipated.

4.8. Effectiveness and Efficiency of the Food Governance

The government and other relevant stakeholders need to reassess the efficiency and effectiveness of the food governance system. Functional food governance should be able to stimulate the formulation, planning, implementation, monitoring and evaluation of food security and nutrition-related legislation, policies, strategies and programs. The food governance system needs to consider the "right to food" as a fundamental human right. Food governance needs to be people-centric, context-specific and provide workable solutions to

all the parties involved. The efficiency and effectiveness of the food governance will not only support the Covid-19 recovery programs but also accelerate poverty eradication, ending hunger, malnutrition and support achieving SDG 2 (FAO, 2021a).

5. CONCLUSION

Covid-19 has caused immeasurable economic and development impacts on the SDGs and the food security sector. Path to achieve SDGs in the 2020-2030 decade will be a daunting task. However, substantial progress is still feasible, provided that the Government designs and implements a measured approach, enabling policies, stimulating strategies and innovative programs to regain resilience and prosperity. Failing to do so will not only delay the recovery phase but also will diminish decades of progress achieved in SDGs and food security. Furthermore, delaying the post-covid-19 recovery will make Sri Lanka further vulnerable to climate change, and climate-induced disasters in the future, and therefore prosperity and splendour may be beyond its reach unless they act wisely and promptly.

REFERENCES

Amaratunga, D., Fernando, N., Haigh, R., & Jayasinghe, N. (2020). The COVID-19 outbreak in Sri Lanka: A synoptic analysis focusing on trends, impacts, risks and science-policy interaction processes. *Progress in Disaster Science*, *8*. https://doi.org/10.1016/j.pdisas.2020.100133

Anthem, P. (2020). *Risk of hunger pandemic as coronavirus set to almost double acute hunger by end of 2020*. Retrieved 28/02 from https://www.wfp.org/stories/risk-hunger-pandemic-coronavirus-set-almost-double-acute-hunger-end-2020

Economist, T. (2020). *Global Food Security Index*. The Economist Intelligence Unit. Retrieved 27/02 from https://foodsecurityindex.eiu.com/Country/Details#Sri%20Lanka

Ediriweera, D. S., de Silva, N. R., Malavige, G. N., & de Silva, H. J. (2020). An epidemiological model to aid decision-making for COVID-19 control in Sri Lanka. *PLoS One*, *15*(8), e0238340. https://doi.org/10.1371/journal.pone.0238340

FAO. (1996). Declaration on world food security. World Food Summit. World Food Summit, Rome, Italy.

FAO. (2021a). *Governance*. http://www.fao.org/right-to-food/areas-of-work/governance/en/

FAO. (2021b). *Home Gardens/Vertical Farming, Hydroponics and Aquaponics*. Retrieved 04/03 from http://www.fao.org/land-water/overview/covid19/homegardens/en/

Herath, G., & Poon, W. C. (2021). Climate Change, Hunger and Food Security in Asia with Special Reference to Sri Lanka: Can the Sustainable Development Goals Be Achieved by 2030? In V. Venkatramanan, S. Shah, & R. Prasad (Eds.), *Exploring Synergies and Trade-offs between Climate Change and the Sustainable Development Goals* (pp. 37-54). Springer Singapore. https://doi.org/10.1007/978-981-15-7301-9_2

Hettiarachchi, D., Noordeen, N., Gamakaranage, C., Somarathne, E. A. R. B. D., & Jayasinghe, S. (2020). Ethical Responses to the COVID-19 Pandemic—Lessons from Sri Lanka. *Asian Bioethics Review*. https://doi.org/10.1007/s41649-020-00153-z

IMF. (2021). *Sri Lanka*. Retrieved 26/02/2021 from https://www.imf.org/en/Countries/LKA

Jayawardena, R., & Misra, A. (2020). Balanced diet is a major casualty in COVID-19. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *14*(5), 1085-1086. https://doi.org/10.1016/j.dsx.2020.07.001

Laborde, D., Martin, W., & Vos, R. (2021). Impacts of COVID-19 on global poverty, food security, and diets: Insights from global model scenario analysis [https://doi.org/10.1111/agec.12624]. *Agricultural Economics*, *n/a*(n/a). https://doi.org/https://doi.org/10.1111/agec.12624

Ma, N. L., Peng, W., Soon, C. F., Noor Hassim, M. F., Misbah, S., Rahmat, Z., Yong, W. T. L., & Sonne, C. (2021). Covid-19 pandemic in the lens of food safety and security. *Environmental Research*, *193*, 110405. https://doi.org/10.1016/j.envres.2020.110405

Mardones, F. O., Rich, K. M., Boden, L. A., Moreno-Switt, A. I., Caipo, M. L., Zimin-Veselkoff, N., Alateeqi, A. M., & Baltenweck, I. (2020). The COVID-19 Pandemic and Global Food Security. *Front Vet Sci*, *7*, 578508. https://doi.org/10.3389/fvets.2020.578508

Netherlands and You. (2020). *Impact of COVID19 on food supply chains in Sri Lanka*. Retrieved 02/03 from https://www.netherlandsandyou.nl/latest-news/news/2020/06/02/impact-of-covid19-on-food-supply-chains-in-sri-lanka

Paitoonpong, S., Abe, S., & Puopongsakorn, N. (2008). The meaning of "social safety nets". *Journal of Asian Economics*, *19*(5-6), 467-473. https://doi.org/10.1016/j.asieco.2008.09.011

Piyasiri, O. A. a. K. (2020). Multiple shocks of Covid-19 and the tragedy of fisheries. *Daily News*. http://dailynews.lk/2020/11/17/features/233714/multiple-shocks-covid-19-and-tragedy-fisheries

Santos-Sanchez, N. F., & Salas-Coronado, R. (2020). Origin, structural characteristics, prevention measures, diagnosis and potential drugs to prevent and COVID-19. *Medwave*, *20*(8), e8037. https://doi.org/10.5867/medwave.2020.08.8037 (Origen, caracteristicas estructurales, medidas de prevencion, diagnostico y farmacos potenciales para prevenir y controlar COVID-19.)

UN. (2020). *UN/DESA Policy Brief #81: Impact of COVID-19 on SDG progress: a statistical perspective*. United Nations. Retrieved 01/03 from https://www.un.org/development/desa/dpad/publication/un-desa-policy-brief-81-impact-of-covid-19-on-sdg-progress-a-statistical-perspective/

UN. (2021). *Sustainable Development Goals*. Retrieved 01/03 from https://www.un.org/sustainabledevelopment/

UNDP. (2020). *Impacts of Covid-19 on the Sustainable Development Goals*. UNDP. Retrieved 02/03 from https://sdgintegration.undp.org/accelerating-development-progressduring-covid-19

UNESCAP. (2019). *SDG implementation and budgetting: Sri Lanka's efforts and challenges*. Retrieved 01/03 from https://www.unescap.org/blog/sdg-implementation-and-budgeting-sri-lanka

UNOHCA. (2020). *Global Humanitarian Response Plan-Covid 19*. Retrieved 28/02 from https://www.unocha.org/sites/unocha/files/Global-Humanitarian-Response-Plan-COVID-19.pdf

Weerakoon, D. (2021). *Sri Lanka's economy hemmed in by COVID-19 and geopolitical tensions*. Retrieved 26/02/2021 from https://www.eastasiaforum.org/2021/01/11/sri-lankas-economy-hemmed-in-by-covid-19-and-geopolitical-tensions/

WFP. (2017). *National Strategic Review of Food Security and Nutrition*

Towards Zero Hunger. WFP. Retrieved 12/05 from National Strategic Review of Food Security and Nutrition

Towards Zero Hunger

WFP. (2020a). *COVID-19: Potential impact on the world's poorest people*. Retrieved 28/02 from https://docs.wfp.org/api/documents/WFP-0000114205/download/?_ga=2.241337546.952775517.1586900153-341597442.1584735263

WFP. (2020b). *WFP Sri Lanka Country Brief*. https://reliefweb.int/sites/reliefweb.int/files/resources/WFP-0000117783.pdf

WFP. (2021). *Sri Lanka*. Retrieved 26/02/2021 from https://www.wfp.org/countries/sri-lanka

WHO. (2020). *Covid-19 Weekly Situation Report*. Retrieved 28/02 from https://www.who.int/docs/default-source/searo/whe/coronavirus19/sear-weekly-reports/weekly-situation-report_week-52.pdf?sfvrsn=7400122d_5

WHO. (2021a). *WHO Coronavirus Disease (COVID-19) Dashboard*. Retrieved 12/05 from https://covid19.who.int/

WHO. (2021b). *WHO Health Emergency Dashboard: Sri Lanka Situation*. Retrieved 12/05 from https://covid19.who.int/region/searo/country/lk

World Bank. (2011). *An Evalution of World Bank Support, 2000-2010, Social Safety Nets*. https://www.oecd.org/derec/worldbankgroup/49023353.pdf

World Bank. (2021a). *Economic and Poverty Impacts of Covid-19*. https://thedocs.worldbank.org/en/doc/15b8de0edd4f39cc7a82b7aff8430576-0310062021/original / SriLanka-DevUpd-Apr9.pdf

World Bank. (2021b). *Food Security and Covid-19*. Retrieved 12/05 from https://www.worldbank.org/en/topic/agriculture/brief/food-security-and-covid-19

Integrating pandemic and epidemic into disaster management/ disaster risk reduction mechanisms in Sri Lanka: From the perspective of local government authorities

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ABSTRACT

Covid-19 has affected both developed and developing countries. Sri Lanka is no exception to other countries in the region, and was able to manage the pandemic at the initial stage with a certain element of success. The local government authorities have also contributed towards the pandemic response measures, though they do not have any legitimate duty in disaster management. Hence, the study was conducted to gain an understanding of the experiences of the local government authorities, in responding to the COVID-19 pandemic outbreak in Sri Lanka. In answering the research aim, the study conducted a literature review and key informant interviews with the officers engaged in local government authorities in Sri Lanka. Seven key informant interviews were conducted using an interview guideline. Accordingly, the study presents the involvement and the role of the local government authorities in overall disaster risk reduction, encompassing the specific roles during the COVID-19 response period. In this study, eleven key aspects were identified as the challenges which the local government authorities faced while performing the related duties during the COVID-19 pandemic. Accordingly, based on the outcome of the interviews, relevant suggestions are presented to address the challenges and strengthen future pandemic response measures. The study findings also justify the importance of integrating the local government authorities into activities related to pandemic preparedness, adopting response measures and disaster risk reduction/disaster management system in Sri Lanka.

Key words: Local government authorities, Sri Lanka, Pandemics, Disaster risk reduction, COVID-19

1. INTRODUCTION

Sri Lanka has been susceptible to the Covid-19 pandemic as the rest of the world and the first COVID-19 patient in the country was confirmed on the 27th of January 2020. Since then, the number of cases has gradually risen over the recent period. As of second week of February 2021, more than 74,000 confirmed or positive cases, 67,000 recovered patients and 390 deaths have been recorded in Sri Lanka (WHO, 2021).

At the beginning of the pandemic, the active or positive cases were limited to 217, with only 11 fatalities being recorded in Sri Lanka (WHO, 2021). These figures exhibit the success in controlling the community spread of the virus and the treatment of COVID-19 patients in the country. Sri Lanka followed strict lockdown measures, contact tracing and

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isolation at the beginning of the pandemic and thereafter there was a gradual relaxation (Ediriweera et al., 2020; Hettiarachchi et al., 2020; Jayatilleke et al., 2020).

The COVID-19 Stringency Index (C19SI) revealed the Sri Lanka's expansive stringent measures as 97% successful, within two weeks of discovering the second COVID-19 patient in the country (Jayatilleke et al., 2020). A similar index, the Global Response to Infectious Disease (GRID), also confirmed the effectiveness and efficiency of the health systems' preparedness to address the COVID-19 pandemic in the country. Accordingly, Sri Lanka was ranked in 10th place, demonstrating its efficiency and effectiveness in the GRID (D'Souza, 2020). These sources have shown satisfactory results compared to other neighbouring countries in the region.

Sri Lankan pandemic response measures have been carried out collectively with the participation of multi-stakeholders attached to the Sri Lankan public administrative system (Amaratunga et al., 2020). Local Government Authorities (LGAs) are one such stakeholder contributing to the pandemic response measures in the country. LGAs services range from providing basic facilities to raising awareness among communities at risk (Hettiarachchi et al., 2020; World Vision, 2020).

However, the integration of LGAs in disaster management was not well coordinated within the national disaster management system in Sri Lanka (Malalgoda et al., 2016). None of the local government statutes in Sri Lanka have referred to disaster management until the National Policy on Local Government was introduced in 2009 (MacAskill & Guthrie, 2016). Until then, the LGAs' engagement was limited to getting involved in postdisaster response efforts instead of being engaged in preparedness planning measures (MacAskill & Guthrie, 2016).

Sri Lanka's disaster management structure is operated through the central government system by the Disaster Management Centre (DMC) and the Ministry of Disaster Management (Ministry of Disaster Management, 2010). Hence, most functions are coordinated and carried out within the central government system administered by the DMC along with other government instutions such as District Secretaries (DSs), Divisional Secretaries etc. . The Presidential Task Force (PTF) has been entrusted with the responsibility of administering the prevaling COVID-19 pandemic situation in Sri Lanka.

This study was conducted to highlight the role of the LGAs during the COVID-19 response stage to justify the significance of integrating LGAs with the overall disaster risk reduction efforts in Sri Lanka. Besides, the study also intends to identify any challenges that the LGAs encountered during the response efforts and accordingly, to propose relevant recommendations towards strengthening pandemic response measures with the integration of LGAs in the disaster management system in Sri Lanka.

2. METHODS

The study adopted a qualitative multi-method system for achieving study objectives. Qualitative methods are suitable for either developing theories or conceptual frameworks or examining participants' meaning and relationships (Saunders et al., 2019). Researchers use qualitative methods in disaster related studies due to its appropriateness and advantages (Collins & Kapucu, 2008; MacAskill & Guthrie, 2016; Malalgoda et al., 2016; Phillips, 1997).

The qualitative multi-method was the chosen methodology for this study. The decision was based on the study's objective to interpret participants' views regarding the contribution made by local governments,and also to identify the strengths as well as the challenges experienced, during the COVID-19 pandemic in Sri Lanka.

Qualitative methods allow non-probability sampling data collection techniques (Saunders et al., 2019) and accordingly this study adopted

such a sampling method to collect the required data. An interview guideline was developed based on the findings of the literature review done using refereed articles, related official websites and reports. The key informants in the LGAs were selected according to the convenient sampling method and seven semi-structured interviews were conducted.

The key-informant interviewees represented Chairmen from two Pradeshiya Sabhas (Wattala & Akurana), a Chairman from an Urban Council (Beruwala), Mayors from two Municipal Councils (Rathnapura and Jaffna), a Commissioner from a Provincial-Local Government (Eastern Province) and a Commissioner from a Municipal Council (Polonnaruwa). The interviews were recorded using a voice recorder and transcribed manually while all the interviewees were given an identification number with the acronym "INT" and ranging from INT1 to INT7. The transcribed data were analysed and presented as thematic analysis.

Furthermore, a documentary review was conducted as part of the qualitative multi-method and it helped to understand the legislative and policy background of LGAs in Sri Lanka. Accordingly, the National Policy on Local Government, Sri Lanka Comprehensive Disaster Management Programme 2014-2018 and the National Policy on Disaster Management were referred as part of the documentary review.

3. FINDINGS

3.1. The governance structure of LGAs in Sri Lanka

The Sri Lankan governance structure comprises three layers; i.e. the Central Government (CG), Provincial Councils (PCs) and Local Governments (LGs). The local government bodies are collectively known as local authorities and therefore, in this study LGAs refer to entities that belong to local authorities in Sri Lanka. Accordingly, LGAs comprises Municipal Councils, Urban Councils and Divisional Councils (also known as Pradeshiya Sabhas) (MacAskill & Guthrie, 2016; Malalgoda et al., 2016). The presence of LGAs can be traced back to 4th Century B.C. and over a period of time LGAs have evolved to provide rudimentary public services at local level, ranging from land utilisation services to disaster risk reduction (DRR).

The LGAs do not derive the mandates and powers from a single codified statute. There are three central acts which govern LGAs namely, the Municipal Council Ordinance No. 29 of 1947, the Urban Councils Ordinance No. 61 of 1939 and the Pradeshiya Sabha Act No. 15 of 1987 along with subsequent amendments. The Pradeshiya Sabhas have been vested with powers under the existing laws while the Provincial Councils have the authority to confer additional powers on local authorities (GOV.SL, 2009).

3.2. The role of LGAs in disaster risk reduction

Local government is regarded as an organised social entity that is acting as an agent of the state,assisting in the governance system through its political mechanism (Khan & Ara, 2006).

In terms of disaster risk reduction, local governments are recognised as the most appropriate administrative level to engage in disaster management (Col, 2007; Kusumasari et al., 2010; Manda, 2014). Local government acts as the city's leader and the closest government body to the local population. Hence, local governments are better positioned to engage in the local DRR activities, addressing the concerns of the communities in an efficient and effective manner (Khan & Ara, 2006; Saito, 2007). These institutions can engage as the first line of response and defence in disaster situtaions, incorporating local knowledge and resources (Manda, 2014).

Disasters are often known to be local events (Solway, 2004) and the relevant responsible authorities can identify the vulnerable people in areas which are likely to be impacted by disasters, raise awareness campaigns, disseminate disaster mitigation

guidelines, ensure adequacy of first aid and train members in the community for better preparedness planning (Solway, 2004). Therefore, several scholars have suggested involving local governments in disaster risk reduction planning and related activities (DRR) (Bajracharya et al., 2011; Col, 2007; Dzigbede et al., 2020; Malalgoda et al., 2016; Saito, 2007). Similarly, the UN-ISDR has identified local governments as critical stakeholders in making a city resilient to disasters and reducing the risk and impact of likely disasters (UN-ISDR, 2012).

The role of LGAs within the Sri Lankan DRR framework is controversial. At present, Sri Lankan LGAs perform a supportive role in emergency response and recovery activities since these insitutions face certain capacity constraint and have not been legally empowered in implementing any DRR measures (Malalgoda et al., 2016). The relevant governing statutes do not specify the role of these LGAs in responding to disasters. Hence, the Sri Lanka Disaster Management Plan (2014-2018) highlighted the importance of incorporating national-level disaster management policies with local level strategies, to strengthen DRR efforts in Sri Lanka (Ministry of Disaster Management 2014).

Nevertheless, a recent improvement in LGAs could be identified with the introduction of the National Policy on Local Government (NPLG) of 2009. In view of that, LGAs have the right to engage in public health and sanitation, public utility services, thoroughfare and general welfare of communities. The NPLG specifically states that LGAs must formulate a comprehensive area specific plan of action to manage disasters based on locally implemented strategies for DRR and disaster management (DM) and the existing rapid response systems. According to the policy, the LGAs must obtain technical guidance from relevant ministries and technical authorities when formulating such a plan of action. The process enables LGAs to identify disaster-prone areas, potential disaster risks and hazards effectively while it further specifies the necessity of aligning any plan of action and operational guidelines to the Sri Lanka Disaster Management Act, No: 13 of 2005 (GOV.SL, 2009).

Section 4.1.4.4 of the NPLG states that any significant local development projects carried out under the Urban Development Authority Act and the Urban Settlement Development Authority Act must consider the impact of frequently occurring disasters (GOV.SL, 2009) considering as a duty of LGAs' disaster preparedness strategy. According to Section 4.1.4.9 of the policy, the LGAs should be pro-actively involved as the planning authority of disaster preparation, mitigation and management within the overall district framework for disaster management. LGAs can formulate a proactive vision, supplementary plans and strategies for local development with minimal threat of natural disasters on human settlements and supporting infrastructure. Besides, the inter-ministerial consultations provide direction and technical guidance to LGAs and the related partners in discharging their statutory responsibilities in environmental improvement, management, prevention and mitigation of disasters, within the overall district framework (GOV.SL, 2009).

The Sri Lanka Comprehensive Disaster Management Programme (SLCDMP) (2014 – 2018) also recognises the significance of strengthening LGs to support national-level policy implementation through capacity building of local authorities, planned within the stated period (Ministry of Disaster Management, 2014). Its second output focused on introducing legal framework to mainstream DRR concepts in LGAs. Furthermore, this programme has given due recognition in identifying the Grama Niladhari (GN) as a critical Local Government Officer (LGO) entrusting the implementation of the National Disaster Resilience Framework (NDRF) at village level. The GNs closely work with locally established disaster management committees and community-based organisations to catalyse DRR and climate change adaptation (CCA) measures at grass-root level. The association or links with local agencies are based on the GN level disaster management plans, including

disaster mitigation and adaptation measures (Ministry of Disaster Management, 2014).

Moreover, the National Disaster Resilience Framework (NDRF) and regulations related to Provincial Councils were also referred in identifying the DRR related functions within LGAs (GOV.SL, 2009). The NDRF has implemented several projects to empower the LGAs and developing and piloting of GN level hazard maps and risk profiles as done by DMC is one such project .

3.3. The role of LGAs during the COVID-19 pandemic response phase

After exploring the designated role of LGAs in DRR within the legislative and policy context, the following section explains the role of the LGAs during the COVID-19 pandemic response stage in Sri Lanka, based on the interviews conducted.

3.3.1. Coordination of provision of subsidised grocery packs:

According to INT1, LGAs have coordinated the provision of subsidised essential grocery packs to families living under quarantine conditions and in lockdown areas. These grocery packs were made by purchasing vegetables from the Dambulla central vegetable distribution market which were distributed at village level through the local Cooperative (Samupakara) system. For example, in the area of Wattala, the LGAs distributed 1200 food packs worth LKR 750 at a subsidised price of LKR 350.

3.3.2. Supporting government relief allowance distribution:

INT1 pointed out that LGAs support Samurdhi officers to distribute LKR 5,000.00 as a monthly relief allowance provided by the Government to all entitled Samurdhi recipients. Though this was not within the mandated responsibility of the LGAs, the relevant officers got involved as the agent of the localities.

3.3.3. Assuring the safety of public areas:

According to INT1, LGAs assist in disinfecting public areas such as markets, bus stops, railway stations, schools, police stations etc. since LGAs have had experience of handling epidemics in the past. As an example, LGAs get involved in cleaning public places to ensure that the areas will not become breeding grounds for dengue , as explained by INT7.

3.3.4. Controlling public gatherings:

LGAs administer local public places and , have the authority to control public gatherings conducted in such locations. INT5 explained how LGAs worked tirelessly to ensure no mass gatherings are held in such public places and that social distancing rules are followed once the lockdown has eased and when gatherings are held. .

3.3.5. Waste management:

Another duty performed by the LGAs during the pandemic response is waste management, including contaminated waste. As explained by INT5, employees of LGAs, especially the health labourers were involved in collecting waste from households, and managing contaminated waste from quarantine centres and hospitals treating COVID-19 patients.

3.3.6. Creating awareness:

LGAs also played a pivotal role in raising awareness of the importance of anti-contamination practices to be followed by the general public. INT5 explained how LGAs in Trincomalee district had used social media platforms to disseminate information on safety measures to be followed at civilian level to be safe from COVID-19. INV6 too explained how local health officers (LHOs) played a significant role as trained health care professionals with a technical background in raising awareness about the pandemic and importance in following health guidelines and regulations imposed

3.3.7. Provision of basic facilities at the quarantine centres:

INT5 explained how LGAs supported the state-operated quarantine centres in providing basic facilities such as water and sanitation. INT1 added an example of the four hundred-odd Army personnel whose leave was cancelled and brought to the quarantine centre operating at the Kerawalapitiya school in Wattala. The LGAs in the area were required to provide water and sanitation facilities as advised by the Wattala Pradeshiya Sabha. Provision of essential services and infrastructure facilities to the general public during the COVID-19 pandemic was no easy task.

3.3.8. Administering the foreigners in the area:

LGAs oversaw and administered the the basic needs of the foreigners residing within the respective LGA areas . INT3 explained how the Beruwala Urban Council managed and helped 34 COVID-19 patients who were Chinese descendants residing within the town limits of the gem business area

3.3.9. Supply of medication and disinfected materials:

INT2 explained the role of LGAs in stocking up of suitable medication, face masks and disinfectant liquid for efficient distribution among families who unable to afford such items.

3.3.10. Establishing local level COVID-19 pandemic response committees:

According to INT4, LGAs led the establishment of local-level COVID-19 Pandemic Response Committees together with representatives from the PCs, local centres of the Ministry of Disaster Management and local level health officers. They gathered once in every two weeks to discuss the strategic approaches that were to be adopted at local level in mitigating the spread of COVID-19.

3.3.11. Implementing National Committee directives:

INV1 stated that LGAs worked hand in hand with key stakeholders such as Public Health Inspectors (PHIs), other LHOs, police, tri-forces and others , in implementing the national directives. INV4 added that LHOs worked under the supervision of the Health Promotion Bureau (HPB) to achieve risk communication and community engagement at a local level.

3.3.12. Provision of early warning:

INT2 emphasised on another role played by LGAs in issuing early warnings in their localities using basic equipment. LGAs in Akurana used loudspeakers provided by the DMC to issue EWs related to the pandemic when the virus had penetrated the area. Furthermore, LHOs under the supervision of the Health Promotion Bureau (HPB) were involved in activities related to risk communication and community engagement at a local level.

3.3.13. Monitoring self-isolation process at local level:

PHIs as local health officers monitored the self-isolation processes of individuals suspected being in contact with COVID-19 positive patients. Furthermore, the LHOs also coordinated the transfer of persons showing symptoms of COVID-19 to state-run quarantine centres and local hospitals.

3.3.14. Strengthening the fragmented administrative system:

INT4 noted that COVID-19 was a novel challenge for the entire national administration of Sri Lanka and that DM mechanisms were introduced on a trial and error basis as the disaster unfolded. He also noted that, COVID-19 has helped to bring into together a fragmented local administration system comprising of the LGAs, LHOs, police force and the PC of the Rathnapura province, to work collaboratively through a newly established

Disaster Management Committee under his leadership.

Based on the above information, LGAs can be identified as a major stakeholder in Sri Lanka's fight against the COVID-19 pandemic. The evidence also provides enough justification as to why LGAs should be adequately integrated into the country's disaster management system. Nevertheless, the interviewees revealed some challenges faced by LGAs while carrying out their duties during the COVID-19 pandemic. The following section highlights the challenges and proposed recommendations.

3.4. Challenges faced by LGAs during the COVID-19 response efforts

The challenges were classified into key thematic areas as presented below.

3.4.1. Unnecessary political interference:

Several interviewees highlighted unnecessary political interventions faced by local government officers (LGOs) during the pandemic response stage. For example, INT1 explained how there had been unwanted political influences over distribution of relief affecting the effectiveness of the DRR measures. The LGAs were authorised to providegroceries at a subsidised prices to local villages. Nevertheless, several politicians in the area attempted to intervene, targeting the impending parliamentary election scheduled in August 2020. Further, the interviewee highlighted how politicisation and consequential unionisation of the public health authorities acted as an obstacle for the public health authorities be appropriately involved in local level pandemic responses.

3.4.2. Conflicting role in DRR planning:

LGAs face an identity conflict regarding the respective role in the DRR planning activities in Sri Lanka. This unclear role of LGAs is as a resul of inadequate legislative and policy background, as noted by INT4. The absence of a clear governing document explaining the mandates and powers of LGAs within the pre, during and post-disaster stages has caused the ambiguity of roles.

3.4.3. Direct access to state funding is limited:

LGAs faced funding limitations during this pandemic response stage while performing duties. As explained by INT3, the Provincial Councils are resourced for COVID-19 relief distribution, while LGAs were held accountable in investing the funding for pandemic response activities. INT3 explained the reasons for LGAs not receiving direct state funding for disaster management and hence these institutions need to utilise the reserve budget for DM purposes. As a result, many LGAs faced liquidation challenges to such an extent that, it was difficult to pay the employees as the funds were utilised for COVID-19 response measures. The interviewee further emphasised the risk of facing a second wave of COVID-19 as the LGAs do not have excess financial capacity to respond to the resurgence of the pandemic.

3.4.4. Absence of inter-agency accountability:

LGAs face the challenge of inter-agency accountability. INT4 explained that the LGAs were not held accountable for the any responsibilities in local DRR planning. When COVID-19struck, the PCs were directly provided with state funds and a monitoring mechanism was not adopted to administer the use of these monies. INT1 provided two examples to highlight the lack of oversight as a result of non accountability and arbitrary decisions taken by the local administrative authorities, receiving funds and support from the Central Government.

3.4.5. Lack of appreciation and disappointment:

INT6 identified another challenge faced by LGOs was that despite the commitment demonstrated by in battling the community spread of the COVID-19, the higher authorities extended their appreciation to the health officers, police and members of the tri forces. Hence, LGAs' officers were not adequately appreciated by the governmental authorities

and general public. Non-recognition of the services rendered by LGOs has created disappointment among officers in the LGAs.

3.4.6. Inadequate representation in local Disaster Management Committees (DMCs):

Another critical challenge faced by LGAs in Sri Lanka during the pandemic situation is the inadequate representation of LGAs in local level DM committees. INT5 added that LGAs are rarely consulted when preparing local DM plans and as a result the first hand experiences of LGAs are not being considered.

3.4.7. Lack of communication:

Due to lack of communication among the institutions, coinciding actions have been taken by various administrative authorities operating within a province. INT1 provided an example stating that ten permits were issued to transport vegetables to Wattala during the lockdown period. The Provincial Secretary's office issued these permits on personal preferences to a single local businessman instead of issuing the permits to existing vegetable sellers. A similar situation was reported when transporting fish while the permits have been outsourced to a businessman in Mattakuliya. The two examples demonstrate as to how lack of communication between officials affected the accountabiity in decisionmaking.

3.4.8. Delay in EW communication at local level:

INT2 noted that the basic equipment provided by DMC to Akurana for early warning purposes were used to communicate COVID 19 related updates, when the virus had affected the area. Advance warnings in the area of Akurana was not practised beforehand, when there were clear warning signs about the spread of the virus at national level. Furthermore, disaster preparedness does not take into account all facets of the diverse disaster experienced by the country. For example, certain villages of Akurana experienced periodic flooding when the sluice gates of the Polgolla dam were opened. However, there is no coordinated effort in disaster preparedness for such flooding, which means that the people are only warned a day or two before the sluice gates of the dam are to be opened.

3.4.9. Lack of experience:

INT5 noted another challenge faced by LGAs is the lack of experience in utilising the early warning systems in the case of biological hazards.

3.4.10. Limited resources:

The overall capacities of LGAs are affected by resource limitations, according to comments made by INT3 and INT6. They emphasised that due to lack of adequate resources ,the overall capacities of LGAs are affected in responding to a more extensive pandemic with a higher reproduction rate. The existing technical capacities and access to equipment within LGAs is limited. These capacity constraints threaten the safety of the staff, due to insufficient safety equipment such as face masks, gloves, boots etc. especially for health labourers as they are involved in disposing contaminated waste collected from local quarantine centres and hospitals. Further, there is insufficient disinfectant and hand sanitiser stocks to be used in a future pandemic situation. The interviewee also noted that in Beruwala, the PHI and MOH officers were not properly geared to deal with the general health issues in the area during, the COVID-19 pandemic.

3.4.11. Limited priority for disaster risk reduction:

Another issue faced by LGAs during the pandemic response is the lack of priority given for DRR planning by the Ministry of Disaster Management as explained by INT1. The Ministry focuses on emergency response and treats this as its sole mandate.

3.5. Suggestions for overcoming the challenges faced by LGAs a to create a pandemic resilient society

To address the above mentioned challenges, the interviewees proposed several recommendations as presented below.

3.5.1. Capacity building:

As stated above, most LGOs faced challenges in handling the pandemic situation due to a lack of experience and knowledge. Hence, INT6 proposed to introduce capacity building programme among LGOs. INT5 proposed three capacity-building measures i.e. provision of training on provincial and district level planning, enhancing the effectiveness of epidemic and pandemic response and conducting a Training of Trainers (TOT) programme and also for LGOs to conduct awareness programmes among the public. Such training must be supported through funding and sharing of technical knowledge and should be focused on providing a sound understanding of existing best practices in handling biological disasters. Training is essential for health labourers (sanitation workers) and garbage collectors to manage hazardous waste material and should be provided with the necessary safety equipment like goggles and gloves. Another recommendation, is to introduce disaster management as a mandatory training for all LGOs since there is a significant number of officers who not aware and familiar with the Disaster Management Act of 2005.

3.5.2. Integration of pandemic into DRR:

The integration of pandemic response into DRR planning is suggested to overcome the issue of limited priority for disaster risk reduction in the country. According to INT5, a second wave of the pandemic is anticipated. Hence, integrating pandemic response measures into local level DRR planning would help LGAs take early action in dealing with future pandemics. Besides, a review of the PCs and LGAs mandates were recommended as necessary in order to mainstream pandemic into DRR.

3.5.3. Introduce representatives from LGAs for involvement in disaster management:

Based on legal and policy measures, LGOs can be appointed to disaster management committees to avoid the minimum representation of LGAs in such committees at the local level. Each district must establish a disaster management council that includes representatives from the LGAs. Such Councils were established temporarily to respond to COVID-19 pandemic and the interviewees suggested that these councils should function throughout the year to respond to any future disasters.

3.5.4. Provision of resources:

LGAs' can be empowered by increasing the carder provisions. The existing carder policies date back to 1940s enacted under the Pradeshiya Sabhas. To address the limited financial allocation for LGAs controlling the COVID-19 situation, additional financial support from the central government must be allocated to the LGAs in order to address the financial constraints experienced in containing the pandemic. Such extra allocation is essential to respond to a potential second wave of COVID-19, as the existing monetary reserves have been used to contain the first wave. Extra funding can be used to purchase necessary equipment and expand infrastructure capacity. The recommendation was to increase the budget of the LGAs to include at least an allocation of LKR 3 million as a disaster management reserve.

3.5.5. Introduce proactive DRR:

The interviewees recommended introducing proactive measures to prioritise DRR. One such strategy is to redefine the terms disaster and disaster management. The present circulars and procedures allow the Ministry to react to natural disasters. Nevertheless, the existing system should allow the Ministry to act in pre-disaster scenarios in a proactive manner. Disaster preparedness must be considered as a priority of the DRR and DM mechanisms of Sri Lanka. Proactive measures should be specifically introduced to

manage biological disasters in the future with the experience gained from managing the COVID-19 pandemic.

3.5.6. Strengthen coordination among various stakeholders:

Minimum coordination between stakeholders was identified as a challenge faced by LGAs. All LGAs should be incorporated in Sri Lanka's DRR process which would reduce the coordination and duplication of work and wastage of resources caused due to lack of communication between stakeholders. Sectorlevel coordination amongst various local government stakeholders could be improved by creating sustainable inter-stakeholder partnerships.

3.5.7. Due recognition for the service rendered by LGAs:

The overall governmental administrative hierarchy must recognise the service rendered by the LGAs to avoid disappointment among LGOs. Appreciation of LGOs will ensure higher human resource productivity amongst the LGAs. Similarly, a consultative workshop with commissioners of local government in Provincial Councils, Sri Lanka Institute of Local Governance, representatives from the Association of Mayors and Chairmen of Local Authorities (LAs) must be organised to identify the role of local governments in Epidemic Risk Reduction (ERR), with specific reference to pandemic and epidemic responses.

3.5.8. An efficient chain of communication:

An efficient chain of communication must be established between the Ministry and the LGAs either by nominating a focal point or introducing a hotline. Efficient communication will support LGAs to reach the Ministry in times of need and to reduce the existing gap in disseminating relevant information. Such a chain of communication also avoids the duplication of work and the abuse of power between agencies. LGAs are required to act as "information hubs" and hence, such local agencies must be well informed of existing realities.

3.5.9. Establish Inter-Agency Accountability in terms of DM:

There should be a system of "Inter-Agency Accountability" established in terms of DM. The inter-agency accountability avoids the issue that each governmental agency seeks to conduct its programmes without any responsibility and accountability to the other agencies. It is needed to establish a system where by PCs and LGAs can monitor DRR interventions during an epidemic or pandemic

3.5.10. Provinciallevel DR framework:

A Provincial Council Disaster Response Framework must be adopted for the nine PCs operating in the country. Such a framework would direct the PCs to develop localised DRR and DM plans based on the unique circumstances of each province in terms of the propensity for disaster exposure. Based on this, a technical and an operational guideline can be prepared for pandemic and epidemic riskbased planning and disaster management at GN level.

3.5.11. Establishing an adequate Early Warning System (EWS):

The necessity of an adequate early warning was proposed for districts that experience natural disasters. In most localities, EWSs are restricted to a set of loudspeakers that are connected to a three-wheeler which goes around the local villages communicating about potential occurrences of any disasters.

3.5.12. Locallevel DM council:

Each district can establish a disaster management council that includes representatives from the LGAs. During the COVID-19 pandemic, such councils were established temporarily to respond to the pandemic. The recommendation of the interviewees was to continue such councils throughout the year to respond to various disasters in the future.

3.5.13. Implementing the National Emergency Operations Procedures (NEOP):

DM plans of different agencies should conform to the National DM plan and the National Emergency Operation Plan of the DMC. Various DM activities must encompass the Provincial and local government set up along with the support extended by the DMC and other nationallevel institutions. This aspect should receive the highest priority.

4. CONCLUSIONS

LGAs are identified as the closest and most suitable institution for handling disasters. During the outbreak of COVID-19, the Sri Lankan LGAs have proven the capabilities by rendering the services across many aspects in pandemic response and handling relevant matters. However, the role of LGAs has not been adequately recognised and incorporated into the present disaster management system in Sri Lanka. This study provides adequate and substantiated evidence to consider integrating LGAs with the present disaster management system in Sri Lanka. While performing the services during the COVID-19 pandemic situation, LGAs have faced several challenges and this study provides recommendations based on the interviews conducted. As per the findings of the study, policymakers can introduce necessary interventions to address the challenges towards building a resilient society, to face the emergence of a second wave of the COVID-19 pandemic in Sri Lanka.

ACKNOWLEDGEMENT

This project is funded by UK Research and Innovation through the UK Government's Global Challenges Research Fund (GCRF) and the Newton Fund [grant number EP/V026038/1]. UK Research and Innovation accept no liability, financial or otherwise, for expenditure or liability arising from the research funded by the grant except as set out in the Terms and Conditions or otherwise agreed in writing.

REFERENCES

Amaratunga, D., Fernando, N., Haigh, R., & Jayasinghe, N. (2020). The COVID-19 outbreak in Sri Lanka: A synoptic analysis focusing on trends, impacts, risks and science-policy interaction processes. *Progress in Disaster Science*, *8*, 100133.

Bajracharya, B., Childs, I., & Hastings, P. (2011). Climate change adaptation through land use planning and disaster management: Local government perspectives from Queensland. 17th Pacific Rim Real Estate Society Conference,

Col, J. M. (2007). Managing disasters: The role of local government. *Public administration review*, *67*, 114-124.

Collins, M. L., & Kapucu, N. (2008). Early warning systems and disaster preparedness and response in local government. *Disaster Prevention and Management: An International Journal*.

D'Souza, C. (2020). GRID Index: Tracking the Global Leadership Response in the COVID-19 Crisis. In.

Dzigbede, K. D., Gehl, S. B., & Willoughby, K. (2020). Disaster resiliency of US local governments: Insights to strengthen local response and recovery from the COVID-19 pandemic. *Public administration review*, *80*(4), 634-643.

Ediriweera, D. S., de Silva, N. R., Malavige, G. N., & de Silva, H. J. (2020). An epidemiological model to aid decision-making for COVID-19 control in Sri Lanka. *PloS one*, *15*(8), e0238340.

GOV.SL. (2009). *National Policy on Local Government* Sri Lanka: Government of Sri Lanka

Hettiarachchi, D., Noordeen, N., Gamakaranage, C., Somarathne, E. R. B. D., & Jayasinghe, S. (2020). Ethical Responses to the COVID-19 Pandemic—Lessons from Sri Lanka. *Asian Bioethics Review*, 1-9.

Jayatilleke, A. U., Dayarathne, S., de Silva, P., Siribaddana, P., Abeygunawardana, R. A., Nieveras, O., de Silva, N., & de Silva, J. (2020). COVID-19 case forecasting model for Sri Lanka based on Stringency Index. *medRxiv*.

Khan, M. R., & Ara, F. (2006). Women, participation and empowerment in local government: Bangladesh union Parishad perspective. *Asian Affairs*, *29*(1), 73-92.

Kusumasari, B., Alam, Q., & Siddiqui, K. (2010). Resource capability for local government in managing disaster. *Disaster Prevention and Management: An International Journal*.

MacAskill, K., & Guthrie, P. (2016). Disaster risk reduction and empowering local government–a case comparison between Sri Lanka and New Zealand. *International Journal of Disaster Resilience in the Built Environment*.

Malalgoda, C., Amaratunga, D., & Haigh, R. (2016). Overcoming challenges faced by local governments in creating a resilient built environment in cities. *Disaster Prevention and Management: An International Journal*, *25*(5), 628-648. https://doi.org/10.1108/DPM-11-2015-0260

Manda, M. Z. (2014). Where there is no local government: addressing disaster risk reduction in a small town in Malawi. *Environment and Urbanization*, *26*(2), 586-599.

Ministry of Disaster Management. (2010). *National Policy on Disaster Management*. D. S. R. o. S. Lanka.

Ministry of Disaster Management. (2014). *Sri Lanka Comprehensive Disaster Management Programme 2014-2018*. Sri Lanka: Ministry of Disaster Management

Phillips, B. D. (1997). Qualitative methods and disaster research. *International Journal of Mass Emergencies and Disasters*, *15*(1), 179-195.

Saito, T. (2007). Disaster management of local government in Japan. National Workshop, organized by UNCRD and Japan-Peru Center for Seismic Research and Disaster Mitigation (CISMID)/Peru National University of Engineering (UNI),

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (Eighth ed.). Pearson.

Solway, J. S. (2004). Reaching the Limits of Universal Citizenship:'Minority'Struggles in Botswana. *Ethnicity and democracy in Africa*, 128-147.

UN-ISDR. (2012). *How to make cities more resilient: a handbook for local government leaders,* .

WHO. (2021, 30 06 2020). *Coronavirus disease (COVID-19) pandemic*. World Health Organization. Retrieved 12 01 2021 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019

World Vision. (2020). *COVID-19 Global Health Emergency Response in Sri Lanka: Keeping our children and communities safe*. World Vision. Retrieved 14 02 2021 from https://www.wvi.org/covid-19-response-srilanka

Health resilient cities in a post Covid world

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ABSTRACT

Since the World Health Organization (WHO) declared the coronavirus infectious disease 2019 (COVID-19) outbreak a pandemic on 11 March 2020, the everyday lives of the whole global population have been drastically changed. Lockdown shortened many of the physical worlds to homes and immediate neighbourhoods. Since the beginning of the COVID-19 pandemic, multi-unit residential buildings/apartments/condominiums have been of particular concern to both public health practitioners and the occupants due to the enhanced risk they faced. There is an immense trend in constructing condominiums. Sri Lanka is particularly investing in condominium development for luxury housing as well as to resettle low-income communities. Given the circumstances, it was required to investigate what are the additional risks/exposures that inhabitants of the condominium developments faced during the CoVID19 and how that can be overcome in a future pandemic scenario to support creating health resilient cities. This study is as reported in this chapter is based on a detailed literature critique. It is also framed as a preliminary study that is aimed at supporting the development of an in-depth future study. Accordingly, an exploratory literature review was carried out with 41 published literature which included journal papers, books, online research reports and news articles.

Results of the study indicated the need to rethink how we design, develop and construct condominiums that can massively support to enhance the social, economic, physical lives of people and thereby support to create health resilient future cities. Sri Lanka is heavily investing in condominium developments should consider these factors in constructing condominium developments to ensure that future cities are health resilient.

Key words: Condominium development, Health resilience cities, Pandemic

1. INTRODUCTION

1.1. Cities, High rises and Covid 19

Today, 55% of the world's population live in urban areas, a proportion that is expected to increase to 68% by 2050 (UN DESA, 2018). Condominium living near to the city center is very popular and demanding as people intend to find a residential space close to the city center (Rosen & Walks, 2013). Growth of white-collar office employment, mainly that in the finance, insurance and real estate sectors, but, also in government institutions which tend to be located close to the urban cores has increased the demand for a residential place close to the city centre (Ley, 1996; Walks & Maaranen, 2008). Multi-unit apartment buildings are no longer for social housing, but, a demanding residential living space for the middle and upper classes (Ford, 1994). Gottmann, (1966) informs that high-rise buildings reflect the landscape of the modern era, expressing the social,

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economic and intellectual evolution of urban society. Young adults and families, typically without kids tend to live in higher-density settings in condominium developments as Condo-living offers a low maintenance burden and the possibility to reside at central locations near work (Rosen & Walks, 2013). Further, condominium living offers a 'bundle' of other attributes, such as *amenities, security, image, social opportunities*, *a range of transportation options and living close to cultural attractions* (Rosen & Walks, 2013).

Currently, under different forms of lockdown millions of people staying inside and working at home. Since the beginning of the COVID-19 pandemic, multi-unit residential buildings/apartments/condominiums have been of particular concern to both public health practitioners and the occupants (Eykelbosh, 2021). In the UK, as average house sizes fall, and there is a headlong rush to fill London and core cities with micro-apartments aimed at young professionals and students, many living under the government's COVID-19 lockdown are trying to home-work, not in well-appointed homes, but, in apartments where living, sleeping and eating spaces are often combined (Hubbard, 2020). Dwellers who work from home in small apartments sharing space with others, face multiple problems of interruption and noise disturbance and have to compete with others to secure a suitable workstation. Recent social media accounts have revealed some of London's workers resorting to working on fire escapes or in hallways just to escape from their roommates (Hubbard, 2020). Further, apartment dwellers face a host of additional risks, because, those living in apartments are exposed to shared facilities such as elevators, common rooms, and mailboxes (RentSeeker Team, 2020).

Accordingly, it is evident that COVID19 has profoundly impacted our condominium living in cities and it highlights the large influence that our housing has on our lives and wellbeing. Therefore, COVID19 has provided us with a platform to rethink our cities and housing policies in a post-covid world.

1.2. The concept of Health Resilient city within the context of COVID19

The terms, Health resilient cities, Healthy cities, Resilient cities, Sustainable cities are interchangeably used in the literature, yet ill-defined and sometimes used with an incongruity to the context. Therefore, it is vital to understand 'What is a Health Resilient City?' and what elements need to be considered under the concept of 'Health Resilient City' within the concept of COVID19.

The term 'resilient city' became popular with the challenges posed by global climate change and the increase of the severity and intensity of the disasters and conflicts around the world. Accordingly, the 'Resilient cities' are cities that can absorb, recover and prepare for future shocks of economic, environmental, social & institutional challenges (OECD, 2021). A Resilient city should always promote the enhancements of sustainable development. With this idea, the 'Healthy cities' concept came promoting the idea that cities can produce cleaner air; sustainable modes of transportation and the introduction of the exploitation of the water cycle, greywater recycling, storage, design to rainwater harvesting and so on.

However, the challenges that emerged from the COVID-19 global pandemic, made us rethink and revisit these concepts. Moreover, placing public health at the priority, the COVID-19 outbreak demands the necessity of a 'health resilient city'.

Resilience does not imply a return to dysfunctional or unsustainable community conditions, but adaptation to dynamic social and ecological conditions in ways that protect and enhance the quality of life, long term ecological productivity and public and personal health (Beatley & Newman, 2013). Two factors that can be extended to the city context is that cities should not return to dysfunctional or unsustainable community conditions, instead, they should protect and enhance the quality of life and public health. The coronavirus pandemic has at least temporarily significantly reconfigured city life the relation of work and

residence, and leisure, use of public space, safety and security of transportation, both public and private and posed fundamental equity of access to resources (Banai, 2020). Therefore, each of these elements of the city has a role to play in resisting, absorbing, and recovering from the effects of pandemic and public health issue. Health Resilience also needs to be created by strengthening health systems, meeting the needs of vulnerable populations, and promoting organizational competence, social connectedness, and psychological health, community resilience encourages actions that build preparedness, promote strong day-to-day systems, and address the underlying social determinants of health (Wulff et al., 2015).

Combining the above with the UNDRR definition for resilience (UNDRR, 2021), Health Resilient City can be defined as the ability of a city exposed to public Health crisis to resist, absorb, accommodate, adapt to, transform and recover from the effects of a health crisis in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions to protect and enhance the quality of life and public health.

Accordingly, the focus of this study is to evaluate the COVID risk associated with the condominium developments and how condominium developments could potentially support the creation of a health resilient city by enhancing the social, physical, psychological, environmental and economic lives of the inhabitants of condominium developments in a post-covid world.

1.3. Sri Lanka and Condominium developments

In Sri Lanka, condominiums are now a popular solution to the growing housing demand, mainly due to the prevailing scarcity and the cost of land (LBO, 2020). According to the certifications issued by the Condominium Management Authority (CMA), the absolute rate of growth of condominiums during the past decade is 34%, while it has increased by an unprecedented 64% in 2017 alone, compared to 2016(LBO, 2020). There are three types of condominium housing schemes in Sri Lanka, *luxury multi-storey housing schemes, semi luxury middle class housing schemes* and *multi-storey housing schemes for low-income earners* (DailyFT, 2021).

In 2003 there were around 48 luxury apartments and in 2016 there are 96 luxury apartments in Colombo and there are about 24 luxury apartments available for commencement (Bandara et al., 2020). The Urban Development Authority (UDA) states that over fifty percent of the Colombo city population lives in shanties, slums or dilapidated old housing schemes, which occupy nine percent of the total land extent of the city. Accordingly, UDA aimed to make the city free of shanty dwellers by 2020 by relocating them into low-income condominium developments (JLL Lanka, 2017). One of the key examples for low-income condominium development is the Sahaspura development project which was the biggest high-rise relocation programme undertaken in Sri Lanka, housing 671 households in 671 units over 14 floors (Samaratunga & O'Hare, 2014).

Despite the type of the condominium development, DailyFT, (2021) summarises the following reasons as the key reasons for the rapid trend in condominium living in Sri Lanka,

- The population shift from rural to urban areas
- Limited availability of lands in urban areas required for housing purposes.
- Possibility of constructing a large number of houses in a relatively small area
- People looking for houses in urban areas to admit their children to popular urban schools
- An extremely busy lifestyle compels people to live in an environment where all amenities are available
- Preference of increasing number of tourists visiting Sri Lanka to stay in condominium housing units at more concessionary prices rather than staying in hotels
- Better protection offered by condominium living as compared to living in a separate house.

1.4. The gap

Currently, a large number of dwellers in high rise apartments in Sri Lanka are in lockdown. Therefore, in this context, it is important to assess how condominium living in Sri Lanka have affected the lives of people during the lockdown. Accordingly, section 3.1 describes the gaps associated with condominium living during the pandemic, at the general scale and then how they are associated with the Sri Lankan context. Finally, the learning points identified from this literature review are explained with reference to Sri Lanka in creating a health resilient city in a future pandemic scenario.

2. METHODOLOGY

This is a desk-based study that employed an exploratory literature review. Based on the background and the research problem, the following initial questions were posed for the exploratory literature review.

1. What were the development trends and patterns of the condominiums prior to Covid19?

2. What are the risks/problems condominium dwellers face during Covid19?

3. What is a health resilient city?

4. What are the possible solutions to make cities health resilient with reference to condominium development?

Unlike a narrative literature review, the purpose here was to provide a broad approach to the topic area and to get an initial idea about the problem. The aim of this study was preliminary breadth rather than investigative depth. Accordingly, grey literature including government reports, news articles and online research reports have been reviewed in this study. In addition to that available academic papers were also referred to in this study. Table 1 provides a summary of the types of articles that have been reviewed for this study.

Table 1. Summary of the sources

Type of publication	No.
Journal papers	11
News articles	10
Research reports and online databases	15
Government reports	2
Books	3
Total	41

2.1. Limitations and Prospects of the Study

As mentioned above, the purpose of this study was mainly to provide a brief outline of the research problem, therefore, the review is more general than an in-depth literature review. Consequently, the findings of this study need to be further investigated through a comprehensive literature review, supported via fieldwork, before arriving at more detailed conclusions. However, this study provides a foundation for the researchers to conduct similar research in this area. Further, the research team here intends to conduct a comprehensive study on this area and this study acted as the preliminary point to begin the study.

3. RESULTS AND DISCUSSION

3.1. Risks/Problems Condominium Dwellers Face during Covid19

Lockdown restricted many of our physical worlds to our homes and their immediate neighbourhoods. However, the roles we needed to perform there expanded. Homes became offices, classrooms and gyms. Technology filled gaps and allowed homes to become remote social spaces (Carmona, 2020). While lockdown rules affected all people, the literature indicates people in condominium developments faced extra risks and problems due to the living arrangements in condominiums.

3.1.1. Limited Living Space, Lack of Greenery and Mental Health-related Issues

Globally, during the lockdown, individuals who lived in small apartments without habitable balconies, with a poor housing quality such as a little natural lighting and acoustic comfort, a

low thermo-hygrometric comfort, the absence of soft qualities in the living quarters (e.g., art objects, green plants), and living spaces, that do not guarantee adequate privacy during phone calls for work or personal reasons suffered from moderate to severe depressive symptoms. Views through a window of a condominium dweller have played a significant role in enhancing mental health. People with a greenery view had a better mental status compared to the others who had a view of another building (Amerio et al., 2020). Further, households with a private garden or terrace space, a balcony or a shared garden were comfortable during the lockdown. Households with no access to any sort of private open space were considerably less comfortable during the lockdown (Carmona, 2020). People living within a five-minute walk of a park or significant green space was the strongest predictor of satisfaction with neighbourhoods during lockdown (Carmona, 2020). As a result of impacts on mental health, domestic violence is reported to have increased 25% since the onset of the UK lockdown, some no doubt due to the pressures of sharing restrictive domestic spaces (Hubbard, 2020). Homeworking in small homes adds to the stress of everyday life, and the impossibility of separating home and professional life can exacerbate existing work-related anxieties and depression (Hubbard, 2020).

In Sri Lanka, many areas with low-income condominium developments were in a prolonged lockdown. Methsanda Sewana and Mihijaya Sewana in Modara, Randiya Uyana in Mattakuliya, Muwadora Uyana and Samagipura in Grandpass and Mihindu Sethpura in Dematagod are all low-income apartments that were in a lockdown where residents were asked to remain indoors (Warakapitiya, 2020). The average plot size of these condominiums is 442 square foot which consists of two bedrooms, an attached bathroom, kitchen, living room and a balcony (MirorCitizen.lk, 2018). Figure 1 is the outlook of the 'Sahaspura' low-income settlement in Sri Lanka.

With prolonged isolation living in an apartment with only 442 square foot has put dwellers under extreme stress which resulted in protests against isolation orders. For example, Residents of the 'Methsanda Sevana' housing scheme in Henamulla, Modara, launched a protest on 06th of December 2020 against the isolation orders (Udayanga, 2020).

Further, in Sri Lanka, 90% of small condominium developments (number of units ranging from 15 to 65) and 50% of large condominium developments (over 65 units) have less than 1% of green space on site (Rajapaksha & Jayaweera, 2018). A report published by UNDP Sri Lanka (2020) with reference to their staff living in lockdown informs that having at least some small green spaces along the balcony in an apartment helped to reduce the stress and anxiety during the lockdown. Cultivating green plants such as chillies, ginger, onions have given a better mental satisfaction during the lockdown in living in an apartment (UNDP, 2020).

People living in apartments in a small space and less view or access to green space had created a chaotic situation, therefore, Police in

Figure 1. Outlook of 'Sahaspura' low income settlement in Sri Lanka (USDA, 2020)

Sri Lanka was using music to help people in apartments in coronavirus-hit areas to stay calm (IANS, 2020).

Accordingly, the above literature suggests that we need to reverse the recent trend of creating smaller apartments and change the way we design urban spaces in the future in order to tackle the existing issues and to support the creation of a health resilient city.

3.1.2. Common Space Use and Exposure to Risks

Since the beginning of the COVID-19 pandemic, multi-unit residential buildings (MURBs) have been of particular concern to both public health practitioners and MURB occupants (Eykelbosh, 2021). People who live in multi-unit residential buildings have a higher risk of getting COVID-19 due to extensive use of common or shared spaces, such as handrails, lifts, door nobs. Apartment complexes have closed and/or put heavy restrictions on common areas like gyms, pools and clubhouses, but it's hard to avoid places such as mail and laundry rooms (Bagenda, 2020). Transmission from high-touch surfaces is considered a 'fomite' transmission (Eykelbosh, 2021). Unfortunately, it was very difficult to investigate/track the fomite transmission, because people are unlikely to remember their movements in minute detail. In addition, common areas are regularly cleaned, especially if an outbreak is declared (Eykelbosh, 2021). Further, Eykelbosh (2021) indicates that riding in an elevator masked or unmasked longer with each other increases the opportunities for transmission of the virus.

In Sri Lanka, several regulatory reforms have been implemented in recent years to relocate 66,000 low-income people from underserved settlements into high-rise housing (Karunanayake, 2020). This indicates people with a low educational background are highly exposed to the use of shared facilities in condominium developments. Accordingly, the Urban Settlement Development Authority (USDA) conducted an awareness programme on 'COVID 19 Prevention and Control' in July 2020 to the residents of the 'Shahaspura' low-income settlement to control the spread of the disease due to extensive use of shared spaces such as receptions rooms, stairways and elevators (USDA, 2020). In addition, sanitary measures such as having washbasins and sanitisers outside the common spaces have been made compulsory as a precaution to control the spread of the virus (Erandi et al., 2020).

This indicates that there is a need to have special measures in using shared spaces to reduce the exposure of condominium dwellers in a future pandemic scenario.

3.1.3. Airflow in Apartments and Potential COVID risk

Heating, ventilation and air conditioning (HVAC) systems have been considered as potential source of contamination. There are two key concerns around HVAC systems. The first is the use of re-circulated air, which is a necessary feature of some HVAC systems, as continuously heating/cooling 100% outdoor air can be cost-prohibitive or simply beyond design specifications. The concern is that stale air carrying a viral aerosol could be collected from one room and delivered to other rooms connected to the same air handling unit, spreading the virus if not removed through filtration or some other air cleaning device. To date, there is no evidence of HVAC systems facilitating transmission in this way. There have been instances in which the SARS-CoV-2 virus has been detected in filters and in ducts, which is exactly where one would expect the virus to end up after having been drawn out of the room. However, there is (currently) no evidence of transmission occurring across different rooms or zones of a building through the HVAC ductwork (Eykelbosh, 2021). HVAC systems in large residential buildings are not spreading COVID-19 by moving the virus from one dwelling to another, but, multiple studies have shown that large air-handling systems can filter out viral particles from the air and knock down the spread of the virus (Tate, 2020). Several scientific studies conducted by various leading scientists, informs, if someone

is infected in an inside environment, others are much more likely to inhale the virus in those smaller microscopic particles, because they float around in the air longer and can travel more than 3 to 6 feet (Tate, 2020). Accordingly, in that circumstances, large ventilation systems such as HVAC are "highly effective" at capturing and filtering out those tiny particles in the air. Accordingly, there is no evidence that HVAC systems in large facilities can suck in, store, and spread the coronavirus from one apartment or condo to another. But if viral particles are already in the air inside a room, the venting from HVAC units can spread it around, as in the case of the Chinese restaurant in Guangzhou (Tate, 2020).

The above evidence confirms that corridors, reception areas of apartments with HVAC systems can spread the virus from one to another. Most of the luxury apartments in Sri Lanka are fully air-conditioned including the corridors, reception areas and other shared facilities. The Chief Epidemiologist of the Epidemiology Unit, of Sri Lanka, informs, a person in a small room with closed doors and windows, especially in an air-conditioned area is at a high risk to spread the virus to another person (Perera, 2021). Further, considering the risk in air-conditioned enclosed areas, the Epidemiology Unit, Ministry of Health & Indigenous Medical Services, (2020) Sri Lanka, suggested keeping the doors open wherever possible to reduce the circulation of the same air. Further, the Ministry of Health (2020) issued general guidance to the public on the prevention of COIVD 19, it specifically posed the threat that airconditioners could spread the disease and advised that Air filters should be cleaned weekly and AC drain water should be discharged properly to the drain system. These evidence indicators that enclosed air-conditioned spaces in condominium developments pose an additional risk to spread the virus and therefore, it is required to find additional measures to overcome this situation in a future pandemic scenario.

3.1.4. Air Duct, Sewer pipe, U bends and COVID Risk

Some condominiums especially older buildings are connected through communal ducts that allow aerosol exchanges. It is more than likely that the ventilation system allows air to flow from one apartment to another with only a grille by way of a barrier. In these buildings, opening a door or a window, using the kitchen exhaust fan, and temperature changes between two apartments all create a constant movement of air that seeks to occupy any free space. In just five minutes, all the air from one bathroom can pass to another through the air ducts if they are not fitted with filters or other devices to prevent the air from making its way in. The suction caused by the kitchen exhaust fan can renew 100% of the air in a 100-square-meter apartment in 100 minutes. If the windows are closed in buildings with old air ducts, this "new" air will come from one or more neighbouring apartments (Galloway, 2021). Accordingly, it is assumed that transmission may occur in these circumstances. See Figure 2.

An epidemiological study in a building in Seoul, South Korea where there were eight Covid-19 infections in five apartments sharing bathroom ventilation, concluded that there was "no other possible contact" between those infected other than their communal air duct (Galloway, 2021). Figure 3 further explains the aerosol transmission in Seoul South Korea.

Eykelbosh (2021) identifies, a "plumbing stack" refers to the interconnected drainage and ventilation pipes that run vertically down the interior of the building that can also transfer the virus in cases where the plumbing has been altered or if drain traps are allowed to dry out. A typical configuration of a plumbing stack involves one or two "soil" or "drain" stacks that collect blackwater and/or greywater, respectively, which are then cross-connected to an air-filled ventilation stack or "vent stack." The purpose of the vent stack is to exhaust odours and to also equalize pressure between the plumbing and the outdoor environment so that the soil and drain stacks can flow freely and noiselessly. Although plumbing stacks

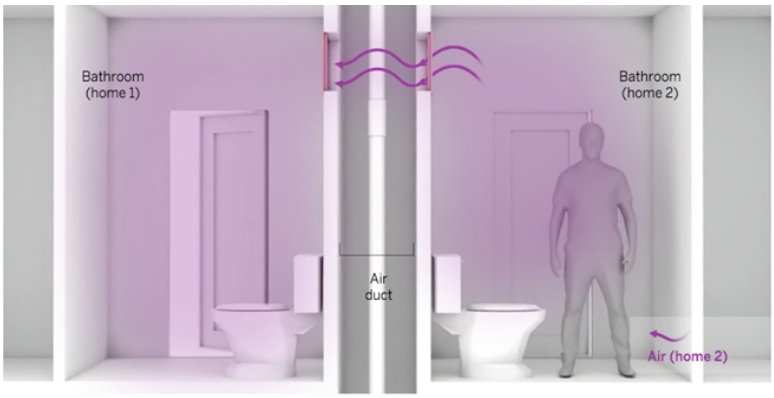

Figure 2. Air duct transmission of air floor from one bathroom to another(Galloway, 2021)

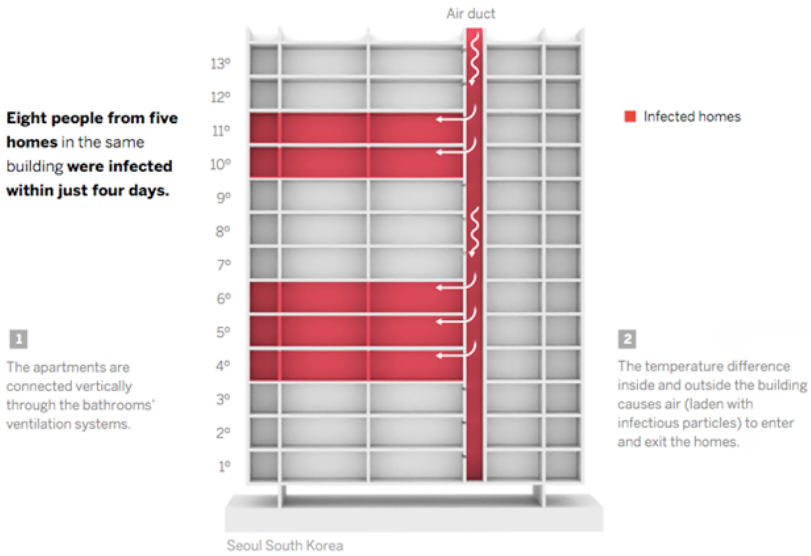

Figure 3. Air duct transmission, Seoul, example (Galloway, 2021)

vertically connect all the units built over top of one another, the stacks and associated plumbing are designed to ensure that gas/odours cannot flow back into the individual units (e.g., through water-filled drain traps or other mechanisms). However, as Eykelbosh (2021) explains, cross-contamination is possible where the plumbing has been altered or if drain traps are allowed to dry out.

During the current COVID-19 pandemic, (Kang et al., 2020; Lin et al., 2021) did a combination of airflow analyses, meteorological analysis, tracer gas studies, and CFD (Computational fluid dynamics modelling) modelling to separately examine the same outbreak in a 29-floor block of a large MURB in Guangzhou, China. Together, the two studies indicated that the virus deposited into the toilet was aerosolised into the soil stack (due to agitation while flushing) and was then borne upward through the soil stack or cross-connections into the ventilation stack. The viral aerosol was then drawn into the connected upper-floor washrooms through unsealed drain traps, which survey data suggested were typically left dry. Movement through drain traps was facilitated by both the negative pressure in the bathrooms created by wind effects, as well as impeded egress of air through

an inappropriately modified ventilation stack opening at the top of the building. Although the studies did not isolate the viable virus in aerosol form moving through the pipes (which is extremely unlikely after infected cases have been removed), the published studies provide fair evidence that air was able to move between bathrooms. Sequencing of the SARS-CoV-2 S gene indicated that all three affected units were infected with the same strain (Eykelbosh, 2021).

Adding to this argument, Gormley (2020) indicates when U-bends are dry, contaminated air can move freely in and out of the living space in question. Such buildings are also more prone to large pressure surges from overuse when lots of people are at home, which can force water out of U-bends and break their "seal". During the lockdown, the U-bends in the plumbing in large buildings are particularly vulnerable to water seals being blown out from the added pressure of more people using these systems at the same time than usual. The same risks, incidentally, can come from the water in U-bends evaporating because of plumbing being underused – even in a lockdown there will be old sinks or bathroom floor drains in flats that don't get used. Figure 4, below demonstrates how a dry U bend can transfer contaminated air to another apartment.

The above literature evidence clearly indicates that air ducts, sewer pipes and U bends can bring additional risk in a pandemic and actions to be taken in the future to be resilient in a future pandemic.

In Sri Lanka, there is no direct evidence to determine that Air Ducts, Sewer pipes and U bend carried an additional COVID risk for the condominium dwellers. But, there is strong evidence to justify that several COVID outbreaks occurred in low-income condominium developments even people were asked to remain inside their houses without any other contact. In November 2020, multiple low income housing complexes have been designated as high-risk zones and all occupants had to remain indoors which completely restricted their movements and having contacts with their neighbours (Farzan, 2020). Even in this condition, outbreaks occurred in more than 13 low-income condominiums where most of these areas were in complete isolation for more than 51 days (Borham, 2020). However, there is no single report to demonstrate that luxury apartments areas in Colombo have been identified as high-risk areas. In this context, there is evidence which states that building maintenance and management of low-income condominiums are poor in Sri Lanka. As Fernando (2017) states, most of the state-led public housing projects especially carried

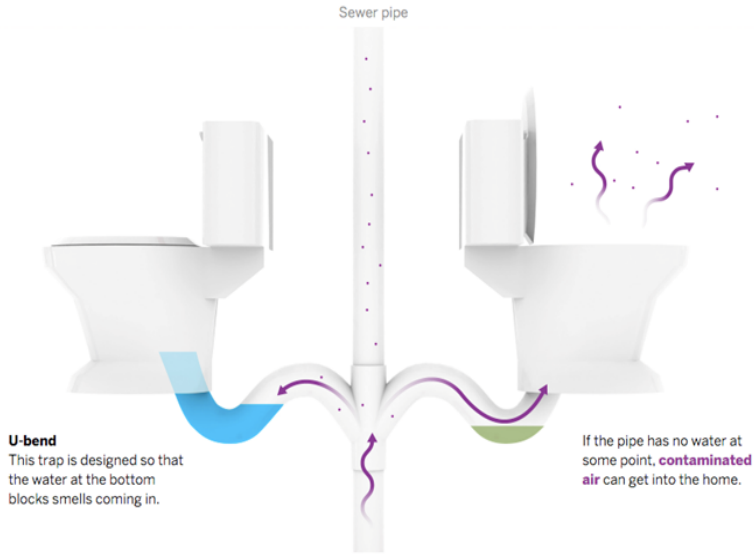

Figure 4. Dried U bend and transfer of contaminated air (Galloway, 2021)

out for urban under-served settlers, have suffered severe deterioration due to the poor maintenance and management of the building structures and their infrastructure, including solid waste systems, sewerage and drainage. This indicates that there could be a very strong relationship with the extensive virus spread in low income apartments and the condition of the air ducts, sewer pipes and u bends. This emerges as a research problem which needs further investigation.

3.2. Learning points to tackle these issues

One would argue severe trend in condominium development should be scaled down or one would argue measures should be taken while facing the reality of persisting trend in a condominium development. Following are some of the learning points that are identified from the literature review to tackle the issues identified above. These learning points are relevant to the condominium development context of the Sri Lanka as well.

3.2.1. Condominiums with more spacious living space, with access to private space, public open space, green view, and greenery

Hubbard (2020) argues dense urban living may be more environmentally-friendly, and energy-efficient. But, if the price to pay is people living in smaller homes that preclude flexible working and home lives, and also encourage the transmission of COVID-19, or other yet-to-be-known viruses, perhaps the answer is not to continue the rush towards vertical living and micro-apartments. Instead, Hubbard (2020) suggests thinking about using urban space better to provide meaningful personal space and the opportunity to spend at least some time apart from one another. A home comfort survey conducted by the UCL with the responses of 2,500 households across the UK during the early summer of 2020 indicates people with private open space from the home was extremely important. Households with a private garden or terrace space were very comfortable during the lockdown, followed by those with a private balcony or shared garden. Households with no access to any sort of private open space were considerably less comfortable (Carmona, 2020). Further, Good environmental conditions in the home, notably fresh air, daylight and good noise insulation, were widely seen as fundamental (Carmona, 2020). Accordingly, Carmona (2020) stresses that we need to learn from the stress test that lockdown has given our homes to build better living environments and to retrospectively adapt to those we are living in today. This means decent space and environmental standards in the home and access to private open space is required – even if just a balcony. Further, neighbourhoods should be walkable and cyclable, with convenient access to parks and local facilities, high-quality streets and public spaces. Particular care is required to balance all these needs when building neighbourhoods that are dense and high.

Further, there is a strong association between poor housing and moderate-severe and severe depressive symptoms, with particular reference to living in apartments that are small and have a poor-quality view and indoor area. Accordingly, the built environment is a key determinant of health, the quality of which depends on the availability of resources, site location planning, and green spaces. Housing design strategies should be focused on larger and more livable living spaces facing green areas. An interdisciplinary approach involving urban planning, public mental health, environmental health, epidemiology, and sociology is needed to investigate the effects of the built environment on a mental health outcome (Amerio et al., 2020).

3.2.2. Awareness Programs on the Risk Associated with the Use of Shared Spaces

If we are to continue with condominium living, even with more access to green and public open spaces, the high exposure to a pandemic due to the use of shared spaces persists. Therefore, research suggests providing more awareness on the risk associated with the use of shared spaces should be increased and continued even after the Covid19 as then people will be well trained to face a future pandemic.

Condominium management must maintain enhanced cleaning programs and continue engaging occupants on other standard public health measures, like hand hygiene and mask use. Further, Eykelbosh (2021) suggests due to "pandemic fatigue," it may be necessary to periodically refresh communications strategies to sustain occupant engagement. Liu et al. (2021) explain people lacked the awareness of correct transmission routes during the outbreak of COVID 19. In that regards, it suggested that local agencies should provide information in simple languages to support those with no college education during an outbreak. An informative presentation in the form of a workshop will also help to increase the awareness of people to enhance resilience for a future pandemic. For example, the USDA of Sri Lanka, conducted a workshop in July 2020 which provided awareness on prevention and control measures, demonstrations on proper handwashing techniques and the use of masks for the low-income condominium dwellers in Colombo, Sri Lanka (USDA, 2020).

3.2.3. Solving Airflow and Aerosol related issues

It is important that Heating, ventilation and air conditioning (HVAC) equipment that is installed in common areas of condominium developments are fitted with air filters. Eykelbosh (2021) suggests a properly maintained HVAC system is critical for supplying fresh air and removing stale or contaminated air. In older buildings dependent on corridor pressurization, HVAC is also critical for maintaining airflow and pressure differentials such that contaminated air from a suite does not leak into the corridor.

Condominiums that are recently built may not have an Air duct that could transfer a virus from one apartment to another. For example, In Spain, the bathrooms of older buildings are connected through communal ducts that allow aerosol exchanges. In 1975, building regulations were passed in Spain changing this system, but in older buildings – 37.7% of those existing today (Galloway, 2021). Accordingly, it is required to take actions to install modern methods in all buildings to stop the aerosol transfer from one apartment to another. Sri Lanka, as a developing country may need to look into this issue in particular and ensure correct measures are taken to stop the spread of a virus through toilet aerosols. Particularly, this might be the case in low-income condominium settlements in Sri Lanka. In addition to that Eykelbosh (2021) informs plumbing stacks need regular cleaning to ensure that wastewater can flow and that neither wastewater nor air can inadvertently backflow into bathroom or kitchen fixtures.

Also, in future, it is extremely important to make sure that all sinks and toilets have a functioning U-bend (Gormley, 2020). This should be included in condominium development guidelines and further, facilities managers should continually monitor the whole system performance of their buildings, looking out for things such as drainage problems and bad smells. Condominium dwellers should also be prepared to keep an eye on wastewater pipework from a toilet, sink or other household appliance as a practice in a COVID free world, but to be resilient for future pandemic scenarios.

Based on the above findings, following measures can be summarised as key learning points (Table 2) to improve the health resilience of Condominium developments and thereby to support the creation of health resilient cities in a future pandemic.

4. CONCLUSION

The global pandemic COVID 19 has changed the everyday lives of the whole global population. The way we work, study, shop, hang out, and play is drastically changed which certainly triggered new patterns in urban life. Since the beginning of the COVID-19 pandemic, multi-unit residential buildings or apartments/condominiums have been of particular concern to both public health practitioners and the occupants due to the enhanced risk they faced. There is no certain guarantee that our cities will not face a pandemic in the near future again or in the

Table 2. Summary of learning points

Issue	Possible measures
Lack of living space	• Revisit current condominium development guidelines and introduce new standards to increase the floor area
Access to a private space and access to fresh air	• Balcony to be included in condominium housing especially for low income condominium developments
Noise from room to room or apartment to apaprtment	• Intorduce proper noise filteration methods • Use appropriate noise filtering building construction materials
View to greenery	• Windows with views to greenery • Condominium layout with a view to a green not to another apartment • Increase the greenspace ratio
Access to greenery and open spaces	• Increase the green space ratio of condominium developments • Open outdoor spaces should be provided within the condominium development premises
Limited access to Parks and playgrounds	• Convenient access to parks and playgrounds from the condominium
Use of shared spaces and high exposure	• Condominium managements to introduce enhanced cleaning programs • Periodic awareness programs on the use of shared spaces and correct transmission routes
Airflow and Aerosol related issues	• Fitting and regular maintenance of air filters • Proper disposal of AC drain • Avoid air ducts in new condominums and install modern sewer systems for older condominium buildings • Regular cleaning of plumbing stacks • Functional U bends and install U bends • Regular checks on the whole drainage and sewer system performance • Introduce new condominium management guidelines for condominium management authorities on regular maintainence

distant future. On the other hand, the immense trend of constructing condominiums does not seem to be scaled down. Especially, Sri Lanka is particularly investing in condominium development for luxury housing as well as to resettle low-income communities. Therefore, it was required to investigate the additional risk that condominium dwellers faced during Covid-19 and how that can be overcome to reduce the risk in a future pandemic scenario to support creating health resilient cities.

Results of the study indicate creating a health resilient city involves many social, economic, environmental and physical factors, but, rethinking how we design, develop and construct condominiums can massively support to enhance the social, economic, physical lives of people and thereby support to create health resilient future cities. Large living spaces, access to a personal space (at least a balcony), view to greenery from an apartment window, access to public open spaces are some of the key factors which need to be reconsidered in constructing apartments in the future to enhance the mental health of people. Awareness of using common or shared spaces during a pandemic should be enhanced in a form of public education. Airflow and aerosol flow should be monitored in the existing condominiums and where required new aerosol and airflow methods should be introduced, especially for novel condominium developments. Facility managers have a key role in ensuring that these new methods are used in condominium developments and to support the practical implementation, building regulations should be updated in line with the requirements to create health resilient condominium developments. Sri Lanka as a country heavily investing in condominium developments should consider these indicators in constructing condominium developments.

REFERENCES

Amerio, A., Brambilla, A., Morganti, A., Aguglia, A., Bianchi, D., Santi, F., Costantini, L., Odone, A., Costanza, A., Signorelli, C., Serafini, G., Amore, M., & Capolongo, S. (2020). COVID-19 Lockdown: Housing Built Environment's Effects on Mental Health. *International Journal of Environmental Research and Public Health*, *17*(16), 5973. https://doi.org/10.3390/ijerph17165973

Bagenda, C. (2020). *Doctors: People who live in an apartment complex have a higher risk of getting COVID-19*. CBS58. https://www.cbs58.com/news/doctors-people-who-live-in-an-apartment-complex-have-a-higher-risk-of-getting-covid-19

Banai, R. (2020). Pandemic and the planning of resilient cities and regions. *Cities*, *106*, 102929. https://doi.org/10.1016/j.cities.2020.102929

Bandara, W. H. M. S. D., Rathnayake, R., Mahanama, P. K. S., & Wickramaarachchi, N. (2020). An investigation on community spaces in condominiums and their impact on social interactions among apartment dwellers concerning the city of Colombo. *Social Sciences & Humanities Open*, *2*(1), 100043. https://doi.org/10.1016/j.ssaho.2020.100043

Beatley, T., & Newman, P. (2013). Biophilic Cities Are Sustainable, Resilient Cities. *Sustainability*, *5*(8), 3328–3345. https://doi.org/10.3390/su5083328

Borham, M. (2020, December 13). *Isolation of seven housing complexes to be lifted soon—Army Commander | Sunday Observer*. Sunday Observer. http://www.sundayobserver.lk/2020/12/13/news/isolation-seven-housing-complexes-be-lifted-soon-army-commander

Carmona, M. (2020, October 13). *People living in newer homes found lockdown more difficult: New research*. The Conversation. http://theconversation.com/people-living-in-newer-homes-found-lockdown-more-difficult-new-research-147724

DailyFT. (2021, May 5). *Sustainable development of condominium housing schemes in Sri Lanka | Daily FT*. DailyFT. https://www.ft.lk/front-page/Sustainable-development-of-condominium-housing-schemes-in-Sri-Lanka/44-717318

Epidemiology Unit, Ministry of Health & Indigenous Medical Services. (2020). *Guidance for workplace preparedness for covid version 2.pdf*. Ministry of Health & Indigenous Medical Services. https://www.epid.gov.lk/web/images/pdf/Circulars/Corona_virus/guidance%20for%20workplace%20preparedness%20for%20covid%20version%202.pdf

Erandi, K. K. W. H., Mahasinghe, A. C., Perera, S. S. N., & Jayasinghe, S. (2020). Effectiveness of the Strategies Implemented in Sri Lanka for Controlling the COVID-19 Outbreak. *Journal of Applied Mathematics*, *2020*, 1–10. https://doi.org/10.1155/2020/2954519

Eykelbosh, A. (2021). *Contextualizing the risks of indirect COVID-19 transmission in multi-unit residential buildings* (p. 19). National Collaborating Centre for Environmental Health. https://ncceh.ca/sites/default/files/FINAL%20Murb%20outbreaks%20March%2023%202021.pdf

Farzan, Z. (2020, November 8). *Occupants in several housing complexes ordered to stay indoors*. News 1st. https://www.newsfirst.lk/2020/11/08/occupants-in-several-housing-complexes-ordered-to-stay-indoors/

Fernando, D. (2017). *Design of a Preventive Maintenance & Management Mechanism for Public Urban Housing Schemes*. Lund University. https://www.lth.se/fileadmin/hdm/alumni/papers/SDD_2007_242a/Deepika_Fernando__Sri_Lanka.pdf

Ford, L. (1994). *Cities and buildings: Skyscrapers, skid rows, and suburbs*. Johns Hopkins University Press.

Galloway, H. (2021, March 12). *Coronavirus: How infected air can flow from one apartment to another*. EL PAÍS. https://english.elpais.com/science_tech/2021-03-12/coronavirus-how-infected-air-can-flow-from-one-apartment-to-another.html

Gormley, M. (2020, April 8). *Coronavirus: People in tall buildings may be more at risk – here's how to stay safe*. The Conversation. http://theconversation.com/coronavirus-people-in-tall-buildings-may-be-more-at-risk-heres-how-to-stay-safe-135845

Gottmann, J. (1966). 'Why the Skyscraper? *Geographical Review*, *56*(2), 190. https://doi.org/10.2307/212878

Hubbard, P. (2020, May 4). *How COVID-19 might change the way we live and work for good | Feature from King's College London*. King's College London. https://www.kcl.ac.uk/how-covid-19-might-change-the-way-we-live-and-work-for-good

IANS. (2020, April 9). *Watch: Sri Lankan Cops Get Creative, Play Music To Help People Relax Amid Covid-19 Outbreak*. ABP Live. https://news.abplive.com/news/world/coronavirus-outbreak-sri-lanka-cops-play-music-to-help-people-relax-1193834

JLL Lanka. (2017). *Sri Lanka—Land of Real Estate Opportunities*. JLL Lanka. https://www.jll.com.lk/content/dam/jll-com/documents/pdf/research/lk-research-sri-lanka-land-of-real-estate-opportunities.pdf

Kang, M., Wei, J., Yuan, J., Guo, J., Zhang, Y., Hang, J., Qu, Y., Qian, H., Zhuang, Y., Chen, X., Peng, X., Shi, T., Wang, J., Wu, J., Song, T., He, J., Li, Y., & Zhong, N. (2020). Probable Evidence of Fecal Aerosol Transmission of SARS-CoV-2 in a High-Rise Building. *Annals of Internal Medicine*, *173*(12), 974–980. https://doi.org/10.7326/M20-0928

Karunanayake, C. (2020, October 28). *Sri Lanka: Pandemic recovery in urban settings*. PreventionWeb. https://www.preventionweb.net/go/74462

LBO. (2020, August 28). Opinion: Importance of nurturing the condominium industry in Sri Lanka. *Lanka Business Online*. https://www.lankabusinessonline.com/opinion-importance-of-nurturing-the-condominium-industry-in-sri-lanka/

Ley, D. (1996). *The new middle class and the remaking of the central city*. Oxford University Press.

Lin, G., Zhang, S., Zhong, Y., Zhang, L., Ai, S., Li, K., Su, W., Cao, L., Zhao, Y., Tian, F., Li, J., Wu, Y., Guo, C., Peng, R., Wu, X., Gan, P., Zhu, W., Lin, H., & Zhang, Z. (2021). Community evidence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission through air. *Atmospheric Environment*, *246*, 118083. https://doi.org/10.1016/j.atmosenv.2020.118083

Liu, Y., Li, P., Lv, Y., Hou, X., Rao, Q., Tan, J., Gong, J., Tan, C., Liao, L., & Cui, W. (2021). Public awareness and anxiety during COVID-19 epidemic in China: A cross-sectional study. *Comprehensive Psychiatry*, *107*, 152235. https://doi.org/10.1016/j.comppsych.2021.152235

Ministry of Health. (2020). *GENERAL GUIDANCE FOR THE PUBLIC ON COVID-19 PREVENTION-E.pdf*. Ministry of Health & Indigenous Medical Services. http://www.health.gov.lk/moh_final/english/public/elfinder/files/feturesArtical/2020/46/GENERAL%20GUIDANCE%20FOR%20THE%20PUBLIC%20ON%20COVID-19%20PREVENTION-E.pdf

MirorCitizen.lk. (2018, September 18). UDA intends to construct condominiums and housing schemes countrywide. *MirrorCitizen*. http://mirrorcitizen.dailymirror.lk/2018/09/18/uda-intends-to-construct-condominiums-and-housing-schemes-countrywide/

OECD. (2021). *Resilient Cities—OECD*. OECD. https://www.oecd.org/cfe/regionaldevelopment/resilient-cities.htm

Perera, M. (2021, April 29). *Working in air conditioned spaces increases risk of Covid-19: Dr. Sudath*. The Morning - Sri Lanka News. http://www.themorning.lk/working-in-air-conditioned-spaces-increases-risk-of-covid-19-dr-sudath/

Rajapaksha, R. M. K. U., & Jayaweera, N. (2018). *Condominium development in Sri Lanka: Current status and recommendations*. University of Moratuwa.

RentSeeker Team. (2020, June 19). Apartment Resources During Covid: How Apartments are Affected. *Rentseeker.Ca*. https://www.rentseeker.ca/blog/apartment-resources-covid-19/

Rosen, G., & Walks, A. (2013). Rising cities: Condominium development and the private transformation of the metropolis. *Geoforum*, *49*, 160–172. https://doi.org/10.1016/j.geoforum.2013.06.010

Samaratunga, T. C., & O'Hare, D. (2014). 'Sahaspura': The first high-rise housing project for low-income people in Colombo, Sri Lanka. *Australian Planner*, *51*(3), 223–231. https://doi.org/10.1080/07293682.2013.820204

Tate, N. (2020). *Coronavirus and Apartments: What's the Risk?* WebMD. https://www.webmd.com/lung/news/20200916/coronavirus-and-apartments-whats-the-risk

Udayanga, S. (2020, December 6). *'Methsanda Sevana' residents protest against isolation orders*. Ada Derana. http://www.adaderana.lk/news.php?nid=69732

UN DESA. (2018, May 16). *68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs*. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

UNDP. (2020, April 9). *Coping in the time of COVID-19 | UNDP in Sri Lanka*. UNDP. https://www.lk.undp.org/content/srilanka/en/home/stories/Coping_in_the_time_of_COVID19.html

UNDRR. (2021). *Resilience*. UNDRR. https://www.undrr.org/terminology/resilience

USDA. (2020, July 7). Awareness Programme on Covid 19 Prevention & Control, Sahaspura Housing Scheme – USDA. *Urban Development Authority-News*. http://usda.gov.lk/awareness-programme-on-covid-19-prevention-control-sahaspura-housing-scheme/

Walks, R. A., & Maaranen, R. (2008). Gentrification, Social Mix, and Social Polarization: Testing the Linkages in Large Canadian Cities. *Urban Geography*, *29*(4), 293–326. https://doi.org/10.2747/0272-3638.29.4.293

Warakapitiya, K. (2020, December 13). Apartment complexes lockdown lifted. *Times Online - Daily Online Edition of The Sunday Times Sri Lanka*. http://www.sundaytimes.lk/201213/news/apartment-complexes-lockdown-lifted-425276.html

Wulff, K., Donato, D., & Lurie, N. (2015). What Is Health Resilience and How Can We Build It? *Annual Review of Public Health*, *36*(1), 361–374. https://doi.org/10.1146/annurev-publhealth-031914-122829

NATIONAL SCIENCE FOUNDATION

Section 8

Governance

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Governance: Introduction

Ajantha S. Dharmasiri

The response to Covid-19 has involved actions by all levels of government and other public bodies and agencies, especially those responsible for health, civil protection, education, and social issues. It has also rested on the front-line role of local authorities as those who are the closest to citizens and their needs. The effectiveness of the response to the Covid-19 emergency greatly depends on the level of coordination and cooperation between the different actors involved. It also depends on the active participation of civil society, as regards not only the respect of confinement measures but also the direct involvement in voluntary work aimed at sustaining the response effort. Hence the research related to governance aspects connected to Covid-19 is timely and insightful. It can cover a wide array of topics ranging from democratic frameworks to delivery of people needs in a free and fair environment.

This section contains two papers selected for publication, based on the presentation of abstracts during the conference. Despite the fact that these papers do not cover the entire gamut of governance, encompassing a wide array of institutions, they can be considered as case studies of governance in action amidst COVID19. The first paper deals with how the Inland Revenue Department responded to transfer pricing issues related to COVID19 and the way clarity was reached through confusion. The second paper speaks of a premier academic institution dedicated to management have demonstrated governance practices during pandemic times. Both papers invite us to reflect on the way we manage our institutions highlighting the requirement to be flexible and adjustable to change as the only way to survive and succeed.

The first paper titled, "Tax administration and governance in transfer pricing in post-COVID19 transition" deals with a specific technical aspect faced by the Inland Revenue Department (IRD) of Sri Lanka. One objective of the paper was to assess the needed tax administrative policy measures and tax corporate governance by respective tax authorities (TAs) and multinational enterprises (MNEs) around the globe in administering the transfer pricing to 'build-back-better' the economy hard-hit by global health crisis of COVID-19. The paper also aimed at appraising the practical application of ALP in identified priority issue areas of comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and advance pricing agreements (APAs).

The above paper highlights that the administration of transfer pricing could be well-managed through revisiting the existing tax corporate governance framework (TCGF), and the alternative dispute resolution system (ADRS). As no 'one-size-fits-all approach' is possible, appropriate policy decisions should be made promptly, based on the COVID19 adversity level. The paper recommends following the four-step-mantra of: plan purposefully, prepare prayerfully, proceed positively, and pursue persistently, *inter alia*, to build-back-better TP governance and to rise up resiliently from this catastrophe.

The second paper deals with a governance related case study. Titled, " Performing amidst a planetary pandemic: Persevering experiences of a premier enterprise", the paper discusses how the Postgraduate Institute of Management (PIM) has responded to COVID19. Its five pillars, namely, teaching, research, partnerships, sustainability and governance are discussed with linkages to initiatives and insights. Past, present and future of PIM is logically linked to people, processes, and practices, with reference to its enriching experiences through the involvement in Tsunami-related development projects.

The above paper highlights several initiatives by the PIM in the financial, professional, and intellectual fronts, with the involvement of its faculty, staff, students, and alumni. As the only state

sector higher education entity that does not get any funds from the treasury neither for its recurrent expenditure nor for its capital expenditure for over the past twenty years, despite having an ongoing building expansion project, self-reliance by itself has shown a significant signal to other state sector educational institutions to have a different revenue model.

As obvious, the two papers included in this section are barely adequate to discuss the vast ramifications of the governance related aspects amidst a ravaging pandemic. The Organization for Economic Corporation and Development (OECD) states that "in times of crisis such as the current COVID-19 pandemic and its economic and social repercussions, public governance matters more than ever. Governance arrangements have played a critical role in countries' immediate responses and will continue to be crucial both to the recovery and to building a "new normal" once the crisis has passed."

Areas such as public trust with regards to vaccination, digital government with a data-driven decisions, risk governance with proactive crisis management, revision of regulatory policies should be well researched for better clarity towards purposeful policy making. A significant lacuna in this respect with regards to local research interest is sadly noted. As governance has its overarching implications to many diverse areas of policy formulation and implementation, research focus should be intensified and incentivized in order to obtain the required insights.

Tax administration and governance in transfer pricing in post-COVID-19 transition

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ABSTRACT

This paper attempted to address the problem of how governance of transfer pricing (TP) be revisited to prevent uncertainty as to arm's length price (ALP) and base erosion and profit shifting in cross-border transactions amidst challenges of COVID-19 pandemic. The objectives were: to assess the needed tax administrative policy measures and tax corporate governance by respective tax authorities (TAs) and multinational enterprises (MNEs) around the globe in administering TP to 'build-back-better' the economy hard-hit by global health crisis of COVID-19; and to appraise the practical application of ALP in identified priority issue areas of comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and advance pricing agreements (APAs). IMF forecasted adverse global economic growth and unfavourable world trade as minus 4.4% and minus 10.4% respectively by end of 2020 due to challenges of COVID-19 spread, lockdowns, travel restrictions, movement control orders and business closures. To bounce-back, proposition was set as flexibility in administering TP along with relief measures and APAs could assure taxing rights and fair share of tax revenue to government fiscus. To mitigate adversity of COVID-19 in TP governance, literature suggested that TP administration could be well-managed through revisiting tax corporate governance framework (TCGF), APA, and alternative dispute resolution system (ADRS). Study framework and methodology of qualitative exploratory edge-cutting analysis of in-depth interviews of TP governance experts were adopted. Research found that TAs should adopt good governance principles, where they could mutatis mutandis apply, and TP relief measures of extending deadlines for TP declaration form filings, including country-by-country report, temporary suspension of TP-specific audits and litigation to mitigate catastrophe of volatility, uncertainty, complexity, and ambiguity (VUCA 1.0) posed by COVID-19. MNEs should redefine tax function and TP policy with vision, unambiguity, certainty and agility (VUCA 2.0) in light of OECD corporate governance principles to improve legal, regulatory, and institutional framework to prevent corporate collapses. TP policy governance of MNEs should consider value chain reorganization based on economic, functions, assets and risks analyses, and maintain TP documentation at this COVID-19 transition. APAs as a way forward to resolve and prevent TP issues should be crafted by including force majeure clause to tackle catastrophes like COVID-19. Existing APAs could be amended if critical assumptions as to ALP changed in economic substance due to COVID-19 and TAs should facilitate suo moto to this effect. To administer TP regime robustly, ADRS could be promoted as opposed to litigation. As no 'one-size-fits-all approach' was possible, TAs and MNEs should take TP tax policy measures at right time based on adversity level caused by COVID-19 to rise up resiliently.

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Key words: Advance pricing agreement, COVID-19 challenges, Alternative dispute resolution system, Governance, Transfer pricings

1. INTRODUCTION

The landscape of tax administration and governance in transfer pricing (TP) confronts many challenges in international taxation and needs to be robustly and resiliently managed and monitored than ever before due to the unexpected catastrophic impact of the novel coronavirus disease 2019 (COVID-19). The COVID-19 pandemic has caused, *inter alia,* global health crisis, serious global economic downturn, adverse contraction of global trade or cross-border transactions and TP tax policy specific challenges. Thus, this global economic turmoil stemming from COVID-19 has far-reaching and serious implications for many multinational enterprises' (MNEs) existing TP policies in many facets (Deloitte, 2020). In this backdrop, this paper aims to examine and give readers a high-level overview on the problem of how TP administration and governance be revisited to prevent uncertainty as to arm's length price/principle (ALP) and base erosion and profit shifting (BEPS) in cross-border related party transactions amidst challenges of COVID-19 pandemic. In this respect, TP administration and governance issues and relief measures in post-COVID-19 transition are discussed with global perspective in general and Sri Lankan context in particular.

This research examines TP policy measures and tax corporate governance that need to be adopted by both the respective tax authorities (TAs) and MNEs thinking globally and acting locally in post-COVID-19 transition. Thus, it discusses the pragmatic application of ALP in scholarly identified priority issue areas of comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and advance pricing agreements (APAs) due to practical challenges posed by COVID-19 pandemic (OECD, 2020c). As TP typically focuses on ensuring that profits align with value creation and satisfying competing TAs that intercompany prices are at ALP and not opportunistic or worse, MNEs should make tough decisions to adapt their TP tax corporate governance policies to dramatically changed global economy due to COVID-19 pandemic (Minnear et al., 2020). From a TP perspective, it also concentrates to highlight the need of contemporaneous documentation be maintained by the MNEs to substantiate the economic circumstances and tackle potential challenges from TAs regarding ALP and profitability issues during the COVID-19 pandemic.

The gravity of global economic crisis posed by the unprecedented impact of COVID-19 global pandemic also needs to be considered when administering the TP in post-pandemic era. The International Monetary Fund (IMF) forecasts the global economic growth as minus 4.4% (minus 5.8% in developed economies) by the end of 2020 as a result of COVID-19 spread, health safety measures, isolation and lockdowns, travel restrictions, movement control orders, business closures and imminent corporate collapses. The IMF describes this sudden economic downturn as the worst recession since the great depression of 1930 and far worse than the global financial crisis of 2008. The international cross-border transaction or world trade is adversely affected and projected as minus 10.4% in the end of 2020 (IMF, 2020). In the 'double-hit' scenario, global GDP is projected to decline by 7.6% in 2020 and remain well short of its pre-crisis level at the end of 2021. Many advanced economies could lose the equivalent of five years or more of per capita real income growth at the end of 2021 (OECD, 2020b).

1.1. Justification of the Research Work

At this challenging period of COVID-19 transition, from the TP perspective, it is typically submitted and justified on one hand that TP as one of the complex and evolving issue areas in international tax administration and governance should be better administered to prevent uncertainty as to ALP and BEPS,

and to assure a fair share of tax revenue to the government *fiscus* demarcating the taxing rights to a country from cross-border transactions. On the other hand, MNEs also have to revisit their TP policy in tax corporate governance to the practical application of ALP to economic incidence and circumstances posed by the COVID-19 pandemic. Care should also be taken to strike a balance in this context and certain level of flexibility and relief measures are warranted on the part of competent authorities. However, deficiency in the administration of related party cross-border transactions could seriously erode the tax base of a country and lead to profit shifting and tax evasion through TP manipulations. Therefore, these TP manipulative and abusive activities by the MNEs for tax avoidance need to be properly curtailed to minimize the revenue loss to the government *fiscus* (Amidu et al., 2019). As most of the intra-group cross-border transactions involve the practice of transfer mispricing, MNE's related party transactions should be governed by the TP regulations (Beebeejaun, 2019).

To mitigate the adversity of the impacts and challenges of this COVID-9 pandemic in TP governance and to build-back-better serendipity in this area, literature suggests that resilient post-COVID-19 TP administration and governance could be well-managed through revisiting the drivers of tax corporate governance framework (TCGF), APA, and alternative dispute resolution system (ADRS). In administering the TP governance, 'the Organization for Economic Cooperation and Development (OECD) Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations ("the OECD TPGs")' are widely adopted by many jurisdictions along with domestic TP guidelines. Thus, taxpayers are encouraged to follow these TP guidelines in evaluating for tax purposes whether their TP complies with the ALP. Tax administrations are encouraged to take into account the taxpayer's 'commercial judgement' about the application of the ALP in their examination practices and to undertake their analyses of TP from that perspective (OECD, 2017). It is also needed to determine whether the financial transactions such as treasury functions, intra-group loans, cash pooling, hedging, guarantees and captive insurance between associated enterprises (AEs) incurred during the COVID-19 pandemic are consistent with the ALP in light of 'OECD Transfer Pricing Guidance on Financial Transactions' that contributes to the consistency in the application of TP and helps avoid TP disputes and double taxation (OECD, 2020a).

1.2. Objectives of the Study

The main objective of this study is: (i) to assess the needed tax administrative policy measures and tax corporate governance by the respective TAs and MNEs around the globe in administering the TP regime to 'build-back-better' the economy hard-hit by the global health crisis of COVID-19 that leads to the economic recession and financial crisis in almost all the jurisdictions. The sub objectives are: (i) to appraise the practical application of ALP in identified priority issue areas of comparability analysis, allocation of losses and the allocation of COVID-19 specific costs, government assistance programmes, and APAs; (ii) to argue and justify the application of ALP and OECD TPGs to the exacerbated TP issues emanated from the COVID-19 pandemic to assist both for taxpayers in reporting the financial periods affected by the pandemic and for tax administrations in evaluating the implementation of taxpayers' TP policies; and (iii) to evaluate and propose TP relief measures to ease the pressures experienced by the MNEs in cross-border transactions, documentation, compliance, payments, audits and litigations due to the outbreak of COVID-19 pandemic.

1.3. Proposition

The proposition in this study is set as: flexibility in practically applying the ALP in administering TP and APAs along with relief measures for tackling the issues pertaining to TP governance posed by the COVID-19 pandemic could assure taxing rights and fair share of tax revenue to government *fiscus* and assist tax corporate governance of MNEs to bounce-back-better from the pandemic.

2. LITERATURE REVIEW

2.1. Transfer Pricing Administration and Governance

Transfer pricing administration of controlled related party cross-border transactions of MNEs has become a pressing issue in all most all the jurisdictions generally, and especially in post-COVID-19 transition. TP is *per se* deemed to be a dispute as cross-border transactions between AEs are not determined having regard to the ALP. In analyzing the theoretical background to the problem, Ross's 'arbitrage pricing theory (APT)' lays the rational of economic foundation of TP that the APT considers the arbitrage or risk-free profit earning from the temporary price differences through buying securities in one market and selling them in a different market at a higher rate; and arbitrageurs by using APT expect to take benefits of any deviations from the fair market value (Ross, 1976). According to Eden (2009), TP is defined as the price charged for cross-border transactions between AEs (as cited in Hamid et al., 2016). Thus, TP represents the prices invoiced within related party transactions; and the price difference in controlled related party transactions and uncontrolled independent transactions is the undue profit or arbitrage earned by the MNEs leading to BEPS in cross-border transactions (Ioana, 2017). Therefore, to govern this issue, related party cross-border transactions between AEs should be determined having regard to the ALP in light of OECD TPGs as clearly stated in Article 9(1) of the 'OECD Model Tax Convention on Income and Capital' (OECD, 2017).

Therefore, the controlled related party cross-border transactions between AEs need to consider this ALP or the principle of fairness as a measure of the fairness of the price level for tax purposes in comparison with uncontrolled independent non-related party transactions. This price or income comparison is termed as reasonable price or a reasonable profit determined having regard to the arm's length standard in TP (Rahmiati & Sandi, 2016). As most of the intra-group cross-border transactions involve the practice of transfer mispricing, MNE's related party transactions should be governed by the TP regulations (Beebeejaun, 2019). However, the TP regulations of TAs in different jurisdictions shall not sometime be similar as to how the TP should be calculated in the cross-border transactions (Borkowski & Gaffney, 2018). Anyhow, as TP is used by MNEs as a strategy for profit shifting, minimizing tax liabilities and maximizing profits on a global basis, TP regulations need to be strengthened for the reduction of TP issues. Thus, MNEs often aim to shift profit to low-tax jurisdictions and to charge high costs to AEs at high-tax jurisdictions (Guvemli et al., 2017).

Generally, TP governance by the MNEs is expected to comply with OECD TPGs ensuring the ALP in related party transactions. The violation of TP regulations gives a significant opportunity for the TAs for auditing and litigating against transactions which are not at arm's length (Franklin & Myers, 2016). Further to counter such TP manipulation practices and to ensure taxing rights of the countries, TP regulations should be strengthened to ensure the ALP computed by using the most appropriate method (Martins, 2017). However, the unique economic conditions arising from COVID-19 and government responses to the pandemic have posed practical challenges for the application of the ALP pertaining to cross-border transactions. For MNEs/taxpayers applying TP rules for the financial years impacted by the COVID-19 pandemic and for tax administrations that would be evaluating this application, there is an urgent need to address these pragmatic questions that would arise due to COVID-19 pandemic in the most significant issue areas of comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and APAs (OECD, 2020c).

2.2. Tax Corporate Governance Framework (TCGF)

The corporate tax governance becomes a key focus area for TAs when it comes to MNEs that need to redefine their tax function and TP policy with the disruptions caused by the

COVID-19 pandemic. TP is considered as one of corporate governance issues (Ohnuma & Sakurada, 2017). Hence, many TAs implement initiatives that require MNEs to be more transparent about the amount of tax paid and their tax policies and strategies. Corporate tax governance can be shaped by the MNEs by re-designing the tax approach that is often laid down in a tax strategy and policy, with clear roles and responsibilities, a risk management framework, and comprehensive reporting (PwC, 2020). Corporate governance is defined as a system of rules, regulations, mechanisms, practices and procedures by which a corporate body is controlled and directed with the purpose to facilitate the building of an environment of trust, transparency and accountability which is required to foster long-term investment, financial stability and business integrity. Corporate governance practices would help policy makers to evaluate and improve the legal, regulatory, and institutional framework, with a view to support economic efficiency, sustainable growth and financial stability (OECD, 2015).

Typically, tax control framework or TCGF can be implemented with six essential building blocks in light of the experiences of many countries like New Zealand, UK, and Australia. They are: 1) tax strategy established: this should be clearly documented and owned by the board; 2) applied comprehensively: all transactions entered into that are capable of affecting its tax position in one way or another should be governed; 3) responsibility assigned: the board is accountable for the design, implementation and effectiveness of the TCGF and the tax team is responsible for the implementation of the TCGF; 4) governance documented: the governance process should be explicitly documented and sufficient resources should be deployed to implement the TCGF and review its effectiveness periodically; 5) testing performed: compliance with the policies and processes embodied in the TCGF should be the subject of regular monitoring, testing and maintenance; and 6) assurance provided: the TCGF should be capable of providing assurance to stakeholders, including external stakeholders such as a tax administration, that tax risks are subject to proper control (OECD, 2016). Therefore, these essential elements of TCGF could deal in defining tax risk, tax risk management processes, tax risk appetite, tax risk management segregation of duties, and tax risk governance that in turn could prevent corporate collapses of MNEs and financial institutions from economic turmoil driven by the COVID-19 pandemic.

2.3. Advance Pricing Agreement (APA)

Generally, the instrument of APA is considered as a way forward both for resolving and avoiding TP issues giving certainty and reliability as to ALP computed through most appropriate TP method but care should be taken to include *force majeure clause* in crafting the APAs to tackle catastrophes like COVID-19. APA is essentially a long-term contract between a TA and a taxpayer, the key feature of which is agreement that the TA will not disturb the taxpayer's TP as long as the taxpayer follows an agreed method for setting those prices (Foley et al., 2020). The OECD defines APA as an arrangement that determines, in advance of controlled transactions, an appropriate set of criteria (TP method, comparables and appropriate adjustments thereto, critical assumptions as to future events) for the determination of the TP for those transactions over a fixed period of time; and APA could be unilateral involving one tax administration and a taxpayer or multilateral involving the agreement of two or more tax administrations (OECD, 2017).

Through the APAs, TAs could provide the assurance to the AEs in their jurisdiction that no TP adjustment would be made as long as taxpayers follow the terms of the APAs entered into for mitigating the TP risks. Hence, APAs can be used not only for certainty purposes but also to reduce TP disputes, to encourage foreign direct investments (FDIs) and thereafter to promote economic growth (Beebeejaun, 2019). The APA also supplements the traditional administrative, judicial, and treaty mechanisms for resolving TP issues between the MNEs and the competent TAs (ICSI, 2018). However, existing APAs and ruling concluded during

prosperous economic times may require to be renegotiated if the adverse changes in economic circumstances posed by the COVID pandemic would have affected the critical assumptions underlying the APAs (Mariscalco, 2020). In APAs and inter-company contracts, the contract law doctrine of 'rescission' and the common law doctrine of *force majeure* may be invoked where necessary based on the 'economic materiality' of the impact caused by the COVID-19 pandemic (Martin et al., 2020).

2.4. Alternative Dispute Resolution System (ADRS)

The administrative approaches of ADRS could be encouraged instead of highly costly and time-consuming TP litigation for avoiding and resolving TP disputes in cross-border transactions generally and it becomes particularly more important in the post COVID-19 transition of the economy. These administrative procedures can be applied to minimize TP disputes and to help resolve them when they do arise between taxpayers and their tax administrations and between different tax administrations. Notably, these administrative approaches include mutual agreement procedure (MAP) authorized by Article 25 of the OECD Model Tax Convention for eliminating double taxation that could arise from a TP adjustment, developing safe harbours for certain taxpayers, APAs, dispute resolution panel, arbitration, and mediation procedures including the referral of factual disputes to third party experts (OECD, 2017). The experiences of many countries including Malaysia, Australia, UK and US show that ADRS could be used to achieve dispute resolution process objectives of resolving TP tax disputes speedily, providing effective and acceptable outcomes within the corners of the laws (Muhammad & Hamid, 2015).

3. METHODOLOGY

The methodology adopted is exploratory and comparative in nature and it explores the impacts of COVID-19 in TP governance and administration in all jurisdictions, but not exclusive, including with particular reference to Sri Lanka. The paper examines literature in the areas of TP administration and governance, TCGF, APA, and ADRS for resilient management of post-COVID-19 implications and based on these the study frame work is developed as depicted in Figure 1.

Further, to enrich this write-up, the writers use the methodology of qualitative exploratory edge-cutting analysis with the primary data collected domestically from purposive sampling of ten (10) in-depth interviews of key TP governance experts. The analytical survey of interview data collected from using purposive sampling techniques basically adopts a tabular form which illustrates the summary of key TP experts' interviews pertaining to the impact of

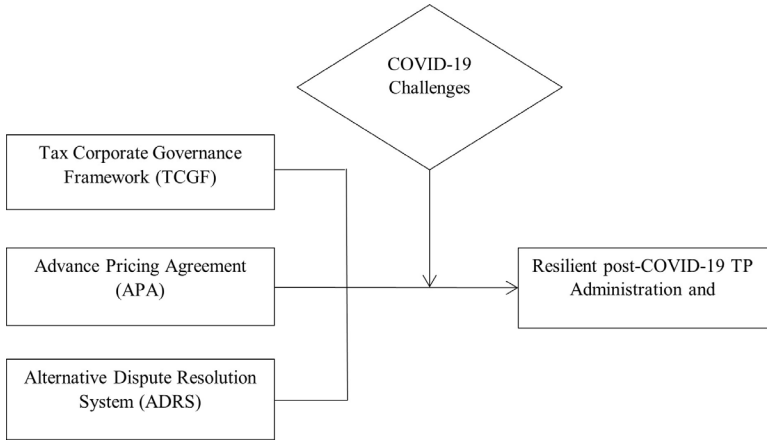

Figure 1. Study Framework

Source: Authors

COVID-19 on TP and governance as depicted in Table 1. In designing this approach, the criteria of likert scale of existence of COVID-19-related TP & governance issues as: 1) strongly disagree 2) disagree 3) neither agree nor disagree 4) agree 5) strongly agree, and likert scale of implementing COVID-19-specific TP policy measures & governance as: 1) very unnecessary 2) unnecessary 3) neither necessary nor unnecessary 4) necessary 5) very necessary are adopted as measurement scales to quantify and weigh the TP and governance experts' opinions to revisit and better administer the TP regime in post-COVID-19 pandemic transition.

4. RESULTS AND DISCUSSION

It is apparent that the unexpected uncertainty around the health and economic crises created by the COVID-19 pandemic all over the world has posed many challenges in the administration and governance of TP in cross-border transactions. In this respect, COVID-19 related key TP and governance issues, and suggested specific TP response policy measures and governance based on the literature and summary of key TP experts' interviews pertaining to the impact of COVID-19 on TP and governance are illustrated in Table 1. Further, 'the OECD Guidance on the Transfer Pricing Implications of the COVID-19 Pandemic issued on 18 December 2020' also highlights that the uncertainty and unreliability as to ALP and most appropriate TP method in the practical application of the ALP could emerge in four priority issue areas of comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and APAs due to the impact of COVID-19 pandemic (OECD, 2020c). Thus, COVID-19 related key TP governance issues could also arise in the areas of TP audits, APAs, TCGF, TP documentation, TP litigation, country-by-country reporting (CbCR) and exchange of information etc., posing imminent threats to tax avoidance, evasion and profit shifting. Especially, these very issues are substantiated with key TP experts' interviews by almost in the degree-range of 10% agreed and 90% strongly agreed as depicted in Table 1.

4.1. Revisiting MNEs' TP Policy in light of OECD TPGs

It is evidenced that the adverse consequences of COVID-19 pandemic include in reduction of consumer demand, supply chain disruption, and an increase in risk aversion in financial markets, decrease in profitability or making a loss and corporate collapses. Observably, MNEs are facing supply chain, consumer demand, and cash flow issues arising from the COVID-19 pandemic (Majure et al., 2020). Therefore, AEs of MNEs may find that their corporate governance operations need to be reorganized, reduced, or relocated and TP policy and tax function be revisited. The TAs should also promote TCGF that needs to be adopted by the MNEs. Further, the catastrophic environment of volatility, uncertainty, complexity, and ambiguity (VUCA 1.0) posed by the COVID-19 pandemic can be mitigated if MNEs could redefine tax function and TP policy with vision, unambiguity, certainty and agility (VUCA 2.0) in light of the OECD corporate governance principles to improve legal, regulatory, and institutional framework to prevent corporate collapses. In this respect, MNEs should undertake a severe stress test of their TP policies to check their suitability to the current COVID-19 situation and redesign them (Holzmiller et al., 2020).

In this regard, MNEs can still adopt the provisions OECD TPGs. Thus, the OECD TPGs should continue to be relied upon when performing a TP analysis, including under the possibly unique circumstances introduced by the COVID-19 pandemic (OECD, 2020c). Accordingly, the 'OECD TPGs (2017)' and the recently issued 'OECD Transfer Pricing Guidance on Financial Transactions (2020)', which recognize an economic crisis that leads to a wide-ranging impact on TP posing many challenges and questions for tax practitioners and MNEs and provide a series of practical approaches and useful tools for dealing with such crisis, can still be used as key reference points in the application of the ALP and the

Table 1. Summary of Key TP Experts' Interviews Pertaining to the Impact of COVID-19 on TP and Governance from Purposive Sampling of Techniques Used

S/no	COVID-19 related key TP & governance issues areas	Likert scale of existence of TP & governance issues and %	S/no	COVID-19 specific TP response policy measures & governance	Likert scale of implementing COVID-19 specific TP policy measures & governance and %
1	Uncertainty and unreliability as to ALP and most appropriate TP method	Agree: 20% Strongly agree: 80%	1	Implementing the APA regime with roll-back, roll-forward and renewal mechanism	Necessary:10% Very necessary: 90%
2	COVID-19-related impacts on transfer pricing-specific audits	Agree: 10% Strongly agree: 90%	2	Temporary suspension of TP-specific audits and promoting compliance audits	Necessary: 20% Very necessary: 80%
3	Impacts or changes to APAs, rulings, or other TP related certainty measures	Agree: 30% Strongly agree: 70%	3	Amending APA if critical assumptions changed, and include *force majeure* clause	Necessary: 10% Very necessary: 90%
4	Nonexistence of tax corporate governance framework (TCGF)	Agree: 30% Strongly agree: 70%	4	Encouraging MNEs to establish TCGF with help of tax authorities to promote compliance	Necessary: 30% Very necessary: 70%
5	Traditional TP litigation and nonexistence of ADRS	Agree: 20% Strongly agree: 80%	5	Temporary suspension of TP litigations and policy formulation for ADRS	Necessary: 10% Very necessary: 90%
6	Difficulties in timely complying with TP documentation & TP declaration form filing	Agree: 30% Strongly agree: 70%	6	Extending deadlines for TP declaration form and return filings	Necessary: 10% Very necessary: 90%
7	Difficulties in timely complying with CbCR notification, CbCR and exchange of information	Agree: 40% Strongly agree: 60%	7	Extending deadlines for submitting local file, master file and CbCR and promoting automatic TIEAs	Necessary: 20% Very necessary: 80%
8	Non-implementation of TP-specific stimulus measures like safe harbours	Agree: 40% Strongly agree: 60%	8	Implementing safe harbour rules, APA guidelines and TP guidelines	Necessary: 20% Very necessary: 80%
9	Tax avoidance, evasion and profit shifting	Agree: 10% Strongly agree: 90%	9	Fully implementing OECD/ G20 BEPS Actions project	Necessary: 10% Very necessary: 90%
10	TP and governance related VUCA 1.0; issues related to comparability analysis, allocation of losses and COVID-19 specific costs, government stimulus	Agree: 10% Strongly agree: 90%	10	Redefining tax function and risk and TP policy with VUCA 2.0 by the MNEs in light of OECD corporate governance principles; doing FAR analysis & apply ALP as per OECD TPGs	Necessary: 10% Very necessary: 90%

Source: Authors.

conditions of an unexpected, global economic crisis do not change these (D'Avossa et al., 2020).

4.2. Supply Chain Reorganization

The TP policy governance of MNEs should consider value chain reorganization based on economic, functions, assets and risks (FAR) analyses, and maintain contemporaneous TP

documentation at this COVID-19 transition to substantiate the TAs and mitigating TP risks. As supply chains are under strain due to COVID-19, MNEs should consider whether TP changes are appropriate to ensure which party is ultimately bearing the risk and accordingly, make changes to reduce levels of guaranteed profit in entities whicht are limited-risk distributors, contract manufacturers, and sales agents, etc. (Nolasco et al., 2020).

4.3. Promoting Compliance Audits

This study also finds that TP-specific investigative audits are generally very challenging for the TAs as MNEs use many tactics for TP audit disruptions. It is observed that TP audits are temporarily suspended in many jurisdictions due to COVID-19 pandemic. MNEs use 3Ds tactics of deny, delay, and defeat as illustrated in Figure 2. When considering the tactic of deny, MNEs inappropriately convince the TAs that there is no material TP problem and point out other taxpayers with worse TP issues for the TAs to look at and manipulate and misrepresent statistics. MNEs often attempt to delay the audit process so that any statutory period of limitation expires by making late staged request for a ruling or interpretative view and delaying in providing material information on major issues. Similarly, when regarding to the defeat, MNEs occasionally attempt for taking actions that risk the cessation of a TP audit and adjustment to the tax payable, threatening individual tax officers and TAs stating legal action or closure of business function be made to defeat TP audits (Guj et al., 2017). Hence, promoting APA compliance auditing is supported by TP experts' interviews as 20% necessary and 80% very necessary to resolve TP issues generally and particularly in the post COVID-19 transition as depicted in Table 1.

4.4. Collaborative APA Process

It is submitted that taxpayers and TAs should be encouraged to take constructive and collaborative approaches in the APA process for the conducive and long-run success of an APA programme amidst the COVID-19 pandemic. According to Table 1, implementing the APA regime with roll-back, roll-forward and renewal mechanism as shown in Figure 3 is supported by the experts by 10% necessary and 90% very necessary as the APAs could provide certainty to taxpayers and tax administrations by ensuring predictability in the treatment of international transactions for tax purposes. Although APAs are used in many jurisdiction including US, UK, Australia and India with some uniqueness, Sri Lanka has not yet implemented the APA regime despite statutory provisions are available from 2013, therefore, this research recommends for Sri Lanka to implement an APA regime like the typical APA model of India depicted in Figure 3 for avoiding and resolving TP disputes. Taking into account the material economic impact of COVID-19 on critical assumptions of existing APAs in

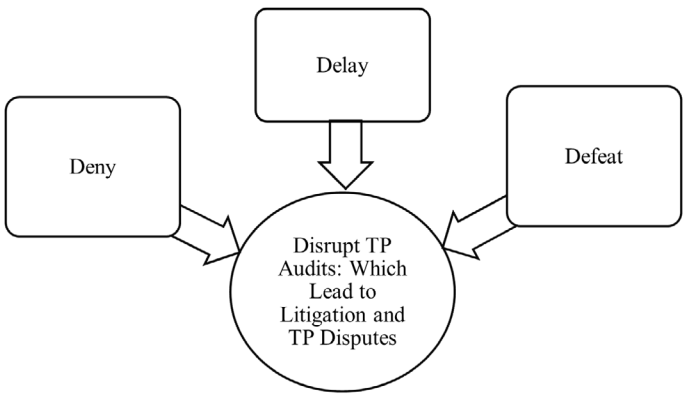

Figure 2. The 3Ds Tactics Model for Explaining Transfer Pricing Audit Disruptions

Source: Adapted from Guj et al., (2017, p. 302).

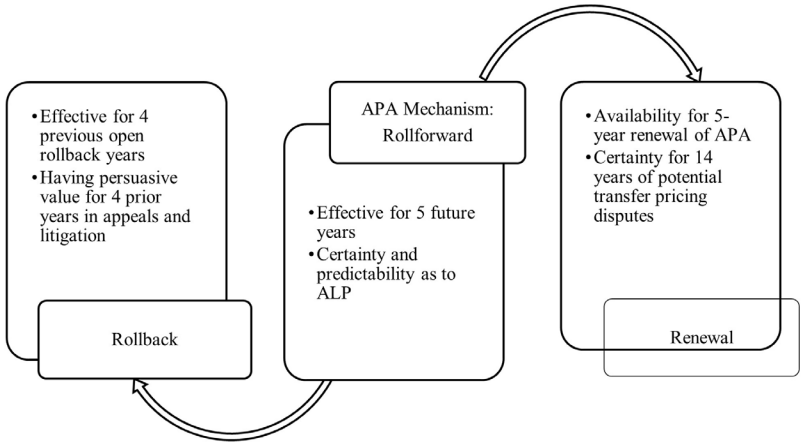

Figure 3. Typical APA Model of India

Source: Authors

many jurisdictions, taxpayers can renegotiate their APA terms if necessitated (ICSI, 2018; Butani, 2020).

The experiences pertaining to APAs during prior recessions and economic shocks like in 2008/09 can be utilized as guidance during this COVID-19 pandemic. Thus, the APA adjustments could include separating the APA term into separate testing periods such as a 'normal' period and a 'downturn' period, during which certain downward adjustments to the ranges or screening mechanisms for the comparables would be allowed; applying a term test so that the impact of certain non-recurring, extraordinary expenses can be spread out over a longer period of years, rather than resulting in an adjustment to the single year's results; permitting certain extraordinary expenses incurred to respond to the economic environment or system losses to either be borne entirely by the parent company or shared among the relevant entities if appropriate; making adjustments to the comparable sets to account for the economic impacts of the downturn, particularly where the tested party and comparables experience dissimilar impacts and levels of economic demand (Campmajó et al., 2020). The existing APAs can be amended if critical assumptions as to ALP changes in economic substance due to COVID-19 and TAs should facilitate *suo moto* to this effect; and in APAs, the contract law doctrine of 'rescission' and the common law doctrine of *force majeure* can also be triggered where necessary to tackle catastrophes like COVID-19 (Martin et al., 2020).

4.5. Comparability Analysis

The unprecedented adversity in the economic environment due to the outbreak of COVID-19 creates unique challenges for performing comparability analysis. The pandemic may have a significant impact on the pricing of some transactions between independent enterprises and may reduce the reliance that can be placed on historical data when performing comparability analyses. This may require taxpayers and TAs to consider practical approaches that can be adopted to address information deficiencies, such as comparability price adjustment mechanism and detailed profit and loss analysis including a variance analysis of budgeted (pre-COVID-19) versus actual results. The taxpayers may encounter difficulties in determining ALP due to the lag in time between the occurrence of controlled transactions and the availability of information regarding contemporaneous uncontrolled transactions. Taxpayers and TAs should be mindful that determining a reliable estimate of ALP requires flexibility and exercise of 'reasonable commercial judgments' supplemented by contemporaneous data (OECD, 2020c).

It could not be possible to determine the ALP of a controlled transaction occurring in 2020 based on comparable companies' 2017-2019 financial data, as this data would not reflect the financial consequences of the COVID-19 crisis. Therefore, it needs to adjust the financials of the comparables; perform a second TP adjustment in 2021; and use 2020 financial data of the comparable companies to test 2020 financials (Barat et al., 2020). It is further found that TP adjustments pertaining to tested party financials, benchmarking period, and comparable companies' profitability measures could be considered in cost-plus method (CPM) or transactional net margin method (TNMM) analyses in view of the unprecedented global economic disruption due to COVID-19 pandemic (Subramanian et al., 2020).

4.6. Allocation of Losses and COVID-19 Specific Costs

Many MNEs have incurred losses due to a decrease in demand, inability to obtain or supply products or services or as a result of exceptional, non-recurring operating costs led by the COVID-19 pandemic. The extent of the loss that may be earned at arm's length will be determined by the conditions and the economically relevant characteristics of the accurately delineated transaction compared to those of comparable uncontrolled transactions, including application of the most appropriate TP method. Especially, care should be taken when analyzing the loss scenario of 'limited-risk' entities as the functions performed, assets used and risks assumed (FAR) by these entities vary, and therefore it is not possible to establish a general rule that entities so-described should or should not incur losses; it needs to consider the specific facts and circumstances when determining whether a so-called 'limited-risk' entity could incur losses at arm's length as simple or low risk functions in particular are not expected to generate losses for a long period of time. Further, during the COVID-19 pandemic, MNEs have incurred exceptional, non-recurring operating costs including expenditure on personal protective equipment (PPE), reconfiguration of workspaces to enable social distancing, IT infrastructure expenses relating to 'test, track and trace' (TTT) obligations and to implement teleworking arrangements for 'working-from-home'. In the allocation of these COVID-19 specific costs between related parties, it is necessary to consider how these costs could be allocated between uncontrolled independent parties operating in comparable circumstances (OECD, 2020c).

When considering TP methodology that can be applied in allocation of losses incurred during the pandemic, application of a profit/loss split method is preferred than the use other methodologies. In this context, the analysis should carefully consider the new data and apply a TP methodology that independent third parties would have agreed to under similar facts and circumstances (Davis et al., 2020). As TAs would not accept a wholesale explanation by taxpayers that the losses or reduced profits are due to the pandemic and simply out of their control, the analysis of each factor contributing to the losses should help identify which parts of the losses or the profit decline that are attributed to the COVID-19 outbreak and which parts are due to the impact of the TP systems itself (Chi et al., 2020).

4.7. Government Assistance Programmes

To minimize the adverse effect of the COVID-19 pandemic on businesses, many countries have introduced government assistance programmes including monetary or non-monetary programmes. These government assistance programmes provide a direct or indirect economic benefit to eligible taxpayers such as grants, subsidies, forgivable loans, tax deductions, or investment allowances. A government for instance could directly subsidise the labour costs incurred or indirectly support businesses through the provision of local infrastructure like business parks. Job retention programmes are also widely used in many jurisdictions to preserve jobs in enterprises experiencing a temporary reduction in business activities. Financial and liquidity supports including loan guarantees, direct financing to business on preferential

terms, loan deferrals; specific grants and tax relief are also provided to ensure enterprises' business continuity amidst the pandemic. Therefore, the materiality of the change in economically relevant circumstances created by the impact of government assistance programmes available in a market could pose challenges to the comparability analysis through the application of a particular TP method and search for comparable transactions. Arguably, an uncontrolled transaction that has been considered comparable to a particular controlled transaction would be considered not comparable by virtue of the fact that one of the transactions is subject to government assistance programmes and while the other is not. Consequently, a revised strategy and potentially the use of a corroborating TP methodology should be applied in such cases considering differences in comparability (OECD, 2020c).

Furthermore, this paper also finds that the TAs need to adopt good governance principles of participation, consensus oriented, accountability, transparency, responsiveness, effectiveness and efficiency, equity and inclusiveness and rule of law, where it could *mutatis mutandis* apply in TP tax administration and governance. Additionally, the MNEs/taxpayers are also encouraged to adopt the 'cooperative compliance model of TCGF' to build-back-better trust-based relationship with tax administration in the post COVID-19 era. This study also discloses that TAs in administering TP amidst the COVID-19 pandemic should bail out TP relief measures of extending deadlines for filing of TP declaration form, local file, master file, country-by-country report and return filing; temporary suspension of TP-specific audits; temporary suspension of litigation and policy formulating for promoting ADRS; implementing safe harbour rules; extending time for tax payment and holding tax collection actions, etc. to mitigate catastrophic impact of the pandemic as significantly evidenced from expert's interviews shown in Table 1 and as per literature which shows that counties such as Belgium, Brazil, Denmark, France, Honk Kong, India, Malaysia, New Zealand, Philippines, UK and US, etc. already have implemented these relief measures (Ernst & Young, 2020).

Importantly, the interview data along with literature in any circumstances also support the fully implementation of the OECD BEBS Actions; promoting automatic tax information exchange agreements (TIEAs) for tax transparency and implementing APAs for certainty as to TP methodology and ALP for preventing tax evasion and profit shifting and for protecting the fair share of tax revenue needed to the government *fiscus* to sustainably develop the economy of country like Sri Lanka. It is worth finally noting that TP issues raised by the COVID-19 pandemic are wide-ranging, and vary between industries and even between taxpayers. This paper has only discussed a few of the most significant concerning areas. Many scholars suggest that TAs should take a 'flexible approach' to addressing COVID-19's impact on the application of ALP in TP, and taxpayers should proactively initiate discussions with TAs where appropriate while clearly documenting the facts and analyses as the first layer of defense (Martin & Bettge, 2020). Thus, the proposition set in this paper is favourably supported by the literature and the key TP experts' interviews.

5. CONCLUSION

This paper in light of above analysis revealed that TP administration and governance pertaining to cross-border transactions in the post-COVID-19 transitional era could confront many challenges. Notably, such challenges *inter alia* significantly observed in the practical application of ALP in the broadly identified four priority issue areas of: comparability analysis, allocation of losses and COVID-19 specific costs, government assistance programmes, and APAs; and they were discussed in detail. Technically, it was found that TP adjustments pertaining to tested party financials, benchmarking period, and comparable companies' profitability measures could be considered in applying the TP methods in view of the unprecedented global economic disruption due to COVID-19 pandemic. Especially, the APA regime with roll-back, roll-forward and renewal mechanism

was identified as a way forward to avoid and to resolve TP disputes in any circumstances as it also could be facilitated with the contract law doctrine of 'rescission' and the common law doctrine of *force majeure,* which could be triggered if critical assumptions as to ALP changed in economic substance due to COVID-19. The non-adversarial system of ADRS instead of TP litigation and the TP compliance auditing instead of investigative TP audit should be adopted by the TAs; and the TAs needed to take a 'flexible approach' to addressing COVID-19's impact on the application of ALP in TP. Further, this paper emphasized that MNEs should revisit their TP policies and strategies and should recalibrate the governance systems adopting TCGF with the lesson learnt from the COVID-19 pandemic to avoid possible TP tax disputes and to tackle future economic shocks resulting from an act of God or an act of government. In this regard, TAs and MNEs could still rely upon the OECD TPGs. Finally, as no 'one-size-fits-all approach' would be possible, TAs and MNEs should take TP tax policy measures at right time based on the adversity level caused by the COVID-19 pandemic. In this regard, it could be useful to follow the four-step-mantra of: plan purposefully, prepare prayerfully, proceed positively, and pursue persistently, *inter alia,* to build-back-better TP governance and to rise up resiliently from this catastrophe.

REFERENCES

Amidu, M., Coffie, W., & Acquah, P. (2019). Transfer pricing, earnings management and tax avoidance of firms in Ghana. *Journal of Financial Crime, 26*(1), 235-259. DOI: http://dx.doi.org/10.1108/JFC-10-2017-0091

Barat, F., Bergmann, G., Seck, C. O., Borrego, M., Tchumburidze, E., Semper, B., & Seth, S. (2020, October). The impact of Covid-19 on transfer pricing. France: Mazars. Retrieved from https://www.mazars.com/content/download/1015596/53068537/version//file/The%20impact%20of%20Covid-19%20on%20transfer%20pricing%20-%20October%202020.pdf

Beebeejaun, A. (2019). The fight against international transfer pricing abuses: A recommendation for Mauritius. *International Journal of Law and Management, 61*(1), 205-231. DOI: http://dx.doi.org/10.1108/IJLMA-05-2018-0083

Borkowski, S. C., & Gaffney, M. A. (2018). Transfer pricing and FIN 48: How managers attempt to mitigate audit risk. *Management Accounting Quarterly, 19*(2), 8-17.

Butani, M. (2020). India: Overview of the principal transfer pricing rules. In S. Edge & D. Robertson (eds.), *The Transfer Pricing Law Review* (4th ed.), pp. 80-92. London: Law Business Research Ltd.

Campmajó, M., Dominguez, B., Aguirre, R. G., Lingier, R. K., McComber, D., Rahim, S., & Raybould, C. (2020). APAs: The quest for certainty in times of uncertainty. In Baker McKenzie & Bloomberg Tax & Accounting (eds.), *Covid-19: Impact on (the Other) TP* (pp. 34-44). US: The Bureau of National Affairs.

Chi, C., Teoh, C. B., Tang, T., & Cody, B. (2020, March). Insight: Covid-19 puts limited risk structure at risk—Analysis from the Chinese angle. *Tax Management Transfer Pricing Report*, US: Bloomberg Tax. 1-7.

D'Avossa, M., Fox, C., Garcia, M. C., Penney, A. O., Gonzalez, G. S., Thomas, P., & Garcia, F. T. (2020). The OECD transfer pricing guidelines: A practical guide for applying the arm's-length principle during an economic crisis. In Baker McKenzie & Bloomberg Tax & Accounting (eds.), *Covid-19: Impact on (the Other) TP* (pp. 4-12). US: The Bureau of National Affairs, Inc.

Davis, R., Hennelly, J., Sharma, V., & Beirnes, S. (2020). COVID-19: Implications and considerations for transfer pricing. Canada: KPMG. 1-7.

Deloitte. (2020). *Transfer Pricing Considerations in Light of COVID-19*. Deloitte Touche Tohmatsu Limited, 1-3. Retrieved from www.deloitte.com/transfer-pricing-considerations-in-light-of-COVID-19.htm

Ernst & Young. (2020, November). *COVID-19 response tracker: Transfer pricing.* .UK: EY Ltd. 1-83.

Foley, S., Frank, M., Vincent, F., Kolish, T., Martin, M. R., & Bonardi, L. (2020). Advance pricing agreements and COVID-19. *Tax Notes Federal*, *167*(8), 1343-1347.

Franklin, M., & Myers, J. K. (2016). An analysis of transfer pricing policy and notable transfer pricing court rulings. *Journal of Business and Accounting, 9*(1), 73-85.

Guj, P., Martin, S., Maybee, B., Cawood, F., Bocoum, B., Gosai, N., & Huibregtse, S. (2017). *Transfer Pricing in Mining with a Focus on Africa: A Reference Guide for Practitioners.* Washington: World Bank Group (WBG).1-309.

Guvemli, B., Alpaslan, H. I., & Susoglu, M. E. (2017, July). Transfer pricing in the Balkans. *The Journal of Accounting and Finance,* 152-164.

Hamid, A. A., Arshad, R., & Pauzi, N. F. M. (2016). The prediction of transfer pricing manipulation among public listed companies in Malaysia. *Malaysian Accounting Review, 15*(1), 341-361.

Holzmiller, E., Cantaluppi, C., Mazzoleni, C. (2020). Transfer pricing and covid-19: Practical issues and possible approaches. *TP and Covid-19-Position Paper,* 05/2020, Italy: Baker Tilly International Limited. 1-15. Retrieved from https://www.bakertilly.global/media/7679/transfer-pricing-baker-tilly-italy-tax-position-paper.pdf

IMF. (2020, October). *World Economic Outlook: A Long and Difficult Ascent.* Washington, DC: IMF Publication, 1-184.

Institute of Company Secretaries of India (ICSI). (2018). *Transfer Pricing.* New Delhi: ICSI. 1-304. Retrieved from www.icsi.edu

Ioana, I. N. (2017). Advance pricing agreements and double taxation: Key concepts in the context of transfer pricing. *Economic Sciences Series, 17*(2), 565-570.

Majure, K., Subramanian, P., & Bloom, B. (2020, July). COVID-19 disruption: International tax and transfer pricing issues. *Journal of International Taxation*, *31*(7), 1-11.

Mariscalco, F. (2020). Transfer pricing implications of COVID-19. Italy:HLB. 1- 6. Retrieved from https://www.hlb.global/transfer-pricing-implications-of-covid-19/

Martin, M. R., Horowitz, M. J., & Bettge, T. D. (2020). Revisiting transfer prices and intercompany contracts in light of COVID-19. *Tax Notes Federal*, *167*(12), 2051-2058.

Martin, M., & Bettge, T. (2020, April).Transfer pricing implications of COVID-19: Revisiting pricing, contracts, and APAs. US: KPMG.1-2. Retrieved from www.itrinsight.com

Martins, A. F. (2017). Accounting information and its impact in transfer pricing tax compliance: A Portuguese view. *Euro Med Journal of Business, 12*(2), 207-220. DOI: http://dx.doi.org/10.1108/EMJB-11-2016-0029

Minnear, M., Subramanian, P., Che, R., & Farooqui, I. (2020). COVID-19's impact on transfer pricing in the life sciences industry. *Tax Notes Federal*, *167*(13), 2247-2255.

Muhammad, I., & Hamid, S. A. (2015). Public awareness and perceptions on the Inland Revenue Board of Malaysia Dispute Resolution Department: An exploratory study. *Procedia Economics and Finance, 35*, 699-704. DOI: http://dx.doi.org/10.1016/S2212-5671(15)01158-2

Nolasco, A. C., Cowley, J., Karjalainen, J., Koball, S., Levin, T., Russo, A. & Tien, G. (2020). Transfer pricing & supply chains: Global developments due to Covid-19. In Baker McKenzie & Bloomberg Tax & Accounting (eds.), *Covid-19: Impact on (the Other) TP* (pp. 13-17). US: The Bureau of National Affairs, Inc.

OECD. (2020a, February). *Transfer Pricing Guidance on Financial Transactions: Inclusive Framework on BEPS Actions 4, 8-10.* Paris: OECD Publishing, 1-45. Retrieved from www.oecd.org/tax/beps/transfer-pricing-guidance-on-financial-transactions-inclusive-framework-on-beps-actions-4-8-10.htm

OECD. (2015). *The G20/OECD Principles of Corporate Governance*. Paris: OECD Publishing, 1-58. DOI: http://dx.doi.org/10.1787/9789264236882-en

OECD. (2016). *Co-operating Tax Compliance: Building Better Tax Control Frameworks*. Paris: OECD Publishing. DOI: https://doi.org/10.1787/9789264253384-en

OECD. (2017, July). *OECD Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations 2017*. Paris: OECD Publishing, 1-609. DOI: http://dx.doi.org/10.1787/tpg-2017-en

OECD. (2020b, July). *Tax Policy Reforms 2020: OECD and Selected Partner Economies.* Paris: OECD Publishing, 1-123. DOI: https://doi.org/10.1787/7af51916-en

OECD. (2020c, December). *Guidance on the Transfer Pricing Implications of the COVID-19 Pandemic.* Paris: OECD Publishing, 1-31. DOI: https://doi.org/10.1787/731a59b0-en

Ohnuma, H., & Sakurada, J. (2017). Corporate governance issues regarding transfer pricing taxation: Evidence in Japan. *Asian Business Research*, *2*(3), 58-74. DOI: http://dx.doi.org/10.20849/abr.v2i3.238

PricewaterhouseCoopers (PwC). (2020, March). *Corporate Tax Governance: Creating a Sustainable Tax Approach in Times of Fundamental Change*. Netherlands: PwC. 1-10.

Rahmiati, A. & Sandi, R. (2016). Exploring the arm's length transfer pricing strategy for taxation purpose: An ethnographic study in a manufacturing enterprise. *Asian Journal of Accounting Research, 1*(1), 8-15. DOI: http://dx.doi.org/10.1108/AJAR-2016-01-01-B002

Ross, S. (1976). The arbitrage theory of capital asset pricing. *Journal of Economic Theory*, *13*(3), 341–360. DOI: http://dx.doi.org/10.1016/0022-0531(76)90046-6

Subramanian, P., Krustev, V., Eisenberg, H., & Hughes, M. (2020, June). Insight: Transfer pricing adjustments to the Covid-19 economic downturn. *Tax Management Transfer Pricing Report*, US: Bloomberg Tax. 1-10.

Performing amidst a planetary pandemic: Persevering experiences of a premier enterprise

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ABSTRACT

This paper traces the perseverance demonstrated by the Postgraduate Institute of Management, in the wake of Sri Lanka getting affected by COVID19. It was a challenging time for governance, with regards to the administrative and academic responsibilities in order to ensure continuity without disruption. Past, present and future of PIM is logically linked to people, processes, and practices. With the enriching experiences of PIM through its involvement in Tsunami-related development projects, continuing with COVID19 was another challenge being faced confidently. Sound bedrock of PIM's vision, mission and values are discussed in relation to its "edifice of excellence", which offered resilience and revival amid a ravaging pandemic. Its five pillars, namely, teaching, research, partnerships, sustainability and governance are discussed with linkages to initiatives and insights. With specific emphasis on governance, resilience, and revival amidst COVID19 are elaborated with evidence.

Key words: Response to COVID19, Institutional excellence, Strategic approach, Persevering initiativess

1. INTRODUCTION

Much has been said about the rapid spread of Covid19 which has become almost like the third world war. Nature has stricken back, without sparing any cast, creed or country with cruel implications associated. It was a clarion call for the learning community of PIM to collaborate in the name of humanity. Needless to stress the mature adult response that has to be demonstrated in taking care of oneself and others with sound hygienic practices.

The PIM has been conscious about the dire economic downturn globally, regionally, and locally with its associated multiple social impacts. Having been a "leader breeder" with over 35 years of existence in producing over 350 CEOs, over 3500 senior managers and over 35,000 inspired professionals, the PIM acted promptly. The initiatives taken, involvements occurred, and insights learnt so far are indeed illuminating.

2. VISION TOWARDS EXCELLENCE

Excellence is all about being exceptionally good. When applied to enterprises, it involves exceptional achievements in a consistent manner. That is what the Postgraduate Institute of Management (PIM) has been significant in being a self-financed, semi-autonomous public entity. PIM produces thought leaders to the nation. It has been in the forefront in breeding such leaders with character and competence. They are equipped with cutting-edge knowledge and complementary skills needed to perform in both private and public

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sectors alike. In producing them with clarity and commitment, PIM has always been a centre of excellence in management education with its wings spreading beyond Sri Lanka.

As Senge (1990) described, a learning organization is one "where people continually expand their capacity to create the results, they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspirations are set free, and where people are continually learning how to learn together". He further specified the new competencies needed by the leadership of a learning organization, which can be developed only through long-term commitment. The story of PIM aptly fits into it.

As Figure 1 illustrates, the creative tension is generated from the gap between where we want to be and where we are. As Senge (1990) explains, the principle of creative tension shows that an accurate picture of current reality is just as important as a compelling picture of a desired picture. This has been the way for PIM since its inception.

Having established in 1986 by Ordinance under the Universities Act 16 of 1978, the PIM is one of the 10 postgraduate institutes in the university system of Sri Lanka, affiliated to the University of Sri Jayewardenepura. It aims to promote advanced education and professionalism in management in Sri Lanka through the provision of postgraduate instruction, training, research, and development in the various branches of management and administrative studies.

The PIM has continued to serve the national interests of professional management education and training, providing challenging opportunities for learning and skills development to thousands of senior-level managers and administrators. Being the pioneer of advanced management education in Sri Lanka, it provides leadership to those in the business of innovating and disseminating management know-how as well as to those who are in search of higher learning alternatives.

The PIM offers a wide range of programs in the areas of business and public administration. The Master of Business Administration (MBA) is the core degree programme of the Business Unit. Organized into eight academic terms during a two- year period, the programme offers approximately 600 classroom interaction hours and over 60 hours of faculty consultation on research, skills development, directed study and residential workshops.

The Master of Public Administration (MPA) program is based on a needs assessment of the transversal knowledge requirements of executive level officers of the public service. Most public servants belong to a transferable service. They have to therefore, acquire transversal knowledge, which could hold them in good stead in any assignment. Such knowledge has to be reinforced by institution-specific knowledge but the former facilitates creative application of the latter. The course is

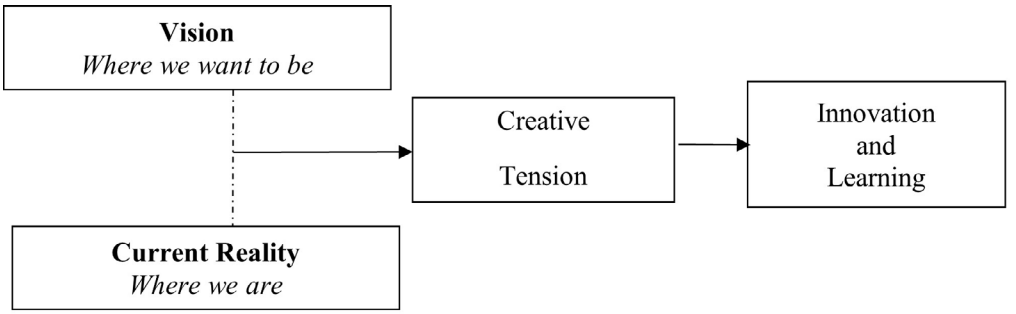

Figure 1. From current reality to desired future

Source: Adopted from Senge (1990)

offered in the blended-learning mode with the involvement of regional centers such as Jaffna and Trincomalee.

The PIM has a doctoral program which offers Ph.D in Business Administration as well as Ph.D. in Public Administration. Among the other programs on offer are MBA in Taxation (MBAT) offered first time in South Asia, in collaboration with the Inland Revenue Department (IRD). Also, there is an MBA in Customs and International Trade (MBA – CIT), offered in collaboration with the Sri Lanka Customs. There is a vibrant Executive MBA (EMBA), a shorter version of the MBA, offered to senior executives in a workshop mode. Our MBA and other programs are designed to help their participants who have a global mind-set but a local 'feel', to gain mastery over the markets in which they operate (Liyanage, 2014). PIM is proud to have speared its wings overseas in forming study groups in Dubai (UAE), Doha (Qatar), Muscat (Oman), Kuwait City (Kuwait), Dhaka (Bangladesh) and Manama (Bahrain) who follow the MBA program of PIM through a blended learning mode.

The PIM also takes pride in conducting client-focused training for employees of organizations in its efforts to be a working partner of the business community. The clients include both public and private sector institutions engaged in manufacturing and services such as banking, finance and insurance. These Executive Development Programs (EDPs) have been on the rise with regards to the demand and delivery.

The PIM has two key publications namely *Sri Lankan Journal of Management* (SLJM) and *Professional Manager* (PM). SLJM, the bi-annual Journal of the Institute, started in 1996, continues to provide a forum for publication and discussion. It is the longest serving management journal in Sri Lanka and the only Sri Lankan management journal to be hosted by EBSCO, one of the top five research databases in the world. The principal objective of SLJM is to provide a medium for addressing issues of relevance in management and for disseminating results of excellent research projects of the faculty and of students. Those from industry are also invited to send in their contributions for publication.

The *Professional Manager,* the bi-annual magazine was launched, in addition to the SLJM, to cater to the emerging needs of the modern manager. It disseminates cutting edge management knowledge in a style that is easy to comprehend without a particular functional bias. Issues that are topical and significant for today's managers operating in a complex and turbulent environment are given emphasis in The Professional Manager.

3. PAST EVIDENCE OF PERSEVERANCE

In discussing perseverance related to PIM, the Tsunami response sheds much light. As we remember, the disaster that killed more than 35,000 people and displaced over one million people was a wake-up call for all Sri Lankans. As ours was the second worst hit country, unity among all irrespective of their cast and creed was the need of the hour. Government of Sri Lanka set up coordinating bodies to plan and implement relief, rehabilitation and reconstruction programs, while non-governmental organizations backed by overseas assistance came forward to help the needy. The PIM was also one of the early movers, in positively responding to the post-Tsunami nation-building.

All business managers and public administrators of the Master's Degree program were required to visit tsunami affected areas of various districts, study the situations, and make proposals for action-driven management projects. Over one hundred proposals were processed. Over one hundred proposals were processed and they were re-formulated into the following five components:

a. Improvement of organization and management of temporary camps for the displaced families

b. Improvement of livelihood of selected families

c. Small business development

d. Business development

e. Institutional capacity development

The initiatives taken by PIM student community aptly guided by the faculty were in line with those five components. The implementation of projects associated with above five components was planned in two stages.

Stage1: Camp Management, temporary housing and restoration of livelihoods

Stage 2: Development Projects

Four guiding principles were adhered to in PIM Disaster Management Program. As Jayawardena & Nanayakkara (2005) describe, they are:

Principle of urgency: While relief measures continued, the first priority was given to rehabilitation of the displaced families and persons as early as possible.

Principle of plan integration: Human resettlement and economic reconstruction according to new plans for regional and town development must begin after giving careful attention to plan integration needs because those plans and programs are of a long-term nature.

Principle of focus: At a time when organizations, managers, and officials were largely unprepared for integrated planning and reconstruction, and their capacity to deliver were obviously poor, a need to be realistic and quickly attend to the immediate resettlement needs of the suffering people.

Principle of participation: As described earlier, dedication (heart), innovation (mind) and execution (hands) must be with the reality of disaster - the destroyed families, their property, and economic infrastructure, with a view of meaningful development.

It was a case of dedicated waves of commitment and care overcoming the challenges posed by the deadly waves of Tsunami. As Jayawardena (2005) explains, PIM managers analyzed the basic needs such as water, food, sanitation etc. of camp inmates and provided them. Secondly, they prioritized the specific needs and identified beneficiaries who are in immediate need to resume their livelihood.

Nearly Rs. 40 million Sri Lankan Rupees was spent in a period of 12 weeks in the camp management process, project in improving camp conditions and providing livelihoods for 890 persons that benefited 2500 families. The writer had personal experience in supervising the management improvement of four such camps done by four two-member MBA student groups. The infrastructure of the camps was improved and physiological and social needs such as food, sanitation, health, education, recreation etc. were attended to by the project teams. Table 1 contains the details of camp management projects.

Tsunami was a clarion call to all persons with ability and purpose to DIE in Disaster (Nanayakkara, 2005).

D – Dedicate their ability, purpose and energy towards the people who are affected

Table 1. Distribution of graduates to camps: Stage 1, Jan-May 2005

District	Colombo	Kalutara	Galle / Ahangama	Matara / H'tota	Balapitiya / Aakurala	Hikkaduwa / Kahawa	Trincomalee
Camps allocated	9	9	8	13	10	8	2
Student (teams)	14	10	10	10	13	10	2
Faculty Supervisors	2	2	2	2	2	2	1

Source: Disaster Management Program Unit, PIM, 2005.

I – Innovate new ideas and ways of doing to reach effective solutions, and

E – Execute the solutions together with speed and targets in mind.

When such DIE took place the victims were elevated to a position to LIVE in a meaningful manner (Dharmasiri, 2006).

L- Learnings for prevention and mitigation

I – Insights into human life and associated uncertainties

V- Values for living as a community in harmony

E- Energy to go through challenges of life.

The development projects are still being handled by PIM students, especially in the areas of productivity improvements at school level.

4. COVID19 RELATED INITIATIVES

Several initiatives by the PIM can be seen in the financial, professional, and intellectual fronts, with the involvement of PIM's faculty, staff, students, and alumni. It was an opportunity for us to pay our tribute to our motherland. We acted accordingly. There was a need to show a rapid response as a sensible corporate citizen. The PIM was the first state sector higher education entity to contribute Rs. 5 million from its self-generated reserves to the COVID19 Healthcare and Social Security Fund established by the President of Sri Lanka.

The PIM has been the only state sector higher education entity that does not get any funds from the treasury neither for its recurrent expenditure nor for its capital expenditure for over the past twenty years. Despite the fact that the PIM is having an ongoing building expansion project, self-reliance by itself has shown a significant signal to other state sector educational institutions to have a different revenue model.

With the presence of MBA study groups in Dubai (UAE), Doha (Qatar), Muscat (Oman), Kuwait City (Kuwait) and Dhaka (Bangladesh), the PIM is the most global higher education entity in Sri Lanka. Despite current setback with regards to air travel restrictions, the PIM has built a solid financial base for the post-Covid19 era with a healthy blend of local and overseas programme offerings.

The COVID19 pandemic offered several key opportunities for the PIM. Somewhat parallel to the post-Tsunami era, where the PIM professionally contributed to *restoration, reconstruction,* and *rehabilitation*, we started working on multiple fronts. The final year project of the MBA programme of PIM is an invitation for the participants to apply what they have learnt in a practical and value-creating manner. The faculty of PIM who are the project supervisors are much geared to work with their respective "learning partners" in identified areas such as business revival, organizational re-structuring etc.

The *PIM Genesis*, our business incubator has started providing advice for the affected Small and Medium Scale Enterprises (SME) for their survival and success. There is a dire need to offer such guidance as the SMEs contribute to over 52 percent to the Sri Lankan economy. With the involvement of PIM alumni in financial and other relevant sectors, this has become very demanding and highly appreciable.

Post COVID19 era will offer a plethora of intellectual prospects in the area of management. We have already started working on multiple fronts, despite being home-locked. Each faculty member is asked to develop a study framework in his/her respective specialization, with emphasis of key managerial challenges in the post-COVID19 era. They are supposed to work with an assigned student or a pair of students with a solid literature review and a sound theoretical underpinning.

It is expected to have a deep dive into Complex Adaptive Systems (CAS) to understand the now common VUCA (volatility, uncertainty, complexity, and ambiguity). This will be a vital part of a series of virtual discussions. In fact, responding to the VUCA 1.0 mentioned earlier with a VUCA 2.0 (vison,

understanding, confidence and agility) will be key for success and survival.

Plans are underway to deploy research students to explore cases of transformation from survival to success amidst COVID19. With the guidance of the PIM Research Centre, several cases will be documented, presented, and published as a PIM case study collection.

5. COVID19 RELATED INVOLVEMENTS

Having discussed the initiatives, the next logical extension of it is the involvements. Let me zoom into faculty, students, and others in particular. There was a need to switch over to online learning platforms and to conduct assessments through take-home mode. There was a high degree of adaptability demonstrated by the faculty. They did much more.

Linked-in has become a popular platform for the faculty to have constructive discussion on managerial aspects of post-COVID19. Moving beyond mere posting of facts and figures, value chain-conversations have been initiated by several faculty members. It was heartening to note the contribution of PIM faculty through regular columns in the print media such as Daily Financial Times (www.ft.lk) and Sunday Observer (www.sundayobserver.lk). Despite the limitations of printing the newspapers and circulating among the entire island due to lockdown, the complementary e-papers became popular. The appreciations received by the business community and the applications highlighted were very encouraging.

Despite the proliferation of webinars of varying standards of quality and relevance, the PIM faculty contributed in an impactful manner through their participations. Figure 2 is an example of such a webinar organized by

Figure 2. A webinar featuring PIM faculty (one among many)

the PIM Alumni (PIMA) with the involvement of one PIM faculty together with other PIM "products" who are proven business leaders.

There was an encouraging response from the students in variety of ways. The key was the adaptability of the changing context, which was essential.

Instead of physical sessions, all learning involvements have to be converted to on-line. With a proven online learning management system (LMS), named *Prajna* (Wisdom in Sanskrit), it was an easy transfer(https://prajna.pim.sjp.ac.lk/). We also have a locally developed platform with the collaboration of a communication provider, Mobitel and the "M-learning" through that has been found to be very useful. The way students positively responded to getting involved in sessions using Zoom webinars and lecture recordings using Loom technology has been encouraging. They were regularly guided by a series of messages. Figure 3 & Figure 4 contains two such messages sent through the learning portal.

As the first response to the island wide lockdown, we decided to convert all sit-down exams planed for the end of the term to be take home exams. With the guidance provided by the faculty, it was a very satisfactory performance with due adherence to plagiarism avoidance requirements (through the similarity index monitored by Turn-it-in software).

Despite restrictions for physical movements, the student community got involved in various service initiatives such as financial contributions, working with their respective organizations in distributing essential items to needy and creative contributions in the social media platforms.

Sharpening the Saw

Dear PIM Learning Community,

We are going through a challenging time where Corona Crisis has affected all walks of life. With much reluctance, the PIM was compelled to resort to self-learning for the next two weeks. I would suggest to make it a productive period with knowledge seeking in a true spirit of "sharpening the saw".

Needless to stress the mature adult response we need to demonstrate in taking care of ourselves and others with sound hygienic practices. We need to be socially conscious about the dire economic downturn globally, regionally, and locally. Let's endavour to empathize with suffering thousands around the globe and energize ourselves to sustain our spirit during a challenging era of VUCA (Volatility, Uncertainty, Complexity and Ambiguity). Perhaps, as Bill George suggests, its high time we embraced VUCA 2.0 (Vision, Understanding, Compassion and Agility).

It reminds me what Victor Hugo observed. "Nations, like stars, are entitled to eclipse. All is well, provided the light returns and the eclipse does not become endless night. Dawn and resurrection are synonymous. The reappearance of the light is the same as the survival of the soul."

Let's move ahead with confidence, in tackling one day at a time.

Yours in service,

Prof. Ajantha Dharmasiri

Figure 3. Director's first message to the learning community

Igniting Self-learning Passion

Dear PIM Learning Community,

We are witnessing an unprecedented uncertainty. Further to my previous mail on "sharpening the saw", the disturbing events around the globe would have distracted you from your focus on self-learning continuously. Despite the Covid19 doom, let's ignite the passion of continuous learning. Stay in touch with study material and as I often mentioned, *read, reflect,* and *relate*.

As Eckhart Tolle expressed in his bestseller, *A New Earth*, "when faced with a radical crisis, when the old way of being in the world, of interacting with each other and with the realm of nature doesn't work anymore, when survival is threatened by seemingly insurmountable problems, an individual life-form, or a species, will either die or become extinct or rise above the limitations of its condition through an evolutionary leap." It is an invitation to awake to our life's purpose. Use the extra free time to ponder on your purpose.

I have no better example than Victor Frankel, a Jewish physician, who survived in a concentration camp during the second World War. "Between stimulus and response there is a space. In that space is our power to choose our response. In our response lies our growth and our freedom." As he stated, we need to have the right response during this prolonged home-stay for a protective and a preventive reason.

Remember, life is all about *loving, learning,* and *leading*. Do take care of yourself and all your loved ones. Do help others in dire need. Whilst doing all these, ignite the passion of self-learning.

Yours in service,

Prof. Ajantha Dharmasiri

Figure 4. Director's second message to the learning community

Figure 5 is such an illustration of an animated video made by a group of students highlighting the physical distancing required to avoid the spreading of the virus.

It was heartening to see some eminent and prominent personnel who play an active role in the COVID19 task force in Sri Lanka are PIM alumni. Also, we must not forget the dedicated

Figure 5. Creative use of PIM logo for a worthy cause

non-academic staff who provide the backbone of running the institution uninterruptedly.

There was a high number of webinars featuring proven business leaders who are prestigious PIM alumni. It included institution heads such as Chairman of the largest state bank, the Director General of Health Services, entrepreneurs, senior government secretaries etc. who really kept the PIM flag high.

Rising up to the occasion, the non-academic staff of PIM responded committedly by attended to assigned tasks from home. Desktop publishing of Professional Manager, the flagship publication of PIM and managing the *Prajna* learning portal are two such examples. It was an acid test for us to see how effective telecommuting could be.

The COVID19 Task Force appointed by the president of Sri Lanka, the apex body that take key strategic decisions in tackling the pandemic included several PIM alumni such as Dr. Anil Jasinghe, the former Director General of Health Services. The economic revival task force appointed by the president of Sri Lanka also have key business leaders who are PIM alumni.

Having discussed the initiatives and involvements, the key insights being captured are worth noting.

The flagship publication of PIM targeting the practicing professionals, will have a special issue published containing a collection of comprehensive articles discussing a variety of managerial dimensions in the post-COVID19 progress. The faculty and alumni of PIM have both shown interest in contributing such informative and insightful articles. It will be an issue similar to what we did after Tsunami titled, "Tsunami Challenged".

Based on the research findings, comprehensive collection of research papers will be published as a special issue of the Sri Lankan Journal of Management (SLJM). Being the only Sri Lankan management journal hosted by EBSCO, it will have a wider reach to share the authentic insights of COVID19 challenge. This will highlight the salience of success practices such as the use of tracing method to identify virus contacts with the use of military intelligence and healthcare personnel.

The annual research conference of PIM (PIMARC) will be focusing on the research findings related to COVID19 in reaching a wider audience of research scholars, learning managers, administrators, decision makers and implementors. Based on the progress of faculty and student research, it is planned to be held in 2021.

6. INSIGHTS GAINED RELATED TO COVID19

Institutional leaders have a key responsibility for protecting the lives and livelihoods of their constituents. In routine times, they may follow time-honored procedures honed over decades of experience, confident that lessons from the past will guide them. As Comfort et al. (2020) highlighted, for public leaders facing unknown risks, decision-making is fraught with uncertainty and becomes an adaptive process that has four distinct components: (1) cognition, (2) communication, (3) coordination, and (4) control. Under conditions of COVID-19, how public leaders exercised these four functions proved critical in different contexts. We saw the relevant of the above four Cs at PIM.

As Comfort et al. (2020) further observe, in crisis management, *cognition* is the "capacity to recognize the degree of emerging risk to which a community is exposed and to act on that information". Importantly, cognition provides the transition to action. It constitutes not simply the perception of risk to self but also comprehension of the risk to others. That is, action taken may help oneself, but action not taken may irretrievably harm others. The fundamental component of empathy in cognition creates a human connection to others who share the risk and spurs collective action for the benefit of the community as a whole. We at PIM saw a glimpse of this reality in the

way of handling the first wave of the pandemic in Sri Lanka.

Communication could be viewed as a process that links sender and receiver in shared comprehension of messages. In doing so, communication creates shared meaning among actors with different roles. It is the means used to inform partner agencies in the global community as well as the public in different nations about the potential risk and rationale for evidence-based mitigation measures and the need for collective response. As Comfort et al. (2020) clearly observe, effective communication to explain COVID-19 to the public as an invisible, novel, deadly threat requires strong leadership, timely and evidence-based information, and trust to build broad public consensus to support collective action. We Sri Lankans still struggle to convince some sections of the society regarding the needed disciplinary approach. We at PIM managed to convince our learning community but it is rather limited in the context of the socio-economic fabric in Sri Lanka.

Coordination in this context can be described as the degree to which organizations align their resources, tasks, and time to engage in interdependent functions to achieve a shared goal. In complex environments, coordination requires articulation of shared goals among diverse actors in response to shared risk. "Be fast, have no regrets... If you need to be right before you move, you will never win", said Mike Ryan, epidemiologist at WHO, last year. Coping with the risk of COVID-19, each nation faced decisions about how to align the components of their respective national response systems in ways that would slow or stop transmission of the virus, actions that would also contribute to the global goal. Public leaders build trust with their constituents through timely, informed communication, enabling citizens to accept the validity of proposed actions for both self and community and to act, collectively, under the extraordinary constraints of crises. We attempted to act so at PIM.

Control can be viewed as the capacity to respond to an external threat and still maintain regular operations in the society. In reference to COVID-19, control means achieving a reasonable balance between mitigating the spread of the infection, building health care capacity, and managing a safe level of economic and social activity. The global crisis generated by COVID-19 requires coordination not only across jurisdictional boundaries within countries but also across national boundaries to bring this massive pandemic under effective control. This is where we have been having major challenges in Sri Lanka leading to a chaotic second wave.

"Human kindness has never weakened the stamina or softened the fibre of free people; A nation does not have to be cruel to be tough", so said Franklin D. Roosevelt. The balance between enforcing controls and ensuring continuity is a tough task in the hands of key decision makers. We saw this here and abroad alike.

7. MOVING AHEAD IN CONFIDENCE

Strategy formulation and implementation is the sure way forward in achieving sustained results. Accordingly, the PIM's forward path is shaped by its current three-year strategic plan (2020-2022). It begins with the PIM's Vision, Mission and Values followed by Goals and Objectives and Key Performance Indicators for the said period. It is a logical extension of the previous goals that were aligned with the twelve strategic goals of the Ministry of Higher Education, formulated in 2014 towards making Sri Lanka an international hub of excellence in higher education. We still think Sri Lanka has the required potential to reach there, despite COVID19 challenges.

PIM's *Vision* is as follows:

To become a Centre for Management Excellence in South Asia

PIM's *Mission* can be stated as given below:

We ignite human imagination by developing leaders having global presence with local pulse.

In this endeavor, we pursue innovative teaching, cutting-edge research, enriching partnerships, inspiring sustainability, and exemplary governance.

PIM has formulated three core values, namely **Passion, Integrity** and **Mindfulness**. Key behavioural indicators of those values are as shown in Table 2.

The above values and the associated KBIs are of high practical significance in moving along the strategic direction. PIM's forward march can be depicted as an edifice of excellence. Figure 6 contains the details:

As depicted in Figure 6, five-fold strategic thrusts, namely *teaching, research, partnerships, sustainability,* and *governance* have been identified.

Table 2. Core values of PIM

Value	What it Means	Key Behavioural Indicators (KBIs)
Passion	Enthusiasm and eagerness towards results in showing professionalism.	1. Is clear about the tasks associated with the job 2. Is enthusiastic in handling tasks 3. Thinks innovatively in finding new solutions 4. Is conscious about one's contribution to the institutional success 5. Willing to put extra effort to achieve objectives
Integrity	Acting in an ethical manner with the best interest of the institution in mind	1. Is honest in conducting oneself 2. Can be trusted in handling confidential matters 3. Conducts oneself fully within the rules and regulations of the institution 4. Cannot be manipulated for unethical actions 5. Keeps the institution's needs ahead of one's interest
Mindfulness	Paying attention to purpose and actions in doing things with self-awareness	1. Pays attention to details 2. Is aware of the needed actions in any given moment 3. Looks at situations unbiased with and open mind 4. Has complete focus on tasks at hand 5. Is efficient in utilizing time

Figure 6. **PIM's edifice of excellence**

Source: PIM's Strategic Plan 2020- 2022

Teaching Excellence: This has been the forte of PIM. III. Introduction of hybrid lecture sessions (partly physical and partly online) for the PIM students due to prevalent pandemic situation in the country was something we did last year.

Research Excellence: PIM with its dedicated research centre conducts research in the discipline of management. Continuation of "In Dialogue With" monthly research series where a recent doctoral graduate is showcased with cutting-edge research findings and the introduction of "Monthly Montage", a Webinar to deeply discuss current topics of management relevance to feature PIM faculty and alumni are some recent initiatives.

Partnership Excellence: PIM recently signed an MOU with the University of New South Wales, Canberra, for research collaboration. This is the first time in Sri Lanka where such a comprehensive collaboration takes place with research fellowships and faculty exchange. Despite financial restrictions, plans are underway to continue PIM's International Management Programme (a vibrant international study course of approx. 10 days duration) in collaboration with University of Kasetsart, Thailand, University of Gadjah Mada, Indonesia and many other leading international institutions.

Sustainability Excellence: Achievement of a healthy surplus (with a significant year-on-year growth) to ensure economical sustainability has been the key. The second stage of the PIM building complex costing more than Rs. 300 million is being implemented, thorough self-generated funds. From ecological sustainability, greener infrastructure, paper-less working, energy-efficient lighting, and many other plans are on the cards.

Governance Excellence: This is the key for above all from a broad strategic perspective. The autonomy of the PIM is enshrined in the enabling legislation which provides for administrative, financial, and operational freedom. Obtaining a "Merit Award" at the National Productivity Awards 2019 is something PIM is proud of. Regular conduct of Board of Management and Boards of Study meetings as planned, continuation of the ISO 9001:2015 quality status for the MBA programme and obtaining a comparatively better Audit Report from the Government Auditors highlighting continuous improvements are other key highlights. As observed by Solechan (2020), the need to be open to new governance challenges in the era of COVID19 should be taken into cognizance.

8. COMPETITIVE CHALLENGES

Though in the early 1980's a monopolistic market existed in the country, now, more than 40 years later, the market for MBAs has become very competitive. Almost all universities in the country offer MBA programmes while over a dozen private, off-shore MBA programmes also compete with PIM. These latter programmes are advertised extensively using foreign funds and charge fees in excess of double that of PIM for their MBA programmes.

Competition comes from lowering entry qualifications and the use of the faculty of the local universities as resource persons with their 'prestigious' name tags. These are the key challenges to PIM, the institution that has taken the bold initiative to operate on self-generated funds. The competitor private educational institutions are not hampered by the restrictions that PIM faces. Owing to its self-imposed initiative to be self-sufficient, PIM has to earn funds to pay for salaries, utilities, supplies, transport needs, capital expenditure, taxes and maintenance, security and audit fees. This is indeed a unique situation where a public sector organization in Sri Lanka has dared to earn its upkeep covering all its expenses, both recurrent and capital, and manage the institution with a surplus.

For private enterprises, profitability provides the key indicator of efficiency. For state-owned enterprises, profitability may not be a sufficient indicator, given that many such enterprises are not created to maximize profits as they perform non-profit making functions. However, where a state-owned enterprise

functions without being a burden on the Treasury, in our view, such activities must be promoted. Only a performance-based auditing will motivate PIM to improve its operational performance and delivery of services.

In seeking to maintain flexibility, we need a criterion for creating, managing, supervising and holding to account different types of enterprise. As a result, a wide variety of enterprises should exist, each with its own funding, reporting, personnel and governance arrangements.

9. ROAD AHEAD

We have explored key governance aspects linked excellence in relation to PIM. It has come a long way amidst key challenges, yet having a forward path to pursue. PIM's theme says, "We ignite human imagination". As Pink (2005) proposes in his best-selling book, "whole new mind", the future belongs to "right brainers". We believe that *imagination* is the starting point that leads to *innovation* and *implementation*. This should be the case for all sensible institutions battling COVID19.

The PIM, as we aptly claim as the Nation's Management Mentor will continue to contribute to the value creation in terms of producing leaders with required competence and confidence, in line with its vision, mission and values. In hindsight, we can be satisfied the way we sought "serendipity in adversity" in the wake of COVID19. "Performing, responsible management is the alternative to tyranny and our only protection against it.", so said Drucker (2005). PIM will continue to serve the aspiring learning community locally and regionally in broadly contributing to the socio-economic upliftment of our beloved nation.

REFERENCES

Comfort, L. K., Kapucu, N., Ko, K., Menoni, S., & Siciliano, M. (2020). Crisis Decision-Making on a Global Scale: Transition from Cognition to Collective Action under Threat of COVID-19. *Public Administration Review*, *80*(4), 616-622.

Dharmasiri, A. S. (2006). *Post-Tsunami Nation Building – A Pioneering Effort from a Premier Business School*, paper presented at the Annual Conference of British Association for South Asian Studies (BASAS), held at the Birkbeck College, London, UK.

Drucker, P. (2005). https://www.drucker.institute/perspective/about-peter-drucker/

Liyanage, U. (2009). "Developing Competency based Skills to Become and Stay Employable", *Sri Lankan Journal of Management*, 14 (1): 25 -37.

Jayawardena, A.K.L. & Nanayakkara, G. (2005). *Managing Temporary Camps and Human Re-settlement*, Colombo: Academy of Management Sciences.

Nanayakkara, G. (2005). *PIM's Response for Tsunami Disaster*, Colombo: PIM Publication.

Pink, D.H. (2005). *A Whole New Mind*, New York: Riverhead Books.

Senge, P. M. (1990). *The Fifth Discipline*, London: Century Business.

Solechan, S. (2020). Rules and Policies Related with Good Governance When Corona Virus 2019 (COVID19) Pandemic. Administrative Law & Governance Journal, 3(2), 206-219.

Strategic Plan of PIM for 2020-2022.

BIBLIOGRAPHY

COVID19 Related Quotes, https://www.bestsolicitorsonline.co.uk/covid-19-3-famous-quotes-to-read-right-now/

PIM Website, www.pim,sjp.ac.lk

NATIONAL SCIENCE FOUNDATION

Section 9

Supply Chain

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Supply Chain: Introduction

Ajantha S. Dharmasiri

A disaster such as the pandemic being experienced is a low probability, high impact event that threatens the viability of the social system that has an ambiguous cause, effect, and resolution. As such, a viable supply chain should be *Agile* to respond to the nature of demand at each phase; *Lean* to eliminate all types of waste during the supply linkages between producer and customer by getting earlier demand information to effectively match supply and demand; and *Green* to meet the standards of sanitation needed for consumption, particularly in a time of a pandemic. Hence, the research related to a *Lean*, *Green* and *Agile,* Supply Chain for essential items is of utmost importance. It can further be extended to cover many diverse areas of socio-economic significance.

This section contains five papers selected for publication, based on the presentation of abstracts during the conference. They cover a range of aspects inclusive of apparel, pharmaceutical and healthcare industries with specific emphasis on mitigating the disruption of supply chains causing socio-economic issues. Both *micro* aspects such as ensuring the effectiveness of door-to-door delivery of medicinal drugs and *macro* aspects such as ensuring the robustness of a healthcare supply chain have been addressed with required depth and breadth.

The first paper titled, "Analysis of correlation of risk in the supply chain disruption in apparel industry during an epidemic outbreak" attempts to identify, categorize, and prioritize supply chain risks faced during an epidemic outbreak, in the context of the Sri Lankan apparel industry in order to monitor and mitigate them to continue in business. It recommends that organizations should consistently monitor and mitigate identified risks, as a priority.

"Survey on online receipt of prescriptions and island wide door-step delivery of medicine though Rajya Osusala and private pharmacies during COVID-19 outbreak of Sri Lanka" is the apt title of the second paper that attempts to measure the progress of island-wide doorstep delivery of medicine using a relatively new channel of reaching to the deserving patients. The paper recommends the ways of further strengthening such channels by way of proper monitoring of the implementation during the periods of outbreaks and disasters.

The third paper titled, "Ensuring uninterrupted services for non-communicable diseases patients during COVID-19 pandemic: Best practices from Sri Lanka", deals with multiple aspects of designing and delivering the expected service with the use of web-based technologies. The paper highlights the issue of most healthcare institutions not maintaining a data base of NCD patients, and as such can hinder service delivery during a crisis situation. Based on an online survey conducted, the paper identifies issues involved and discusses recommendations for consistent care of NCD patients.

"Sri Lankan supply chains: Lessons learnt during Covid-19" is the title of the fourth paper. It, as a viewpoint article reviews experts' opinions and experiences during Covid-19 that are published in newspapers, magazines, research journals and websites. The paper discusses the results of a content analysis showing the impact of Covid-19 on Sri Lankan economy as massive in terms of failures at last mile deliveries, integration and collaboration of supply chains, visibility of supply chains and meeting the excessive demand emerged suddenly for Fast Moving Consumer Goods due to the panic buying behavior of the consumers.

The final paper in this section titled, "Healthcare supply chains in Sri Lanka: Responsiveness and resilience during the COVID-19 Pandemic", deals with impact on the healthcare supply chains and the improvements required. Drawing from, information from diverse global and local sources from scholars, professionals and policy makers, the paper addresses the needs for progressing the current healthcare supply chains to become 'Smart Supply Chains' based on the utilization of digital

technologies, appropriate 'business models' and supplier relationships.

As areas for further studies emerging from the above papers, crafting of strategies on mitigating the pre-identified risks through with the use of simulation models and other versatile tools can be cited as one. and a model developed for other industries to identify their risks.

The above papers do not specifically address the food related supply chains in Sri Lanka. The vital aspects such as post-harvest preservation, timely distribution of perishable items, equitable ways of dealing with farmers, distributors, vendors, and consumers etc. need more in-depth research with implications to policy making. More discussions on the path to unveiling innovative supply chains in varied industries: mobile super-markets, tele-medicine, online lecture delivery and assessments in education industry are required. It is essential to create a positive trend towards collaboration rather than competition with a holistic view of socio-economic upliftment in mind.

Analysis of correlation of risk in the supply chain disruption in apparel industry during an epidemic outbreak

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ABSTRACT

Supply chain disruption is a major breakdown in the distribution channel and can be caused due to natural disasters, strikes, legal disputes, manmade catastrophes and epidemic outbreaks. According to the fortune newsletter, at the arrival of the COVID-19 pandemic, 140,104 companies were temporarily shut down. The paper attempts to identify, categorize and prioritize supply chain risks faced during an epidemic outbreak, in the context of the Sri Lankan apparel industry in order to monitor and mitigate them to continue in business. Potential risks were identified from a review of literature, interviews and then analysed using bivariate correlation. The identified risks are loss of local and international key supplier, local and international port closure, transportation link disruption (other than ports), raw materials delays and shortages, human resource shortages, product demand variations, order cancellations and lead time variations. The study used spearman's rho to calculate the correlation for each category. Under time category, loss of international key supplier, transportation link disruption, product demand variations and lead time variations are highly correlated to the rest of the risks. Under the cost category loss of local key supplier, local port closure, transportation link disruption and raw materials delays and shortages are highly correlated to the rest of the risks. Therefore, companies should monitor and mitigate these risks, as a priority. The study can be further developed to identify the strategies for pre-identified risks and a model developed for other industries to identify their risks.

Key words: Supply chain disruptions, Supply chain risks, Epidemic outbreak, Correlation analysis, Risk prioritization

1. INTRODUCTION

Supply chain disruption is a major breakdown in the distribution channels and it can be caused due to natural disasters, manmade catastrophes, strikes, legal disputes and epidemic outbreaks (Ivanov, 2020; SME, 2011). Due to a tsunami in 2011, Japan's exports reduced between 0.5% to 1.6% (Escaith et al., 2011). Moreover, a brake-fluid proportioning valve supplier was under fire on 1st February 1997 which led Toyota to shut down all its plants and assembly lines and caused a sales loss of 70,000 vehicles (Nishiguchi & Beaudet, 2002; Munim et al., 2015). Further, epidemic outbreaks such as SARS, Ebola, swine flu and recently the corona virus has disrupted supply chains across industries and across geographical boundaries.

Corona virus (COVID-19) emerged at the end of 2019 in Chinese city of Wuhan (Hippold, 2020). There are more than 5 million companies who have direct, tier 1, or tier 2 suppliers from Wuhan, and due to the spread of the virus Chinese factories were temporary

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shutdown (Haren & Simchi-Levi, 2020). Further, according to the fortune newsletter, at the arrival of the COVID-19 pandemic, 140,104 companies in USA were temporarily shut down (Sraders & Lambert, 2020). The effect on the apparel industry is also the same.

Apparel industry is one of the oldest, largest and most global industries in the world and it is the typical 'starter' industry for countries engaged in export orientated and labour-intensive industrialisation (Gereffi, 2002). Moreover, it offers a range of job opportunities even for unskilled labourers in developing countries and it has enable poor countries to keep the first step in the 'industrialisation ladder' (Keane & Velde, 2008). Therefore, the continuity of the apparel industry is crucial.

The garment sector in Asia and the Pacific was affected severely because of COVID-19 which affected millions of workers and enterprises in the supply chains (Jackson et al., 2020). Retail sales were showing sharp decline because most of all supply chain jobs in the region were dependent on domestic or foreign consumer demand from countries with highly stringent lockdown measures. Exports from Asia's garment-producing countries dropped by 70% and the countries experienced imported input supply disruptions up to 60% (Jackson et al., 2020). Moreover, during the onset of the crisis cancellations of buyers' orders were common and thousands of supplier factories were either temporarily or permanently closed, workers were laid-off and dismissals were widespread (Jackson et al., 2020).

The disruption faced by the Sri Lankan apparel manufacturing companies were very similar to global context as most of the apparel manufacturing companies were struggling without raw materials for the upcoming orders. Moreover, Sri Lankan apparel industry contributes 6% to its GDP and 44% to its national export revenue, and set its target before COVID-19, to achieve $8 billion export revenue by 2025 (BOI, 2020; EDB, 2020). Therefore, this paper is focused on the Sri Lankan apparel industry because of its significant contribution to the country's economy.

Therefore, our focus is to identify, categorize and prioritize supply chain risks faced during an epidemic outbreak in the context of the Sri Lankan apparel industry and to identify the relationship among the identified risks for companies to monitor and mitigate them to continue in business.

2. METHODOLOGY

The prioritization of risk is essential as it acts as drivers to other risks. Therefore, it is imperative that managers focus on the few risks which act as drivers to other risks. Based on risk definitions and characteristics stated by Xu (2008), we have selected "risk is an attitude towards future" which is the time factor and "disadvantage to the company" which is the loss or cost factor as the characteristics to categorize supply chain risks.

The main purpose of this paper is to identify risks to analyse the costs and time associated with the supply chain risks and prioritize them. It is important to control these risks since it might lead companies to go through a temporary shutdown during an epidemic outbreak.

A literature review was carried out to identify what risks they faced and how the supply chain disruption was handled in the past. Moreover, interviews were conducted to further identify the supply chain risks during an epidemic outbreak. According to the data that was gathered, it was decided to categorize the risks under time and cost categories because time and cost are essential components to making decisions.

The risks related to pandemic outbreak and apparel industry were identified from past literature and interviews. Ten different risks were identified and they are:

- (R1) - Loss of local key supplier (Tukamuhabwa et al., 2017; Venkatesh et al., 2015; Xu, 2008)

- (R2) - Loss of international key supplier (Tukamuhabwa et al., 2017; Venkatesh et al., 2015; Xu, 2008)
- (R3) - Local port closure (Xu, 2008)
- (R4) - International port closure (Xu, 2008)
- (R5) - Transportation link disruption-other than ports (Tukamuhabwa et al., 2017; Venkatesh et al., 2015; Xu, 2008)
- (R6) - Raw materials delays and shortages (Tukamuhabwa et al., 2017; Venkatesh et al., 2015)
- (R7) - Human Resource shortages (Venkatesh et al., 2015)
- (R8) - Product demand variations (Tukamuhabwa et al., 2017; Venkatesh et al., 2015)
- (R9) - Order cancellations (Tukamuhabwa et al., 2017; Venkatesh et al., 2015)
- (R10) - Lead time variations (Ivanov, 2020; Venkatesh et al., 2015).

Convenience sampling was used to select the companies and random sampling to select the participants for the interviews and survey. The participants were the executive grade staff who have more than five years' experience from the apparel industry and who were involved in supply chain functions. Using the data gathered from the survey, the identified risks were analysed using bivariate correlation to measure the strength of the relationship between each pair. Only 35% of the data follows a normal distribution, therefore, we used spearman's rho to calculate the correlation for each category. We have considered the value which is greater than or equal to 0.7 as highly correlated.

The outcome of the analysis was then represented graphically. With the assistance of experts', the reasons related to the relationship among risks were identified in order to prioritize them and facilitate the management to take appropriate decisions to mitigate the effect from these risks.

3. RESULTS AND DISCUSSION

The results of the survey analysis under time category is shown in Table 1.

Correlation values which are greater than or equal to 0.7 are highlighted in green colour. We have taken them as highly correlated risks and ignored the correlation between the same risk. Using the relationship shown in Table 1 we developed a diagram to understand the relationship between each risks and it's shown in Figure 1.

The doted box in Figure 1 represent that inside the box all risks are correlated to each other. If there is a connection made from one

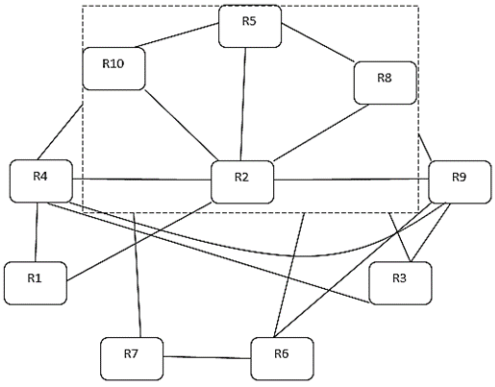

Figure 1. Correlation diagram under time category

Table 1. Correlation results under time category

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	1	0.839	0.648	0.723	0.686	0.487	0.555	0.547	0.638	0.61
R2	0.839	1	0.797	0.813	0.847	0.786	0.775	0.832	0.845	0.856
R3	0.648	0.797	1	0.97	0.725	0.684	0.614	0.923	0.974	0.852
R4	0.723	0.813	0.97	1	0.719	0.635	0.579	0.888	0.965	0.877
R5	0.686	0.847	0.725	0.719	1	0.821	0.873	0.849	0.81	0.809
R6	0.487	0.786	0.684	0.635	0.821	1	0.974	0.861	0.73	0.889
R7	0.555	0.775	0.614	0.579	0.873	0.974	1	0.798	0.668	0.831
R8	0.547	0.832	0.923	0.888	0.849	0.861	0.798	1	0.961	0.944
R9	0.638	0.845	0.974	0.965	0.81	0.73	0.668	0.961	1	0.905
R10	0.61	0.856	0.852	0.877	0.809	0.889	0.831	0.944	0.905	1

node to the doted box, that means that there is a correlation between that particular node with all nodes in the doted box. We have identified that some risks have many connections to nodes but some have less. Considering the connections to each node we developed a hierarchical diagram and it is shown in Figure 2.

According to Figure 2 we can identify that R2 (Loss of international key supplier) is highly correlated to all the other risks which means that there is a high probability of occurrence of other risks due to R2. Therefore, companies should focus primarily to mitigate on losing international key suppliers. Further, companies should focus on R5 (Transportation link disruption), R8 (Product demand variations) and R10 (Lead time variations) as these risks are secondly highly correlated to the rest of the risks.

The results of the survey analysis under cost category is shown in Table 2.

Correlation values which are greater than or equal to 0.7 are highlighted in green colour. We have taken them as highly correlated risks and ignored the correlation between the same risk. Using the relationship shown in Table 2 we developed a diagram to understand the relationship between each risks and it's shown in Figure 3.

According to Figure 3 we can identify that R1 (Loss of local key supplier), R3 (Local port closure), R5 (Transportation link disruption) and R6 (Raw materials delays and shortages) are highly correlated to other risks which means that there is a high probability of occurrence of other risks due to R1, R3, R5 and R6. Therefore, companies should focus primarily to mitigate on losing local key suppliers, local port closure, transportation link disruption

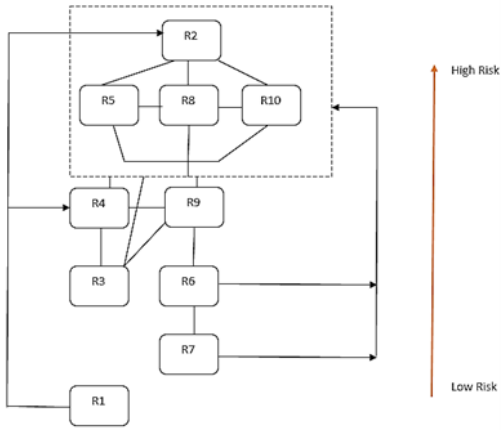

Figure 2. Hierarchical diagram under time category

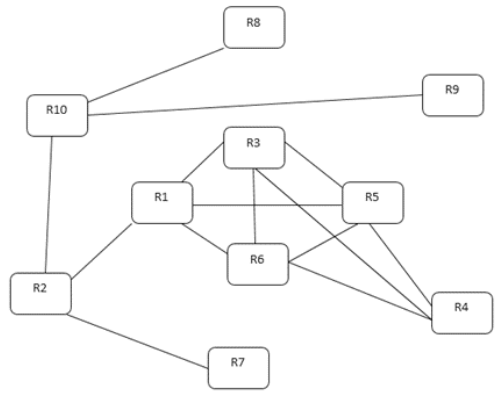

Figure 3. Correlation diagram under cost category

Table 2. Correlation results under cost category

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
R1	1	0.715	0.931	0.6	0.797	0.828	0.63	0.558	0.625	0.586
R2	0.715	1	0.645	0.476	0.661	0.406	0.772	0.538	0.61	0.839
R3	0.931	0.645	1	0.793	0.781	0.821	0.679	0.409	0.668	0.537
R4	0.6	0.476	0.793	1	0.747	0.736	0.531	0.06	0.574	0.398
R5	0.797	0.661	0.781	0.747	1	0.811	0.622	0.135	0.319	0.324
R6	0.828	0.406	0.821	0.736	0.811	1	0.458	0.24	0.55	0.325
R7	0.63	0.772	0.679	0.531	0.622	0.458	1	0.313	0.613	0.52
R8	0.558	0.538	0.409	0.06	0.135	0.24	0.313	1	0.628	0.712
R9	0.625	0.61	0.668	0.574	0.319	0.55	0.613	0.628	1	0.816
R10	0.586	0.839	0.537	0.398	0.324	0.325	0.52	0.712	0.816	1

and raw materials delays and shortages when considering cost.

Considering both time and cost category highest correlated risks, we have developed a Venn diagram and shown in Figure 4.

It can see that R5 (Transportation link disruption) is highly correlated to rest of the risks when you consider in both categories. Therefore, it is better to mitigate transportation link disruption first and then consider R2, R8, R10 under time category and R1, R3, R6 under cost category.

Based on the discussion with experts, the study identified that it takes more time to mitigate loss of international key supplier (R2) and it is highly correlated to the rest of risks because International key suppliers are the main source of income to the company. Therefore, losing them will cause a chain reaction. Customers may not like the alternative supplier, quality issues, and it takes time to find alternative suppliers therefore, lead time will increase, raw materials to produce the product will be insufficient which will lead to order cancellations or delay in fulfilling orders.

Considering loss of local key supplier (R1) under cost category, it was identified that it is costly because losing local key supplier will lead to find alternative suppliers and there will be shipping cost, lead time to deliver the raw materials will be high which is costly to the company. Moreover, local port closure (R3) will lead to sourcing other means of transportation for raw materials into the country and products out of the country. This will be costly because you may be currently using the optimum method of transportation resulting in, shortage and delay of raw materials which will lead to delayed orders. Similarly, raw materials delays and shortages (R6) will result, due to loss of suppliers, port closures, transportation disruptions which will be costly to address them as they are using the optimal ways of conducting business.

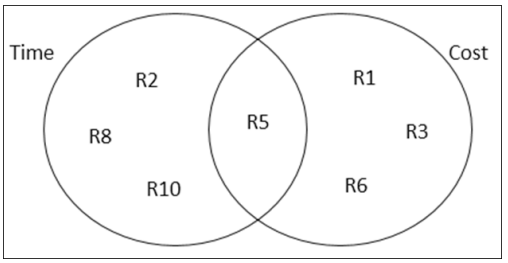

Figure 4. Venn Diagram for both time and cost categories

At the end of every production we should deliver the products on time to gain the benefit from it. Therefore, transportation link disruption is a crucial risk to be mitigated.

4. CONCLUSION

It is difficult to anticipate the arrival of an epidemic outbreak, however, companies can identify the supply chain risks and be prepared for it now rather than waiting for it to occur. It is recommended to focus on the highly correlated risks under time and cost category as its risk is high compared to others. If it's not mitigated the business might have to temporarily shut down due to the disruption caused. Considering the time category, the study identified that loss of international key supplier is highly correlated to all the other risks which means that there is a high probability of occurrence of other risks and companies should focus primarily to mitigate it. Further, companies should focus on transportation link disruption, product demand variations and lead time variations as these risks are also highly correlated to the rest of the risks.

Moreover, considering the cost category, the study identified that loss of local key suppliers, local port closure, transportation link disruption and raw materials delays and shortages are highly correlated to other risks which means that there is a high probability of occurrence of other risks and companies should focus primarily to mitigate them.

The limitation of this study was that an assumption was made that the participants had to assume that clients are international and suppliers are both local and international in order to collect data under a same domain. Further studies can be conducted considering

many domains. Moreover, the weightage given to cost and time is equal. However, this study can be further developed to identify the weightage to be given for the cost and time factors. As for future work, this study can be extended to identify the strategies which should be taken in order to mitigate the supply chain disruptions. These outcomes of the research allow managers to evaluate the course of action that they should take concerning the supply chain disruption that they experience during an epidemic outbreak.

REFERENCES

Board of Investment Sri Lanka (BOI). (2020). *Apparel*. Available at https://investsrilanka.com/apparel/

Escaith, H., Teh, R., Keck, A., & Nee, C. (28 April 2011). *Japan's earthquake and tsunami: International trade and global supply chain impacts*. Retrieved from https://voxeu.org/article/japans-earthquake-and-tsunami-global-supply-chain-impacts.

Export Development Board (EDB). (2020). *Industry Capability Report Sri Lankan Apparel Sector*. Export Development Board, Sri Lanka.

Gereffi, G. (2020). Outsourcing and changing patterns of international competition in the apparel commodity chain, *Conference on Responding to Globalization: Societies, Groups, and Individuals,* Boulder, Colorado, April 4-7.

Haren, P. & Simchi-Levi, D. (2020). How coronavirus could impact the global supply chain by mid-March. *Harvard Business Review*. Retrieved from https://hbr.org/2020/02/how-coronavirus-could-impact-the-global-supply-chain-by-mid-march.

Hippold, S. (3 February 2020). *coronavirus: how to secure your supply chain*. Retrieved from https://www.gartner.com/smarterwithgartner/coronavirus-how-to-secure-your-supply-chain.

Ivanov, D. (2020). Predicting the impacts of epidemic outbreaks on global supply chains: A simulation-based analysis on the coronavirus outbreak (COVID-19/SARS-CoV-2) case, *Transportation Research, 136*, 101922. doi: 10.1016/j.tre.2020.101922

Jackson, J., Judd, J., & Viegelahn, C. (21 October 2020). *The supply chain ripple effect: How COVID-19 is affecting garment workers and factories in Asia and the Pacific*. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/briefingnote/wcms_758626.pdf.

Keane, J. & Velde, D. (2008). *The role of textile and clothing industries in growth and development strategies. Investment and Growth Programme,* Overseas Development Institute, London.

Munim, Z.H., Azmat, M., & Dorfer, B. (2015). Impact of man-made disasters on commercial logistics. *International Journal of Economics, Commerce and Management*, *3*(6), 128-138.

Nishiguchi, T., & Beaudet, A. (2002). *Self-organization and clustered control in the Toyota group: lessons from the Aisin fire*. Massachusetts, USA: Massachusetts Institute of Technology International Motor Vehicle Program.

SME, S. (18 January 2011). *How do supply chain risks occur? A managerial framework for reducing the impact of disruptions to the supply chain*. Retrieved from https://scm.ncsu.edu/scm-articles/article/how-do-supply-chain-risks-occur-a-managerial-framework-for-reducing-the-impact-of-disruptions-to-the-supply-chain.

Sraders, A., & Lambert, L. (11 December 2020). *Nearly 100,000 establishments that temporarily shut down are now out of business*. Retrieved from https://fortune.com/2020/09/28/covid-buisnesses-shut-down-closed.

Tukamuhabwa, B., Stevenson, M., & Busby, J. (2017). Supply chain resilience in a developing country context: a case study on the interconnectedness of threats, strategies and outcomes. *Supply Chain Management: An International Journal*, *22*(6), 486-505. doi: 10.1108/SCM-02-2017-0059

Venkatesh, V.G., Rathi, S., & Patwa, S. (2015). Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. *Journal of Retailing and Consumer Services, 26*, 153-167. doi: 10.1016/j.jretconser.2015.06.001

Xu, J. (2008). Managing the risk of supply chain disruption: Towards a resilient approach of supply chain management, *ISECS International Colloquium on Computing, Communication, Control, and Management,* pp. 3-7. doi: 10.1109/CCCM.2008.9

Survey on online receipt of prescriptions and island wide door-step delivery of medicine through Rajya Osusala and private pharmacies during COVID-19 outbreak of Sri Lanka

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ABSTRACT

With increasing numbers of COVID-19 patients in Sri Lanka, Government decided to limit the movement of people by imposing curfew. With the extension of curfew, a mechanism to obtain drugs to the patients from Rajya Osusala and private pharmacies had to be implemented. The pharmacies willing to receive prescriptions online and carryout doorstep delivery of medicines were enlisted and advertised in the Ministry of Health website.

The objective of the study was to measure the progress of island-wide doorstep delivery of medicine though Rajya Osusala and private pharmacies using the newly developed online system, during COVID-19 outbreak of Sri Lanka.

A descriptive cross-sectional study was conducted in all the districts of Sri Lanka in a random, population proportionate sample of 591 pharmacies selected from list of pharmacies in Ministry of Health web site by 07th April 2020. Data were collected through a pretested tri-lingual online survey form.

On one day of curfew (17th of April 2020), 47,629 prescriptions were received by Rajya Osusala and private pharmacies. 67.8% of them were received online. Other methods of receiving prescriptions were from walk in clients, prescriptions sent through government officers and requesting via telephone. 64.7% (20,927) orders received online on 17th April were delivered doorstep of the clients on the same day. In addition, 43,678 prescriptions received online on other days were delivered to doorsteps on 17th April 2020. 26,656 orders were delivered through government officers, postal services, priests or patients walked-in to the pharmacy. 42.5% of pharmacies delivered medicine free of charge.

Key words: Doorstep delivery, Drugs, NCD, Online, Pharmacies

1. INTRODUCTION

The first local patient with COVID-19 infection of Sri Lanka was reported in Sri Lanka on 11th March 2020 (Epidemiology unit of Ministry of Health Sri Lanka, 2020). On 13th March 2020, the Government decided to close all the schools island wide as a measure to prevent the spread of COVID-19 and during the next two days, the pre-schools and universities were closed. Mass gathering of people including the religious activities were

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prevented. A special public holiday was declared on 16th March and the holiday was extended to another three days. Curfew was imposed in Puttalam district on 18th March 2020 and island wide curfew was imposed for three days on 20th March. Government declared work from home for the public and private sectors on 19th March 2020. The island wide curfew was eventually extended. Curfew was lifted at limited hours to limited geographical locations for people to go out to purchase essential items (adaderana.lk, 2020).

During these limited periods where the curfew was lifted, long ques were observed in front of pharmacies to obtain medicines. To reduce gathering of public as a measure of prevention of COVID-19, the Special Task Force appointed to control COVID-19, recommended to initiate an online system to receive prescriptions and distribute the drugs to the doorstep of patients (Director General of Health Services, 2020a). On 25th March 2020, the Ministry of Health was given the task of developing and implementing a mechanism for this and appointed Deputy Director General (Non Communicable Diseases) (DDG (NCD)) as the focal point. The mechanism was developed by 26th November 2020 (Director General of Health Services, 2020a, 2020b).

The initial process established by Ministry of Health is as follows (Director General of Health Services, 2020b);

A list of pharmacies registered under the National Medicines Regulatory Authority (NMRA), which could obtain prescriptions online using the applications such as WhatsApp®, Viber®, Imo® and email and having the ability of providing the service to the doorstep of the clients was prepared by the office of DDG (NCD) with the support of NMRA, Food and Drugs Inspectors (FDI), Medical Officers of Non Communicable Diseases (MO – NCD) and All Island Private Pharmacy Owners Association (AIPPOA).

- The list with the names of pharmacies, their located districts and Medical Officer of Health (MOH) areas and contact numbers were published in Ministry of Health website.
- The list was sent to the Inspector General of Police to provide the curfew passes to the workers of the pharmacies to operate within the period of curfew.
- The public was informed via mass media and social media to order the medicines via WhatsApp®, Viber®, Imo® and email. They were instructed to upload an image of the most recent prescription to the closest pharmacy with their contact number and address to be delivered the medicines.
- Pharmacies were instructed to issue medicines for a maximum period of one month. They were further instructed to contain each drug in a separate pack with clear and correct instructions for use and the contact details of the pharmacist.
- If the drugs are ordered in a particular brand name and if that brand is not available, the pharmacists were instructed to inform the client over the phone and offer a suitable alternative.
- Pharmacies were informed to charge a reasonable cost for the transport of the drugs to the doorstep of the patient.
- Pharmacies were instructed to deliver the drugs to the patients within 24 hours of receipt of order, through a delivery person who adheres the standard safety precautions issued by the Ministry of Health and NMRA.
- The smooth implementation of the process was supervised by the MOH and FDI. The implementation of the process in the respective districts was coordinated by MO – NCD with the Ministry of Health.

To support the above services, a tri-lingual telephone hotline was established for public. Wide publicity was given to the public via mass media and social media regarding the hotlines. Medical Officers attached to Ministry of Health were assigned to answer the hotlines. They helped in locating the nearest pharmacies to the people, who were not familiar in accessing the list of pharmacies displayed in the Ministry of Health web site (Director General of Health Services, 2020f).

The initial list of pharmacies displayed in the Ministry of Health website on 26th March 2020 consisted of 224 pharmacies. It was updated periodically considering the need of wide coverage within the country (Director General of Health Services, 2020c). By 07th April 2020, there were 1,772 pharmacies listed in the Ministry of Health website (http://www.pharmacy.health.gov/lk).

Initially the list of pharmacies was displayed in the website, using a simple google sheet. With the support of a voluntary team of professionals with information and communication technology expertise, it was converted to a user-friendly appearance with embedded search functions, enabling the public to locate their nearest pharmacy without a hassle, from 30th March 2020 (Deputy Director General (Non Communicable Diseases), 2020). During the 1st three weeks of the implementation of the process there were 165,787 views of the pharmacy list (Kumarapeli et al., 2020). To provide further support to public who do not own smart phones and not having the know-how of uploading the prescriptions, the services of the Public Health Inspectors (PHI), Grama Niladharis and other government officials in the villages were obtained (Director General of Health Services, 2020e).

To have enough stocks of medicines in the retail pharmacies, the Ministry of Health facilitated to obtain curfew passes to the wholesale distributors, importers and pharmaceutical producers to maintain their functions during the period (Director General of Health Services, 2020d).

After implementation of this new mechanism of ordering medicines online and distribution of them to the doorstep of the clients, it was necessary to measure the progress, to decide whether the system to be maintained further or to look into other ways of distribution of medicines to the patients.

The general objective of the study was to measure the progress of island wide doorstep delivery of medicine though Rajya Osusala and private pharmacies using the newly developed online system, during COVID-19 outbreak of Sri Lanka.

The specific objectives were;

1. To assess the sources of receipt of orders by the Rajya Osusala and private pharmacies after implementation of newly developed online system, on a day of curfew during COVID-19 outbreak of Sri Lanka

2. To assess the methods of delivery of orders to the customers by the Rajya Osusala and private pharmacies after implementation of newly developed online system, on a day of curfew during COVID-19 outbreak of Sri Lanka

3. To assess the practices of calculation of transport charges for doorstep delivery of drugs by the private pharmacies

4. To identify the issues faced by the Rajya Osusala and private pharmacies in implementation of the newly developed doorstep delivery of medicine through online receipt of prescription, during COVID-19 outbreak of Sri Lanka.

2. METHODOLOGY

A descriptive cross-sectional study was conducted online, for seven days starting from 20th April 2020. The study assessed the performance of pharmacies on one day of curfew and the date was selected as 17th April 2020.

A randomly selected, population proportionate sample (PPS) of pharmacies from all the districts of Sri Lanka were selected from all the pharmacies enlisted in the Ministry of Health web site to receive prescriptions online and provide doorstep delivery of drugs, by 12.00 midnight of 07th April 2020.

Sample size was calculated using the Sloven's formula in determining the sample size; $n = N/(1+Ne^2)$ (Altares et al., 2003). Where, n denoted the sample size, N denoted

the total population, which was taken as 1,772 pharmacies (which were listed in the Ministry of Health website by 07th April 2020), e denotes the margin of error which was taken as 0.05, and considering a 30% non-response rate, the sample size was 573. Over sampling was done for the districts where less than 10 pharmacies were selected to the sample through PPS method. If the number of total pharmacies listed in a district were equal or less than 10, all the pharmacies listed from that district were selected to the sample. If the total number of pharmacies in the district were more than 10 and if the calculated sample size for that district was less than 10 using the PPS method, 10 pharmacies were selected from that district. After oversampling for 7 districts, the final sample size was 591. The final sample for each district was selected randomly using Statistical Package for Social Sciences (SPSS) version 23 software.

A self-administered online questionnaire was developed as the study tool, using google forms. It consisted of seven sections: introduction, identification details of the pharmacy, receiving orders via online, receiving orders via any method other than online, doorstep delivery of orders to customers, delivery of orders to customers in other methods, transport charges and issues encountered in implementation of this new system.

The construct, content and face validity of the questionnaire were obtained from an expert panel which included the DDG (NCD), Consultants, Medical Officers of office of DDG (NCD) and Non Communicable Diseases (NCD) unit of Ministry of Health, Principal FDI of NMRA and President, AIPPOA. The questionnaire was developed in English language. It was translated to Sinhala and Tamil languages and back translated to check for any errors. The questionnaires were pre-tested in all three languages in pharmacies which were not selected to the study sample in Colombo and Ratnapura districts. The usual time taken to fill one online questionnaire was about 10 minutes.

The link to the questionnaire with a brief introduction of the survey, in all three languages was sent to the selected pharmacies via WhatsApp*, Viber*, Imo* and email. The participants were also given a telephone call, after sending the questionnaire and a reminder call after 3 days.

The first page of the questionnaire consisted of the tri-lingual information sheet. Then the participants had to select their preferred language to fill the rest of the questions. There onwards, the questionnaire appeared in their preferred language.

Once the participants fill the online questionnaire, a google sheet was automatically completed. Access to this google sheet was restricted to the research team. After seven days of commencing the survey, the data were transferred to a SPSS file, where they were analyzed using SPSS version 23.

Quantitative data were multiplied by the district weights in analysis, which were based on the sample size after oversampling. Semi qualitative type of data were analyzed by identification of common themes.

Ethics clearance for the survey was obtained from the Ethics Review Committee of the National Institute of Health Sciences, Kalutara. The administrative clearance to conduct the study was obtained from the Director General of Health Services.

3. RESULTS AND DISCUSSION

From the total of 591 pharmacies selected for the survey, 353 pharmacies responded to the online questionnaire. The response rate was 59.7%.

On 17th April 2020, a total of 47,629 prescriptions were received to the pharmacies island wide. The largest number of prescriptions were received to pharmacies in Western Province, which was 63.8% of the total. From the number of total prescriptions, 67.9% (32,338) were received online.

As shown in Table 1, in Western, Northern, Central and North Central provinces most of the prescriptions were received online. In Uva and Sabaragamuwa provinces, more than 70% of prescriptions were received to pharmacies from sources other than online.

These other sources of sending prescriptions to the pharmacies were, the walk-in clients, sending prescriptions with Grama Niladhari of the area, with the PHI or any other healthcare workers of the area, sending prescriptions with police or armed forces, sending prescriptions with any other government officer of the area, sending prescriptions with the political representatives of the area and informing the prescription over a voice call to the pharmacy. On some occasions, a person from the pharmacy had to visit the client and collect the clinic book or old prescription when they received a request over the phone.

As shown in Table 2, on 17th April 2020, 101,958 orders were delivered by the pharmacies island wide. The province which had delivered the most orders was Western province (44,088, 43.25%) followed by the Central province (33,231, 32.6%). North Central province has delivered an estimate of 1,020 orders on 17th April 2020, which was the lowest on that day.

On 17th April 2020, an estimated 75,302 orders were delivered to doorstep of the clients by the pharmacies island wide. This was 73.9% of the total deliveries of the day. Northern, Western and Central provinces have delivered more than 80% of the orders to the doorstep of the clients. Eastern province has delivered only 30.8% of the orders to the doorstep of the

Table 1. Prescriptions received to pharmacies on one day of curfew (17th April 2020) during COVID-19, in Sri Lanka by provinces

Province	Sample size	Prescriptions received online		prescriptions received via sources other than online		Total prescriptions received
		Number	Percent	Number	Percent	
Central	53	3,715	*58.9%*	2,592	*41.1%*	6,307
Eastern	22	266	*38.1%*	432	*61.9%*	699
North Central	13	292	*56.7%*	223	*43.3%*	516
North Western	31	1,662	*40.7%*	2,426	*59.3%*	4,088
Northern	18	405	*66.7%*	202	*33.2%*	607
Sabaragamuwa	22	381	*27.2%*	1,019	*72.8%*	1,401
Southern	34	1,012	*42.2%*	1,388	*57.8%*	2,399
Uva	19	257	*21.1%*	961	*78.9%*	1,218
Western	141	24,348	*80.1%*	6,048	*19.9%*	30,396
Sri Lanka	**353**	**32,338**	**67.9%**	**15,291**	**32.1%**	**47,629**

Table 2. Numbers of orders delivered by the pharmacies on one day of curfew (17th April 2020) during COVID-19, in Sri Lanka by provinces

Province	Sample size	Orders delivered to doorstep of clients		Orders delivered by any method other than doorstep delivery		Total orders delivered
		Number	Percent	Number	Percent	
Central	53	26,902	*81.0%*	6,329	*19.0%*	33,231
Eastern	22	1,164	*30.8%*	2,613	*69.2%*	3,777
North Central	13	806	*79.0%*	214	*21.0%*	1,020
North Western	31	3,376	*56.0%*	2,655	*44.0%*	6,031
Northern	18	1,625	*82.8%*	337	*17.2%*	1,962
Sabaragamuwa	22	1,998	*37.6%*	3,313	*62.4%*	5,311
Southern	34	2,578	*58.9%*	1,801	*41.1%*	4,379
Uva	19	1,005	*46.5%*	1,155	*53.5%*	2,160
Western	141	35,849	*81.3%*	8,239	*18.7%*	44,088
Sri Lanka	**353**	**75,302**	**73.9%**	**26,656**	**26.1%**	**101,958**

clients. Pharmacies in Sabaragamuwa and Uva provinces also have delivered less than 50% of the orders to the doorstep.

One fourth (26,656, 26.1%) of the orders delivered on 17th April 2020 were delivered to clients in methods other than doorstep delivery. These methods were; the customer walked in and collected the order, sent the order to the customer through the PHI or any other healthcare worker, through the Grama Niladhari of the area, via postal service, through the police or armed forces, through any other government officer, through the political representatives or religious leaders of the area. Some pharmacies have arranged the delivery of drugs through another pharmacy closer to the client using their private networks.

Table 3 shows a comparison of orders delivered to the doorstep of the clients on the same day (17th April 2020) from the online prescriptions received.

From the online prescriptions received on 17th April 2020, 64.7% of the orders (20,927) were delivered to the doorstep of the clients by the pharmacy, on the same day. The percentage was around 90% in 7 provinces. In Western province, only 57% of the orders received online on 17th April were delivered to the doorstep of clients on the same day. One reason may be the high number of orders received (24,348) to the pharmacies, compared to the other provinces.

Table 4 shows the breakdown of the doorstep deliveries completed by the pharmacies on 17th April 2020, with the type and dates of orders received to the pharmacies.

Table 3. Delivery of medicines to the doorstep of the clients on the same day of receipt of prescription on a day of curfew (17th April 2020) during COVID-19, in Sri Lanka by provinces (n = 353)

Province	**Total number of prescriptions received online**	**Doorstep deliveries completed from the online orders received on the same day**	**Percent**
Central	3,715	3,343	*90.0%*
Eastern	266	248	*93.2%*
North Central	292	280	*95.9%*
North Western	1,662	1,518	*91.4%*
Northern	405	361	*89.1%*
Sabaragamuwa	381	341	*89.5%*
Southern	1,012	733	*72.5%*
Uva	257	230	*89.3%*
Western	24,348	13,871	*57.0%*
Sri Lanka	**32,338**	**20,927**	**64.7%**

Table 4. Doorstep delivery of orders made on one day of curfew (17th April 2020) during COVID-19, in Sri Lanka by provinces (n = 353)

Province	**Doorstep deliveries completed on 17th April from the online orders received on the same day**		**Doorstep deliveries made on 17th April, from the online prescriptions received before 17th April**		**Doorstep deliveries made on 17th April among the prescriptions received by any method other than online**		**Total number of orders delivered to doorstep on 17th April**
	Number	**Percent**	**Number**	**Percent**	**Number**	**Percent**	
Central	3,343	12.4%	18,858	70.1%	4,701	17.5%	26,902
Eastern	248	21.3%	746	64.1%	170	14.6%	1,164
North Central	280	34.8%	426	52.9%	99	12.3%	806
North Western	1,518	45.0%	1,225	36.3%	633	18.7%	3,376
Northern	361	22.2%	1,028	63.3%	237	14.6%	1,625
Sabaragamuwa	341	17.1%	229	11.5%	1,427	71.4%	1,998
Southern	733	28.4%	548	21.2%	1,297	50.3%	2,578
Uva	230	22.9%	350	34.8%	425	42.3%	1,005
Western	13,871	38.7%	20,269	56.5%	1,709	4.8%	35,849
Sri Lanka	**20,927**	**27.8%**	**43,678**	**58.0%**	**10,697**	**14.2%**	**75,302**

Total estimated 75,302 doorstep deliveries were done by the pharmacies on the day. Fifty eight percent (43,678) of the doorstep deliveries were done for the online prescriptions received before 17th April 2020. Fourteen percent of doorstep deliveries were done on 17th April, for the prescriptions received in methods other than the online systems (on the same day and on the days before).

Central province had the highest percentage (70.1%) of doorstep deliveries on 17th April, for the prescriptions received online before that day. Eastern and Northern provinces had more than 60% of doorstep deliveries on 17th April, for the prescriptions received online before. Western province had delivered the highest number of orders to the doorstep of clients on 17th April, which they received on previous days. One reason for this backlog of orders to be delivered on 17th April would be the Sinhala and Hindu new year holiday which was 2 days back and the staff of the pharmacies would have taken leave during the festive days.

Among the doorstep deliveries done on 17th April 2020, for the prescriptions received in methods other than online, pharmacies in Central province have delivered the highest number of orders (4,701). This number includes the orders received from these methods on the day of 17th April and the days before (the backlog). Among the orders delivered doorstep on 17th April by the pharmacies in Sabaragamuwa province, the majority (71.4%) belonged to prescriptions received in methods other than the online.

Pharmacies have used various methods to charge for the transport fee for the doorstep delivery of medicines. A wide variation was observed in these methods and the fees between districts and provinces. Table 5 shows some common methods used by the pharmacies to obtain a fee for the transport of drugs.

Forty two percent of pharmacies island-wide delivered the medicines to their clients free of charge. In North Central province more than 75% of pharmacies delivered free of charge.

More than one third of pharmacies, delivered medicines to the doorstep of their clients free of charge for a certain distance and charged a fee from thereon. This free of charge distance was 1 kilometer (km) for most of the districts and ranged from 1 km to 5 km. After the stipulated distance they charged Sri Lankan Rupees (LKR) 50 per km in most of the districts, but it ranged from LKR 5 to 100.

Fourteen percent of pharmacies charged a transport fee for the delivery of medicines to the doorstep of clients from the 1st km. The usual charge was LKR 50 per km, but it ranged from LKR 10 to LKR 100 per km. Some pharmacies charged a fixed amount for each order, irrespective of the distance. The usual

Table 5. Common methods used to charge for transport for delivery of medicines to doorstep of clients by the pharmacies during the period of curfew due to COVID-19, in Sri Lanka by provinces (n = 347)

Province	Completely free of charge		Free of charge for a certain distance and charge for the rest of the distance		Charge per kilometer from 1st kilometer	
	Number	Percent	Number	Percent	Number	Percent
Central	59	36.7%	61	38.3%	25	15.6%
Eastern	33	53.2%	15	24.4%	3	4.8%
North Central	28	76.6%	6	14.9%	0	0.0%
North Western	34	35.5%	44	45.2%	3	3.1%
Northern	26	67.6%	11	29.7%	0	0.0%
Sabaragamuwa	21	33.1%	31	47.9%	9	13.9%
Southern	65	61.8%	22	20.6%	15	14.2%
Uva	28	50.0%	18	33.4%	3	5.4%
Western	151	35.3%	154	36.0%	90	21.0%
Sri Lanka	**446**	**42.5%**	**363**	**34.6%**	**148**	**14.1%**

charge was LKR 100, but ranged from LKR 40 to 300. Some pharmacies reported that they delivered the medicines free of charge to the clients if the total bill value was above a certain amount. The usual amount of bill value to get this offer was LKR 500.

Following are the issues encountered by the pharmacies in receiving orders online and doorstep delivery of drugs during the period of curfew in COVID-19 in Sri Lanka.

The medicines supply was poor to retail pharmacies from the drugs suppliers and distributors during the period of curfew. Therefore, certain brand and drugs were not available in the pharmacies.

Pharmacies had to face issues pertaining to implementation of the law during the period of curfew. It was difficult to obtain curfew passes to the staff of the pharmacies and the delivery persons and vehicles. Even with having proper curfew passes they had to face difficulties in passing the roadblocks. As some pharmacies issued drugs to walk-in customers violating curfew rules, the pharmacies engaged in delivery of drugs to online prescriptions only, received a smaller number of orders. On the days where the curfew is lifted, the pharmacies had to cater both the online orders and the walk-in clients.

There were technology related issues. Frequent calls from the customers consumed the time of the pharmacy staff. Calls were received to the same phone where WhatsApp®, Viber®, Imo® are installed. Which prevented them to look at the online prescriptions at the time of calls. There were no enough credit card machines to send with the delivery persons, in catering huge amount of orders.

There were customer related issues. Certain customers were difficult to contact over the phone, when in need. Some customers used to give recurrent calls to the pharmacy inquiring the order. Certain customers refused to accept the order once delivered, stating the reasons such as they have received the drugs from another pharmacy, the brands of the drugs were different, and the cost was high. It was difficult to find the customers when reached to the given addresses. Some customers sent very old prescriptions where the drugs cannot be issued and some ordered prescriptions only drugs without a proper prescription. Some customers changed the orders frequently and some ordered non-essential grocery items using the same system.

The staff related issued encountered were that there were no adequate staff to carryout the work in the pharmacies. Some staff were reluctant to report for work due to prevailing COVID-19 situation. It was difficult to find the delivery persons.

Pharmacies received higher number of orders online than their usual amount, especially during the first few days of implementation of the new system. Some pharmacies received orders from far away areas where transportation was difficult and costly.

4. CONCLUSIONS

1. 47,629 prescriptions were received to Rajya Osusala and private pharmacies island-wide on one day of curfew due to COVID-19 in Sri Lanka.

2. 67.9% of the total prescriptions received to Rajya Osusala and private pharmacies island-wide on a day of curfew due to COVID-19 in Sri Lanka, were reached online via WhatsApp®, Viber®, Imo® and emails.

3. Pharmacies received 32.1% of orders through the walk-in clients, Grama Niladharis of the area, PHI or any other healthcare workers of the area, police or armed forces, any other government officer of the area, political representatives and informing the prescription over a voice call, other than the online methods during a day of curfew due to COVID-19 in Sri Lanka.

4. Pharmacies have delivered 101,958 orders to clients during a day of curfew due to COVID-19 in Sri Lanka.

5. 73.9% of the orders were delivered to doorstep of the clients by the pharmacies, on one day of curfew due to COVID-19 in Sri Lanka.

6. 64.7% of the online prescriptions received to pharmacies on a day of curfew were delivered to doorstep of clients on the same day.

7. Among the total doorstep deliveries done by pharmacies on one day of curfew due to COVID-19 in Sri Lanka, 58% were the orders received to pharmacies online, on the days before the date of delivery.

8. 26.1% of the total deliveries of orders on one day of curfew due to COVID-19 in Sri Lanka, were done via the customers walked in and collected the order or sent the order to the customer through the PHI or any other healthcare worker, Grama Niladhari of the area, postal service, police or armed forces, any other government officer, political representatives or religious leaders of the area.

9. 42.5% of pharmacies delivered the medicines to the doorstep of clients free of charge. 34.6% of pharmacies delivered the medicines free of charge for a certain distance and charged for transport, thereafter.

5. RECOMMENDATION

This method of online receipt of prescriptions to Rajya Osusala and private pharmacies and doorstep delivery of drugs from the pharmacies should be further strengthened by providing necessary support to the pharmacies and proper monitoring of the implementation during the periods of outbreaks and disasters.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Anil Jasinghe, former Director General of Health Services, Mr. Chandika Gankanda, President, All Island Private Pharmacy Owners Association and Mr. Amith Perera, Chief Food and Drugs Inspector for their support given to implement this project and conduct this study.

REFERENCES

Altares, P.S., Copo, A.R.I., Gabuyo, Y.A., Laddaran, A.T., Mejia, L.D.P., Policarpio, I.A., Tizon, H.D., & Yao, A.M.S.D. (2003). *Elementary statistics: a modern approach* (1 ed.). Manila, Philippines: Rex Book Store.

Deputy Director General (Non Communicable Diseases). (2020). *Requesting approval to operate newly built e-system developed by a team of external voluntary developers to locate pharmacy delivery services for the public*. (DDG/NCD/63/2020 dated 30.03.2020). Colombo.

Director General of Health Services. (2020a). *Doorstep delivery of medicine from Rajya Osusala, its Franchise Pharmacies and Private Pharmacies*. (DDG/NCD/63/2020 dated 29.03.2020). Colombo.

Director General of Health Services. (2020b). *Process of island wide door step delivery of medicines to the patients using the private pharmacy network during the COVID 19 outbreak*. (DDG/NCD/63/2020 dated 26.03.2020). Retrived from https://drive.google.com/file/d/1-kuOUKX1QwhGDjHfLRTPNZjHWmM3Fksj/view

Director General of Health Services. (2020c). *Request for Curfew Passes to facilitate the island wide door step delivery of medicines to the patients using the private pharmacy network during the COVID 19 outbreak*. (DDG/NCD/63/2020 dated 27.03.2020). Colombo.

Director General of Health Services. (2020d). *Request for curfew passes to Sri Lanka Chamber of the Pharmaceutical Industry member companies and authorized sub distributors to supply medicine to selected pharmacies*. (DDG/NCD/63/2020 dated 28.03.2020). Colombo.

Director General of Health Services. (2020e). *Request of Assistance from Public Health Inspector, Grama Niladhari or other suitable officers for delivery of medicine*. (DDG/NCD/63/2020 dated 31.03.2020). Colombo.

Director General of Health Services. (2020f). *Thanking for providing the hotlines to facilitate the process of island wide doorstep delivery of*

medicines to the patients with chronic illnesses using the pharmacy network during the COVID 19 outbreak. (DDG/NCD/63/2020 dated 20.05.2020). Colombo.

Epidemiology Unit of Ministry of Health Sri Lanka. (2020). *Coronavirus disease 2019 (COVID-19) - Situation Report – 12.03.2020 – 10.00 am*. Retrieved from https://www.epid.gov.lk/web/images/pdf/corona_virus_report/sitrep-sl-en-12-03_10.pdf

Kumarapeli, V. et al. (13 authors). (2020). Combating non-communicable diseases during COVID-19 pandemic. *Journal of the College of Community Physicians of Sri Lanka, 26*(Special Edition). doi: 10.4038/jccpsl.v26i0.8324

Ensuring uninterrupted services for non-communicable diseases patients during COVID-19 pandemic: Best practices from Sri Lanka

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ABSTRACT

Sri Lanka is burdened with morbidity and mortality due to chronic Non-communicable Diseases (NCDs). Travel restrictions during COVID-19 outbreak markedly disrupted the health service delivery to patients with NCDs. NCD bureau, Ministry of Health initiated various mechanisms to ensure that patients with NCDs in Sri Lanka receive the necessary services without any interruption. A web-based mechanism helped to get the drugs delivered to the homes for those who usually purchase drugs from the private sector. Patients taking treatment from government hospitals, but for whom there was no urgent need to be seen by a doctor were delivered medicines through the Department of Postal Services. A tri-lingual helpline monitored provision NCD services across the country. Over 1800 pharmacies served, covering all districts and 342 (96.3%) Medical Officer of Health areas; majority (18.8%) from Gampaha district. During the first two weeks of this process, state and private pharmacies had successfully performed over 275000 deliveries to their customers' doorstep. These approaches ensured that NCD services were provided uninterrupted in Sri Lanka at a time they were disrupted globally. It is recommended to take up similar service delivery mechanisms at times of travel and social restrictions.

Key words: Non-communicable diseases patients, Uninterrupted service, Web-based applications, Drug delivery, Travel restrictions, Essential services

1. INTRODUCTION

Burden of NCDs in Sri Lanka has gradually risen over the years. It has been estimated that NCDs were responsible for 83% of the total deaths in the country in year 2016 (WHO, 2018). Coronavirus disease 2019 (COVID-19) markedly disrupted the day today lives of people and has given rise to shortages in supplies of essential medicines and health services across the globe. During March 2020, when the first local cases of COVID-19 started appearing in Sri Lanka, the government enforced countrywide curfew and quarantine regulations to curtail the spread of disease within the country. Continuing regular NCD services amidst curfew was a challenge. NCD Bureau Ministry of Health recognized it as a priority endeavour to ensure an uninterrupted service delivery during this period. Government-coordinated mechanisms with

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multi-sectoral collaborations were initiated to fulfil this objective.

2. METHODOLOGY

A web-based mechanism (Figure 1) was established to get the drugs delivered to the homes for those who usually purchase drugs from the private sector. This system was established with the state and private pharmacies in collaboration with the Pharmacy Owners Association. The public could select a pharmacy through the Ministry of Health website and submit an order (in the forms of an image of the prescription) through a social media application (WhatsApp/ Viber). Pharmacies delivered medicines to the customers for a reasonable delivery fee (Figure 2).

Patients regularly taking treatment from government hospitals, but for whom there was no urgent need to be seen by a doctor were delivered medicines through the Department of Postal Services so that patients do not have to visit the hospital. A list of contact numbers of all government hospital clinics was made available to the public via the Ministry of Health website. In addition health and non-health government officers working at the community level such as Public Health Nursing Officers Midwives, Grama Niladhari, Development Officers attached to Divisional Secretariats, village leaders and volunteers were utilized to deliver drugs to those who unable to use above mechanisms. It was also ensured that patients with NCD who were quarantined received their NCD medications by coordinating with the Sri Lanka Army who managed the quarantine centres. District level medical officers attached to NCD Bureau (Medical Officer-NCD) were instrumental in streamlining these efforts.

Provision of remote healthcare was taken up as a solution to prevent overcrowding and to minimize exposure of high risk immune-compromised NCD patients such as those undergone kidney transplant or on dialysis to COVID-19. The NCD bureau in collaboration with a private sector organization launched My Doctor tele-medicine system in 16 Nephrology clinics in government hospitals. Networking between secondary and primary healthcare

Figure 2. Drug delivery service by pharmacies

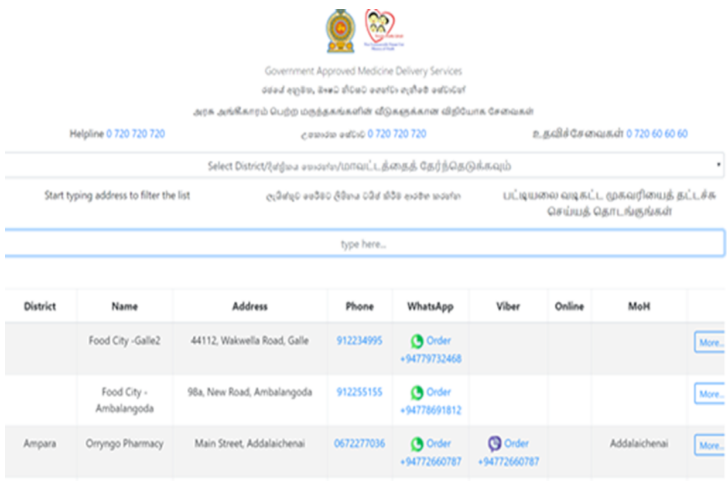

Figure 1. Web-based mechanism of drug delivery

services was initiated as a pilot project at National Hospital Kandy with support of the World Health Organization and private sector organizations. Through this system patients will be able to connect with the treating physicians at the secondary healthcare institution by visiting the primary healthcare institution closest to patient's residence. This project involves patient mapping and construction of an on line data base of patient information which will enable digital tracking of patients.

The NCD bureau also used digital platforms to plan and monitor provision of NCD care across the country. Medical Officers of NCD who provide NCD services at the district level and are scattered throughout the country were regularly guided and supervised by the NCD bureau using video conferencing platforms. Health messages were disseminated via mass and social media on how to recognize danger signs of NCD related emergencies and how to reach for medical services if an emergency is suspected. Social media, such as Face Book and YouTube were utilized as modes of communication to disseminate life style advice during the lockdown period. Relevant experts frequently conducted awareness programmes on mass media on NCD care during the lockdown period.

Several hotlines was established to respond to patient queries and functioned in all three main languages, English, Sinhala and Tamil (Figure 3). The hotlines provided information to patients on NCD related issues, on-line purchase of medicines, contact numbers of government hospital clinics and drug distribution from the government hospitals. Number of calls received and answered was daily monitored by the service providing company and the NCD bureau.

However, during the second wave of COVID-19 in Sri Lanka, it was identified that there was a gap in delivery of services and medication to patients receiving treatment for chronic diseases despite the initiated mechanisms. Whilst postal delivery of drugs was commenced in certain districts, it was notified that the residents of the middle-and


Hospital list and contact details

Ampara Anuradhapura Badulla Batticaloa Colombo Galle Gampaha Har
Eliya Polonnaruwa Puttalam Ratnapura Trincomalee Vavuniya Forces and p
LRH) Mental Health/Psychiatry clinic thalssaemia Cancer/Oncology Chest clini

Hospital	Contact numbers
District General Hospital - Ampara	063 2222261
For medical advices and inquires	
Hospital Director	070 6 155 155
OPD	070 6 143 143
Surgical unit	070 6 151 151
Cardiology unit	070 6 140 140
Gyn & Obs	070 6 135 135
Paediatric unit	070 6 156 156
Clinic section	070 6 145 145
Mental health unit	070 6 144 144
Information center for CORONA	070 6 141 141
Base Hospital - Dehiattakandya	027 2250344
Base Hospital-Mahaoya	063 2244061
DH	
DH-Damana	063 2240116
DH-Lahugala	063 3634699

Figure 3. Drug delivery service by pharmacies

low-income Colombo Municipal Council (CMC) area, whose movements were restricted due to high number of COVID-19 positive cases in CMC area, had not received their clinic medication. Complains on the issue had been reported to the 1999 hotline number for COVID assistance as well as in mass media. Further, the number of COVID-19 deaths increased with majority occurring among patients with NCDs in the CMC area.

Following the identification that certain communities with low-and middle-income residents had not received drugs; mobile medical clinics were commenced by NCD Bureau, Ministry of Health with the support of main hospitals catering to these areas namely National Hospital of Sri Lanka (NHSL), Lady Ridgeway Hospital, Colombo, Castle Street Hospital for Women, Colombo and De Soysa Hospital for Women, Colombo. These clinics were systematically carried out in lockdown areas in CMC. The health care staff were fully equipped with personal protective equipment. Drugs were issued to the patients receiving treatment for chronic diseases and in addition facilities to measure blood pressure, blood sugar and medical consultation were available if it was deemed necessary. A follow up survey

was conducted to describe the mechanism used to distribute medicines, reasons for not receiving medicines and underlying reasons that necessitate mobile clinics to be conducted in the Colombo Municipal Council low-and middle-income communities under lockdown during the COVID-19 outbreak.

3. RESULTS

The adopted drug delivery mechanisms avoided overcrowding at pharmacies and hospital clinics. Over 1800 pharmacies served, covering all districts and 342 (96.3%) Medical Officer of Health areas; majority (18.8%) from Gampaha district. A tri-lingual helpline was established to guide the public in locating their nearest pharmacy and respond to customer complaints. During the first two weeks of this process, state and private pharmacies had successfully performed over 275000 deliveries to their customers' doorstep. There were 165,787 web-page views during first three weeks. Of the 68,167 web-page users, 80.0% (n=64,805) were new users; 94.9% (n=47,489) were local clients; 78.8% (n=53.716) accessed through a mobile application; rest through a desktop computer; 72.64% (n=68.167) accessed the web-page through the link given in the MoH Website, rest accessed through the links shared in Facebook mobile. The drug delivery systems effectively functioned until curfew was lifted. This drug delivery system with public-private partnership was a successful mechanism for ensuring uninterrupted supply of medicines to patients during a time that necessitates physical distancing. However at present most healthcare institutions do not maintain a data base of NCD patients and this was recognized as a shortcoming which hinders service delivery during a crisis situation. My Doctor tele-medicine application facilitated communication between high risk patients and their physicians. The application enabled the patients to interact with the physician via audio, video or e chat and was found useful by the involved parties.

Survey conducted among mobile clinic attendees explored reasons that necessitated mobile clinics to be conducted in CMC areas under lock down. A total of 62 mobile clinic participants participated the study with majority being females (N=43, 69.4 and mean age was 57.9 years (SD+/-12.6). Of the participants 45.2% (N=28) had diabetes, 51.6% (N=32) had hypertension, 19.4% (N=12) had cardiovascular diseases, 9.7% (N=6) had chronic renal disease, 9.7% (N=6) had chronic respiratory diseases and 11.3% (N=7) had hyperlipidaemia. While 91.9% (N=57) were on regular medications for these conditions and usual place of taking medicines was government hospitals 54.8 (N=34). Among the mobile clinic participants 83.9% (N=52) had continuously taken medicine during the last month and the majority had received the medicines from government hospital (54.8%, N=34), 16.1% (N=10) had received from a pharmacy, 6.5% (N=4) and had received through postal service. Out of the mobile clinic attendees (N=10) who had not received medicines ring the last month 40% (N=4) mentioned that they did not contact the hospital clinic and the rest (60%, N=6) had awaited postal delivery but not received by post and one person had wanted to buy from private pharmacy but could not afford it. The participants had attended the mobile clinics to get the routine medication (88.7%, N=55), since the next clinic date was due (4.8%, N=3) and due to other minor ailments (6.5%, N=4).

4. CONCLUSIONS

People who obtained services at the mobile clinics were obtaining drugs from government clinics for their chronic illnesses (Non communicable diseases).Most of the patients in the target populations were taking their medicines from government hospitals and were not in a position to continue their medication taking from private sector if they didn't receive from government leading to a discontinuation of treatments. Majority of the participants who visited mobile clinics have obtained their drugs regularly with minimum disturbances, by visiting the mobile clinic mainly or any other mechanism introduced by the Ministry of Health, showing a success of these interventions in the midst of the second COVID-19 outbreak compared to the first

one, while it led to a close down of all hospital clinics in both occasions,

Response of the MoH to maintain the care services for difficult to reach populations with non-communicable diseases during the second COVID outbreak, has been reported more organized and successful as people who required medicines have received in first or in consecutive mobile clinic visits to their areas. These approaches ensured that NCD services were provided uninterrupted in Sri Lanka at a time they were disrupted globally. It is expected that the established mechanisms will operating to serve Sri Lankan population in the future as well.

BIBLIOGRAPHY

World Health Organization. (2018). Non communicable diseases: campaign for action-meeting the NCD targets: Sri Lanka country profile. WHO Regional Office for South-East Asia.

Huang, C. et al. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 395, 497–506.

Wang, D. et al. (2020). Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA. https://doi.org/10.1001/jama.2020.1585.

Sri Lankan supply chains - Lessons learnt during Covid-19

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ABSTRACT

The Covid-19 outbreak resulted in unexpected downturns in almost every economy in the world. The impact it made seems to be persistent and many industries are still struggling to cope up with the situation. The developing economies have been affected the most due to many reasons and among them; the disruptions to the Supply chains of these nations are paramount. Sri Lanka is also not an exemption being a nation highly dependent on imports. Therefore, the purpose of this paper is to explore the lessons learnt in the process of facing the supply chain disruptions and continuous uncertainties of Sri Lankan Supply Chains during the Covid-19 pandemic.

This is a viewpoint article thus the experts' opinions and experiences during Covid-19 that are published in newspapers, magazines, research journals and websites were reviewed. Further, the information collected from webinars were also highly supplemented the subsequent data analysis carried out as a content analysis exercise. All the gathered data were carefully read and reviewed many times to identify the diverse nature of impacts made by Covid-19 and the lessons learnt from managing those disruptions in the Supply Chains of different industries of Sri Lanka.

The results of content analysis showed that the impact of Covid-19 on Sri Lankan economy is massive in terms of failures at last mile deliveries, integration and collaboration of supply chains, visibility of supply chains and meeting the excessive demand emerged suddenly for Fast Moving Consumer Goods due to the panic buying behavior of the consumers. Consequently, the focus on local industries was improved with agriculture and pharmaceuticals.

Alternative warehouse solutions to improve last mile delivery logistics were introduced. Industries realized the importance of having a robust business continuity plan and studying the consumer behavior during the pandemic such as the shift towards e-commerce, minimalistic consumption habits, health and wellness consciousness and also adoption of new technology to allay health concerns were observed. Improving the understanding of organizations own processes by mapping the end to end supply chains beyond tier 1 suppliers and consumers was also another important lesson learnt during Covid-19 pandemic. The importance of Supply base rationalization through alternative sources of raw materials suppliers and collaborative relationships among them in solving problems of the supply chains was also clearly evident. In overall the prime importance of improving the visibility of own supply chains through digitalization was realized by the different industries as in the new normal scenario operating via virtual environments was the only alternative which paved the path to unveiling innovative supply chains too.

Key words: Covid 19, Supply chain impact, Sri Lankan economy, New normal

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1. INTRODUCTION

Uncertainties are always unavoidable in any industry and business organisation nor predictable precisely. Therefore the impact they exert on the status quo of the business organisations are extent to the level that some of them can go bankrupt so forced to shut down. Any business function is no exceptional as all types of uncertainties would hit every business function badly. Supply chain of any organization becomes one of the important all among them as includes the entire business model of an organization so more robust the supply chain more resilient the supply chains are. Robustness supply chain is a stable supply chain and resilience of a supply chain is how quick it comes back to the normal situation once disrupted (Monostori, 2018).

There can be different types of risks and supply chains should be robust enough to be able to withstand in the face of risks due to volatility in the business environment. Robustness of a supply chain is significantly important in dealing with supplier-side risks, while agility is key in dealing with customer-side risks (Wieland & Wallenburg, 2012). Covid 19 is catastrophic risk that made a massive impact on every organisations' supply chains irrespective of whether they are large or small and service or manufacturing. The Covid-19 outbreak resulted in unexpected downturns in almost every economy. Dun & Bradstreet study estimates that 163 of the Fortune 1000 have Tier 1 suppliers in the impacted areas, and 938 have one or more Tier 2 suppliers in the areas impacted (Smith, 2020). The global giants such as Apple, Microsoft, Nissan, Samsung experience disruptions in their factories in China (Brun, 2020). Further, the developing economies have been affected the most as their infrastructures aren't as established as those that it is found in Europe and the US. Sri Lanka is also not an exemption being a nation highly dependent on imports (Sri Lanka's exports fell 13.2 percent in October 2020 from a year earlier, imports fell 24.9 percent, Central Bank of Sri Lanka, 2020). With this nature of a backdrop, therefore the purpose of this paper is to explore the lessons learnt in the process of facing the supply chain disruptions and uncertainties of Sri Lankan Supply Chains during the Covid-19 pandemic. To achieve the broad purpose of the research following objectives and questions were formulated.

1.1. Objectives of the Study

- To explore how Covid 19 has been impacted on the Sri Lankan Supply Chains
- To explore the lessons learnt during the Covid 19 pandemic period

1.2. Research Questions

- How Covid 19 has impacted on Sri Lankan Supply Chains
- What are the lessons learnt during the Covid 19 pandemic period

2. LITERATURE REVIEW

A supply chain risk is being exposed any event that outcome not certain (Rao & Goldsby, 2009) and managing supply chain risk is all about what approach or a strategy that any organization adapts to face or mitigate those uncertain outcomes (Juttner, 2005). Therefore a risk assessment plan a company have is important in minimizing its vulnerability and ensuring continuity of their business that is highly dependent what their supply chain strategies are. The robust supply chains which in other words the stability of a supply chains is the ability to face the ever-occurring volatility risks necessary to deal with customer-side risks (Wieland & Wallenburg, 2012; 2013) that eventually affects the supply side of the organisations. Kilpatrick and Barter (2020) suggest that uncertainties in supply chains can be managed via: Supply base rationalization by sourcing raw material through various sources and collaboration and integration of supply chains rater being restricted to the formal agreements is important in solving problems. They further highlights that flexibility or being agile in managing their supply chains will support in this kind of turbulent conditions and Responsiveness, Re-configurability, and Resilience (3 R's) of a supply chain often improves the visibility and collaboration of

supply chains too. Static supply chains are never possible with highly volatile markets (Christopher & Holweg, 2011; Simchi-Levi, 2010). Pandemic is a Catastrophic risks that made massive impact on supply chains that made highly volatile markets. Monostori (2018) also highlights that responsive and flexible supply chains are more successful in responding risks.

3. METHODOLOGY

Being the nature of the research questions to be answered is how and why in this study, the approach of the research chosen is a deductive approach as the purpose of this study is not to test any theories but to reveal new knowledge pertaining to the practices adopted by Sri Lankan companies in an effort of facing the new normal conditions when trying to deal with unexpected downturns due to Covid 19 pandemic. Further since Covid 19 and its impact is a novel phenomenon to study for which many previous studies have not been carried out and the due to the lack of literature as this is a unique experience the most appropriate research approach is qualitative design (Creswell et al., 2007). In qualitative research designs unique realities are pursued (Creswell et al., 2007). This is a phenomenological research as the purpose of this research is not necessarily to provide definitive explanations but to raise awareness and increase insights of the phenomenon of the Covid 19 impact on the Sri Lankan Supply Chains. The phenomenological research is designed to raise awareness and insights rather providing definitive explanations of an event, concept or situation (Creswell et al., 2007).

Expert's opinions of the Covid 19 impact on Sri Lankan supply chains were collected from different websites, newspaper articles and many webinars conducted during this period. The collected data were analysed manually and a content analysis was carried out as no primary data were collected. In carrying out content analysis the gathered data were read many times and a free coding strategy was employed as the coding strategy and as and when new codes found the themes were developed. The number of coding for each identified themes were recorded manually and the coded content for each theme was carefully interpreted by the researchers. As a new theme found many rounds of reading the articles collected and listening to the webinars were carried out so the data analysis process was iterate and refute which improved the trustworthiness of data. Further the replication of data was also apparent and triangulation of data from different sources such as websites, newspaper and magazine articles and webinars was also evident that are again the varied aspects of trustworthiness of qualitative data. There were 10 webinars selected for this study as the webinars done by same expert at different points of time were excluded. Newspapers and magazines articles were 08 in total that were chosen to consider for this study. Whenever the same experts whose webinar selected for the study was found they were again excluded as the same views appeared in the articles too. There were 3 independent supply chain consultants of all these sources of articles and webinars and other experts were from well-known supply chain specialists from different industries. Altogether, therefore there were 18 experts views considered to analyse for the study. The experts were numbered from 1 to 15 and independent consultants from 1 to 3 for data analysis and reporting purpose. Moreover, the names of the experts, their designations and working places will be anonymous throughout to adhere with ethical considerations.

4. RESULTS AND DISCUSSION

As a result of the content analysis carried out following key themes were emerged. These themes were supported by data from all different sources.

4.1. Failures at Last Mile Deliveries

Last mile delivery specifically concerns the final delivery of the goods to the customers. During the Covid 19 although the online ordering was possible the physical deliver could never be substituted by an online operation especially in the manufacturing industry.

"…the very function of passing the product cannot be done online, it must physically be handed over to the customer or customer should come and buy it…so it was the main challenge specially the FMCH industry faced…" (Expert 3- A Supply Chain Director)

The impact of the same on services industry was minimum as evident in the industries of education, tele-medicine and training and coaching.

"…services industries were managed to do it as online operations were anyway there in those industries such online banking, distance learning and tele medicine…" (Independent Supply Chain Consultant 1)

A physical good necessarily should physically be delivered and there were many delays in deliveries to the customers especially in Fast Moving Consumer Goods industry. As the transportation and distribution networks were collapsed during a pandemic period delays in last mile deliveries were expected but the Sri Lankan supply chains took unreasonable durations as the pandemic continues to stay long.

" Any supply chain gets affected by uncertainties like this kind of pandemic. But in our case the time we took to get our deliveries correct is the problem when it is compared with countries…" (Expert 11- A Supply Chain Manager)

4.2. Lack of Integration and Collaboration of Supply Chains

Integration of a supply chain refers to the alignment of the business processes of different organisations in the same supply chain (Cheng et al., 2010) whereas collaboration refers to the relationship between the members of a supply chain as a result of working with the same organisations over a long time period (Cheng et al., 2010). The lack of collaboration of Sri Lankan supply chains was highly apparent at many instances by a majority of the experts.

"If you are working with a fixed supplier base you develop a better rapport with them that helps very much, especially in this kind of a situation…" (Expert 10- A Supply Chain Manager)

Business is all about problem solving…. that we need a good relationship with whom we are working with…(Expert 5- A Supply Chain and Logistics Manager)

The relationship between the members of a supply chain develops with the time they are working together. If any organization frequently deals with many different suppliers just as a result of chasing after the lowest price, it may subsequent see their lack support and opportunistic behaviour in regular business activities and obviously in this type of uncertainties as highlighted by the above experts.

A supply chain is a network that many different processes of different organization must be aligned to achieve expected results. If these different process are not consistent with each other there may be various issues encountered by the members of that supply chain. The lack of integration in supply chains therefore is undoubtedly make them more vulnerable in this type of supply chain disruptions.

"…the level of integration or the ability of different organizations of a single supply chain to work as one single extended supply chain is one of the critical factors to ensure the continuity in a business in day to today business activities so no doubt how important it is in a pandemic situation in where every organization should have to make a choice…" (Independent Consultant 3)

4.3. Lack of Visibility of Supply Chains

Well integrated supply Chains are very much visible and for that an organization should have an understanding of its embedded supply chain from its suppliers or sometimes suppliers' suppliers too. From upstream of a supply chain to its downstream, its entire

activities and the members of it, must be known to any organization. The moment the supply chains lacks its visibility it gets disrupted without even not being aware of the critical factors behind it. Then it becomes less resilient due to lack of robustness in facing the risks and uncertainties such as pandemics.

"…when you don't know from whom your suppliers buy their raw materials, how do you know whether you are at a risk or not…although you buy from India and India buys from China finally you are also affected, if you do not track you supply chain to that extent you will be at a risk…" (Expert 8- Manager- Supply Chain and Operations).

4.4. Lack of Supplier Base Rationalisation

Majority of the companies were at risk during this situation as many of them dependent on China for raw materials and other supplies. Heavy reliance on China as a supplier was seen. As a measure managing the risks that can come from suppliers' side, supply bases should be rationalized and heavy reliance on a single supplier should not maintain. There should be a few selected trustworthy and reliable suppliers for each raw material or supply that any organization should work with. During the pandemic many organisations could not continue their business operations the sooner China got affected with Corona which proves that even global supply chains were centered on China as a result of China being able to strategically dominating the global industries.

"…Sri Lanka is country anyway depends on China…unfortunately knowingly or unknowingly our companies' main supplier has been China …" (Expert 6- A Supply Chain Planning Manager)

"…our companies have been in a trap and now only they have realised how badly they have been affected …their main supplier is China… the entire supply chains have got disrupted" (Expert 9- A Supply Chain Director)

4.5. Lack of Flexibility/Agility in Supply Chains

An excessive demand was emerged suddenly especially for Fast Moving Consumer Goods due to the panic buying behavior of the consumers. Most of the companies were unable to deliver the increased number of online orders proving the failure in rapidly adapting to the new normal situation. Every organization must have a strategy /structure but they should be ready to be changed as business environment never be the same. The flexibility or the agility of supply chains will always be highly responsive to the changes that take place in the market. However during the pandemic period what visible was that many of the companies were really rigid that they took their own time to adapt to the new normal scenario. Customers were unable to reach them even to order their groceries online.

"…FMCG industries were overwhelmed with online orders and they could not handle them promptly…they took their own time to change their existing strategies to be adapted with the new normal conditions…" *(Independent Consultant 3)*

" *Many of small and medium scale organisations went bankrupt and some of them were finding it very hard to survive…it is not only due to the consequences of impact but not being able to see the opportunities that it created" (Expert 4- A Supply chain Planner)*

5. CONCLUSIONS

The findings of this study revealed that Sri Lankan supply chains are highly vulnerable in the face of risk and uncertainties management. A reactive approach of risk management can be seen rather a proactive strategy. The robustness of the supply chains are also at a minimum level which was evident through how easily they were disrupted by Covid 19 and how long they took to come back to normal. The less resilience Sri Lankan supply chains are still struggling to bring back them to the routine. Agility of these supply chains should be improved. A responsive supply chain should be designed by improving the visibility of their supply chains

that will always improve the resilience and robustness of any supply chain.

Therefore in conclusion, as lessons learnt through facing the pandemic organisations realised the significance of improving the visibility of own supply chains through digitalization as different industries in the new normal scenario shifted to work via virtual environments.

It had also paved the path to unveiling innovative supply chains in varied industries: mobile super markets, tele-medicine, online lecture delivery and assessments in education industry and most importantly a positive trend towards collaboration was emphasized rather than competitive supply chains.

REFERENCES

Brun, M.H. (14 March 2020). Coronavirus and the anti-fragile supply chain. Retrieved from https://www.supplychaindigital.com/supply-chain-management/coronavirus-and-antifragile-supply-chain.

Central Bank of Sri Lanka (2020), Annual Report 2020, Retrieved from http://www.cbsl.gov.lk.

Cheng, H., Chen, M., & Mao, C. (2010). The evolutionary process and collaboration in supply chains. *Industrial Management and Data Systems, 110*(3), 453-474. doi: 10.1108/02635571011030079

Christopher, M. & Holweg, M. (2011). Supply chain 2.0: managing supply chains in the era of turbulence. *International Journal of Physical Distribution and Logistics Management, 41*(1), 63-82. doi: 10.1108/09600031111101439

Creswell, J.W., Hanson, W.E., Plano, V.L.C., & Morales, A. (2007). Qualitative research designs: selection and implementation. *The Counselling Psychologist, 35*(2), 236-264. doi: 10.1177/0011000006287390

Juttner, U. (2005). Supply chain risk management: understanding the business requirements from a practitioner perspective. *The International Journal of Logistics Management, 16*(1), 120-141. doi: 10.1108/09574090510617385

Kilpatrick, J., & Barter, L. (2020). *COVID-19: Managing supply chain risk and disruption*. New York, USA: Deloitte Development LLC.

Monostori, J. (2018). Supply chains' robustness: challenges and opportunities. *Procedia CIRP 67*, 110-115. doi: https://doi.org/10.1016/j.procir.2017.12.185

Rao, S. & Goldsby, T.J. (2009). Supply chain risks: a review and typology. *The International Journal of Logistics Management, 20*(1), 97-123. doi: 10.1108/09574090910954864

Simchi-Levi, D. (2010). The 6 forces driving supply chain design. *MIT Sloan Management Review, 51*(2), 17-24.

Smith, E. (17 February 2020). Coronavirus could impact 5 million companies' worldwide, new research shows. Retrieved from https://www.cnbc.com/2020/02/17/coronavirus-could-impact-5-million-companies-worldwide-research-shows.html.

Wieland, A., & Wallenburg, C.M. (2012). Dealing with supply chain risks: Linking risk management practices and strategies to performance. *International Journal of Physical Distribution and Logistics Management, 42*(10), 887-905. doi: 10.1108/09600031211281411

Wieland, A., & Wallenburg, C.M. (2013). The influence of relational competencies on supply chain resilience: A relational view. *International Journal of Physical Distribution and Logistics Management, 43*(4), 300-320. doi: 10.1108/IJPDLM-08-2012-0243

Healthcare supply chains in Sri Lanka: Responsiveness and resilience during the COVID-19 pandemic

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ABSTRACT

COVID-19 has affected all countries and all types of organisations around the world, especially healthcare organisations. With coronavirus infections increasing exponentially from March 2020 onwards, hospitals had to respond to the demands placed upon them within a short period of time and with limited preparedness. Procurement and supply chain professionals in hospitals had to deal with high levels of uncertainly in terms of both demand and supply for a range of products, especially for personal protective equipment (PPE), ventilators, and infection control medication. In both developed and developing countries, hospitals were unable to respond quickly to COVID-19 infected patients presented to them. The need for building resilient and responsive healthcare supply chains has been highlighted during this pandemic and requires immediate response from researchers, practitioners and policy-makers.

The aim of this view point paper is to examine how healthcare supply chains are being impacted by COVID-19 in Sri Lanka and their capability with respect to responsiveness and resilience. Drawing from, information from diverse global and local sources from scholars, professionals and policy makers, the paper will address the needs for progressing the current healthcare supply chains to become 'Smart Supply Chains' based on the utilisation of digital technologies, appropriate 'business models' and supplier relationships. Specifically, this paper will identify the specific opportunities for the implementation of emerging technologies and building the associated human resource capability. This paper will present the preliminary analysis of information gathered and outline the future research program in this important area.

Key words: COVID-19, Healthcare-supply chains, Responsiveness, Resilience, Repurposing, Risk assessments

1. INTRODUCTION

The COVID- 19 pandemic which has impacted all industries has posed critical challenges on the healthcare supply chains as well. Attention has been drawn on the capabilities as well as fragility of the supply chains in meeting the consumer needs (Mollenkopf et al., 2021). Disruptions in the supply chain and sudden changes in consumer behaviour warrant renewed attention to the end- end underlying processes in the supply chain from source to consumer. Precipitous shifts in demand together with health- related regulations have resulted in acute disruptions within supply chains. Profound effects have been witnessed in health supply chains affecting active pharmaceutical ingredients,

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shipping, procurements, finished healthcare products and more (European Pharmaceutical Review, 2020).

This view point paper, addresses the impact of COVID 19 and the responses of the organisations involved, focusing on the Sri Lankan healthcare supply chain. The global experiences are reviewed comparatively with the resilience of and the responses to the challenges by the healthcare supply chain in Sri Lanka. Recommendations to better manage the health care supply chain operations are provided and potential area for future research suggested

2. METHODOLOGY

Information gathered from contemporary publications served as the basis to identify factors disrupting the healthcare supply chains and the responses of the industry. Comparative study using Sri Lankan sources such as newspapers, reports, varied discussion fora and interviews with related stakeholders, reinforced the findings and provided rich insights into the Sri Lankan scenario.

2.1. Disruptions to the Healthcare Supply Chain

Supply chain operations are disrupted by natural disasters or pandemics (Grida et al., 2020) which were seen to generate unsustainable demand shocks in the healthcare system during the COVID -19 crisis (Bohmer et al., 2020). Disruptions to supply chains posed by uncertainties and sudden change. The speed, agility and flexibility through which the system reverts to normalcy determines how well the crisis is contained. The COVID- 19 pandemic crisis exerted a novel and unpredicted context which has been described as the Black Swan Effect by Taleb (2009). The term "black swan" describes random events which are outside the realm of regular expectations, carry extreme impacts and explanations for the occurrences are concocted after the fact (Antipova, 2020). Management of the black swan situation is highly critical and require robust crisis management systems for speedy recovery. In fact, this "black swan" pandemic effect has necessitated organisations to reorient their supply chain model for survival.

The pandemic resulted in dire effects on resource utilisation, capacity and demand. An unprecedented demand coupled with low supply is one of the critical factors disrupting the healthcare supply chains. With multiple waves of the disease experienced in many countries, the continually increasing number of infected patients, especially those requiring intensive care treatment has placed considerable strain in healthcare operations and the supply chains. According to the World Health Organisation (WHO, 2020), rising competition, panic buying, stock piling by retailers and consumers, are some reasons for the serious and escalating damage to the global supply of PPE, sanitizers and testing kits (Sharma et al., 2020). The high demand has led to price hikes resulting in the need for price control measures in Sri Lanka. Increased demand directly impacts healthcare's limited resources (e.g. equipment, materials and medications). Many countries are dealing with this situation by stretching the healthcare facility utilisation to the maximum. Alternately, practice of testing and treating at local community centers has been adopted in Germany, Iceland and South Korea to address the issue of arrival rate variability at patient end (Leiti et al., 2020).

The supply chain for PPE has not functioned adequately since the COVID-.19 outbreak to meet the surging demand (Park et al., 2020). Many reasons have been attributed to the low supply of PPEs and other medical requirements of which dependence on China for medical supplies surfaces as the primary reason. Before the pandemic onset, half of the world requirement of masks had been produced in China, which got severely disrupted with closure of factories due to the rapid spread of the disease. Widespread lockdowns and quarantine measures imposed by various countries in the effort to curb the spread of the disease, had a profoundly scaled production. Partial or full border closures has drastically affected international flow of goods and disrupted global supply chains (Liu et al., 2020). As widely identified, China has been

functioning as the world's largest workshop and exporter and the shutdowns of the Chinese production facilities has created tremendous ripples down the global supply chain. In addition to the shortage of PPEs and other medical goods such as test kits, ventilators, medicines supplied by China, the indirect effect through the supply of active pharmaceutical ingredients and machine supplies needed for stitching of PPEs, mainly by China also has impacted the supply of healthcare supplies (Sharma et al., 2020).

Logistics supply chain entails not just the national, international flow of pharmaceuticals and other products but also concerns movement of labour force in industries. The travel restrictions, shut downs and border closures of trucks and people places constraints on production capacities and supply. All these factors cause delays and cripple the supply chain, causing challenges in supplies of vaccines, hand sanitisers, testing kits, PPE, medicines, medical equipment, raw material and many others (The Economic Times, 2020).

Low inventory levels as adopted by lean practitioners toward higher efficiencies proved to be one of the contributory reasons for failure to meet increased demand in healthcare supplies. Worldwide, many companies work toward leaner supply chains. Emphasis on cost minimisation together with timely deliveries has not provided for adequate buffers resulting in reduction in the inventory buffers. These situations have worsened the impact on the supply chains, exposing the fragility of logistics management (Sharma et al., 2020). The surge in demand for PPE, equipment such as ventilators and medicines have exposed the fragility of the healthcare supply chains, relying on just-in- time approaches and failure to effectively manage inventories to cater to crisis situations. The appropriateness of generic supply chain principles of lean inventory, such as just- in-time is questionable. The future inventory management approaches would need to trade off cost considerations to resource increase and capacity responsiveness in combating unforeseen events such as the current pandemic situation (Bohmer et al., 2020). Maintaining just- in- time inventory may be replaced with just- in-case inventory.

Quality challenges have posed rising concerns the supply of healthcare material. Poor quality PPE made from sub- standard material such as non -woven material for mask making, aimed at low prices have been reported. Safe disposal of PPE after usage, finding textile solutions for affordability, accessibility, reusability and scalability remain the current challenges (Hizbullah, 2020). Clearly defined specifications in purchase of PPE, either nationally or internationally, is required in the procurement of personal protective equipment (PPE), either nationally or internationally, to avoid wastes or delays caused due to PPE supplies not meeting the healthcare quality standards. Such failures in material quality management has cascading effects on several types of wastes such as transportation, motion, inventory, waiting, extra processing and defects. Precise specifications, close collaboration buyers and suppliers will serve to minimise such problems and maximise end to end value delivery (Leiti et al., 2020)

2.2. Resilience and Response of Healthcare Supply Chain in Sri Lanka

When unprecedented global health challenges and large- scale shocks strike, resilience of individuals, organisations and society are in great demand. The ability to develop resistance capacity and recovery capacity will determine how well the supply chain is managed in a resilient manner. (Liu, et al., 2020). Management of the black swan situation is highly critical for any industry or for a country. Developing suitable crisis management systems in the organisation, and develop business continuity to build speed, agility and flexibility becomes imperative to manage it proactively. It is worth noting that the organizational capabilities associated with strategic agility are not simply related to resource readiness and allocation; they require coordination mechanisms to be in place to activate and materialize both resources and knowledge bases (Liu & Huang 2018). Flexible

organisational capabilities and skills required to suitably transform business and management practices to resist the disruptions and recover are critical. Resilience calls for avoidance and containment measures while recover phase will focus on stabilisation until return to normalcy or the new normal. Such organisations will reinvent themselves through swift transition to create value for the society and business (Kano et al. 2020). This paper will review the resilience and responses to the current health supply chain disruptions in Sri Lanka and other countries.

It has been widely accepted that the major disruption to the healthcare supply chains have resulted from over- reliance on single sourcing, driven by focus on efficiency in the supply chain to achieve scale advantage and supply rationalization. The pandemic has clearly exposed the fragility of supply chains due to this and many countries are now accelerating efforts to increase local production capacities. Sharma et al. (2020) report that the Indian Council of Medical Research (ICMR) has also given a nod to Indian manufacturers to increase the manufacturing of testing kits and that a few companies that have Already started making testing kits in India.

Sri Lanka imports over $ 500 million of pharmaceuticals annually and nearly half of this comes from India. Last month, India restricted the export of 26 pharmaceutical ingredients and the medicines made from them, including paracetamol, as the coronavirus outbreak plays havoc with their supply chains. The pandemic has posed a wake - up call and the need to increase the local production capability has been seriously felt resulting in plans to triple the value of local pharmaceutical manufacturing within 24 months, given the increased manufacturing capacity in the pipeline and with a focused effort to create new manufacturing capacity (Perera, 2020). The need for Government to accelerate efforts to boost local pharmaceutical industry to increase production capacity for all medicines also has been identified as a pressing need. This has been triggered by the fact that all China, India and Italy, the three main global exporters of Active Pharmaceutical Ingredients (APIs) are being affected severely due to Covid-19 pandemic resulting in a shortage of APIs (Jayakody, 2020).

Positive responses have been initiated in Sri Lanka, with the government decision to establish a pharmaceutical manufacturing zone in the southern coast of Hambantota and also to invite global pharmaceutical companies to set up companies within the zone. (Xinhua, 2020b). It has also been reported that Sri Lanka aims to manufacture 50 percent of its pharmaceutical needs within three years (Xinua, 2020a). It is noted that discussions among Government officials are underway to construct a pharmaceutical manufacturing unit, similar to or more advanced than the State Pharmaceuticals Manufacturing Corporation (SPMC) in Ratmalana (Daily FT, 2020b). In addition to the efforts of the government, private sector organisations in Sri Lanka also have responded to the call for increased production capacity. Morison PLC, the largest oral solid dosage pharmaceutical manufacturer in Sri Lanka and a subsidiary of Hemas Holdings PLC, opened their new state-of-the-art manufacturing plant and research & development facility recently (https://www.onlanka.com/news/morison-opens-largest-pharma-manufacturing-facility-in-sri-lanka.html). The efforts of government and private sector institutions in increasing capacity is a very positive step towards mitigating the disruptions caused to steady supply of healthcare supplies.

Increasing production capacity sufficiently towards meeting the unprecedented demand for medical supplies in not a short -term oriented solution. Unusual, or the black swan situations call for unprecedented interventions. Repurposing of the supply chain is a phenomenon which has sprung to the rescue in this situation, benefiting both the organisations and society where the pandemic has forced organisations to reorient their supply chain model for short-term survival. There are examples of proactive supply chain collaborations to meet the needs of healthcare

organisations where companies (e.g. Airbus, Diageo and Rolls-Royce) have

realigned their product offerings, processes and supply chain to manufacture essential items for healthcare operations, such as PPE, hand sanitisers and ventilators (Davies, 2020). Xing et al. (2020) opines that small and medium enterprises (SMEs) can leverage their flexibility and agility in responding to market needs and societal demands such as the production of personal protective equipment (PPE) by quickly adjusting their production base It is noted by Li et al. (2019) that the current crisis provides manufacturing firms with opportunities to transition to the provision of services in response to the changes in consumer behaviors while capitalizing on the dynamics of global export markets.

Sri Lanka witnessed during the pandemic situation, a great thrust towards repurposing of supply chains. Some organisations, not just SMEs but also large organisations such as in the apparel industry, which were severely affected by the pandemic pivoted into areas presenting more opportunities, which was the health industry. Therefore, it is important to note the swift action of local companies in the apparel industry moving into the PPE space, companies in the automobile industry moving into ventilators, companies in stationery doing robots and individuals doing various innovative equipment to cater to the situation.

Despite its negative impacts, the COVID-19 crisis presents unique opportunities for entrepreneurs and other organisations to come up with creative disruption for the benefit of individuals, organizations, and society. (Li et al. 2019). Korea is also proactively driving initiatives aimed at turning this crisis into an opportunity. In the course of their fight with the virus, the Korean government and businesses developed a variety of innovative prevention measures (e.g., drive-through testing) and products (e.g., testing kits) that can be utilized all over the world. Many Korean manufacturers also took the chance to reconsider and restructure their global supply chains in order to make them more sustainable.

Sri Lanka has risen to seize the opportunities and many innovations are reported. In a historic milestone for Sri Lanka, a group of senior scientists has developed the means to produce COVID-19 testing swabs domestically, amidst growing calls for increased testing and a global shortage of such swabs. Working to address this shortage in COVID-19 testing swabs over the past few weeks, scientists from the Sri Lanka Institute of nanotechnology (SLINTEC) announced having reverse-engineered existing COVID-19 testing swabs, now being ready to produce over 3,000 testing swabs on a daily basis (Razeek, 2020). One other innovation reported in Sri Lanka is the introduction of the next generation smart mask developed by Hirdaramani Group, a leading apparel manufacturer, in partnership with SLINTEC and CirQ (Daily FT, 2020c). The new product, 'Hale' is a low cost, ultra-thin and easily attachable respiratory monitoring smart sensor that has been developed in collaboration with CirQ Labs – a high-tech innovation hub specializing in healthcare solutions (Daily News, 2020). The first ever antibacterial stationery introduced by Atlas, Sri Lanka's leading stationery producer is another pioneering innovation (Salt.lk, 2020). Reporting another successful innovation, SLINTEC in effort to increase the diagnostic capacity for COVID-19 virus in the country, rapidly repurposed its staff and facilities to develop cost-effective COVID-19 diagnostic test kits, including gold nanoparticles and graphene -based strips or electrodes to detect viral antigen, and RT-LAMP PCR to detect viral RNA. (Daily FT, 2020a). Increased production capacity coupled with innovations bring in efficiencies and cost effectiveness are the apt examples of harnessing the opportunities amid crisis, which will strengthen supply chains in future situations.

These initiatives have also pointed towards the beneficial collaborations between government, private sector and research organisations, in the effort to combat the common threat. The crisis has seen business rivals collaborating in the time of need. Examples of business competitors FedEx and UPS in the West getting together to deliver

vaccines and similar occurrences in Sri Lanka where 3 companies, Hemas, Expo Lanka and Emirates got together and collectively submitted a proposal to the government to manage the vaccination program support from the private sector are testimonies for this response.

With the growth of e-commerce, home delivery logistics services have grown rapidly in the past decade (Jara et al., 2018). Sri Lanka saw a resurgence in medicine deliveries, in a commendable effort where the Ministry of Health quickly pivoted to using the Sri Lanka postal services to deliver medicines to the door steps of patients visiting the government medical clinics. Private sector also followed suit, starting medicine deliveries. The government also identified pharmacies for the last mile delivery of these items through WhatsApp, setting up a hotline- Osudiriya. The COVID-19 crisis has created a new set of challenges to which supply chain managers must respond. As demand for home delivery services has surged, supply chain organisations have had to adapt their own supply replenishment processes, their order fulfilment processes and hire new employees to be trained in the specifics of order picking and home delivery (Dodds, 2020). Customer service expectations now include the desire to stay safe and healthy during the shopping experience (Esper, 2020). Thus, contactless delivery becomes an important service attribute in addition to traditional measures of timeliness and order accuracy (Wolfe, 2020). Work environments that foster healthier and more protective situations for both employees and customers will need to be incorporated into systems that have focused on traditional measures of order fulfilment efficiency and quality. (Mollenkopf, et al., 2021).

3. RECOMMENDATONS

Following from the discussion on factors driving the disruptions, the responses and resilience demonstrated, this paper sets out recommendations for the better management of healthcare supply chains.

The foremost consideration is that organisation should seek to diversify supply chains from a geographic perspective to reduce supply-side risk from one country. Multiple sources of key commodities or strategic components should be identified, and protocols should be in place to activate alternative sources of supply on short notice. (Sharma et al. 2020). It is an urgent wake- up call for all countries to step up their production capacities of medical supplies and to invest in research and development of innovative products. Collaboration between government, private sector and research institutions is critical.

Designing a financial risk management framework would be an important step which will help inbuilding a resilient network for logistics supply chain (Sharma, et al., 2020). Along with this a robust disaster management plan including inventory of key resources, reorientation of supply chain management practices by working closer to suppliers are critical in a plan to combat such a future crisis. The lack of resources, PPEs and equipment exposed the healthcare supply chain fragility and dependency. Moving forward, healthcare managers should consider inventory of key resources for unforeseen events, establish closer collaboration between buyers and suppliers and develop projects in collaboration with local industries. Lean supply chain strategies, while increasing short-term profits, contribute to supply chain vulnerability (Kilpatrick & Barter, 2020). COVID-19 has taught corporate decision-makers that in formulating future supply chain designs, apart from cost, quality and delivery, they would also need to stress-test the chains on new performance measures, including resilience, responsiveness and reconfigurability.

The failure to balance demand and supply affects not only manufacturing companies but also retailers, ecommerce suppliers and other traders. The failure to meet high inventories, cash flows and customer services can be managed by effective sales and operational planning to regulate demand and supply. Application of quality assurance methods, with detailed specifications for PPEs and other

material is essential to prevent supply delays and avoid wastage.

A robust demand management system requires accurate, on-time information. As proposed by Govindan et al. (2020) development of a practical decision support system will help with the demand management in the healthcare supply chain, reducing the short supply of equipment and other supplies to treat the infected patients with.

4. CONCLUSION AND DIRECTION FOR FUTURE RESEARCH

Operational and supply chain management issues are not new during critical events. However, the level of global impact and disruption of the current COVID-19 pandemic totally unpredicted. The pandemic has raised awareness of the factors driving disruptions of operations and supply chains in many areas, including healthcare supply chains. The learnings have highlighted the fragility of global healthcare infrastructures and reinforce the role and impact of healthcare operations in the management of demand, capacity and resources, as well as constraints from the wider supply chain. To effectively deal with a crisis, resilience is needed. To effectively capitalize on the opportunities it presents, appropriate (and often new) organizational capabilities, innovation, and entrepreneurship are needed. The overarching need of not relying on a single source supplier is identified. Moving forward, greater collaboration between governments and industries will be needed to ensure minimum disruption in global supply chains.

This paper is a preliminary view point study on the impact of COVID 19 on healthcare supply chains in Sri Lanka. The project is hoped to be continued to a larger study to enhance capability of procurement and supply chain professionals using digital technologies, which will be part of a project by the Monash University research group

REFERENCES

Bohmer, R.M.J., Pisano, G.P., Sadun, R., & Tsai, T.C. (03 April 2020). How hospitals can manage supply chain shortages as demand surges? *Harvard Business Review*. Retrieved from https://hbr.org/2020/04/how-hospitals-can-manage-supply-shortages-as-demand-surges.

Daily FT. (18 August 2020a). SLINTEC develops low-cost Loop Mediated Isothermal Amplification kit to enhance COVID testing capacity. Retrieved from http://www.ft.lk/front-page/SLINTEC-develops-low-cost-Loop-Mediated-Isothermal-Amplification-kit-to-enhance-COVID-testing-capacity/44-704715?fbclid=IwAR1DRlHcAP96S_yUl0NIBV0LUG4le03uLcQDggHTO3Bmvp7vz.

Daily FT. (17 September 2020b). Govt. to expand State-owned pharmaceutical manufacturing capacity. Retrieved from http://www.ft.lk/news/Govt-to-expand-State-owned-pharmaceutical-manufacturing-capacity/56-706165

Daily FT. (5 October 2020c). Hirdaramani group partner SLINTEC and CirQ to introduce next generation smart mask. Retrieved from http://www.ft.lk/business/Hirdaramani-Group-partner-SLINTEC-and-CirQ-to-introduce-next-generation-smart-mask/34-707015?fbclid=IwAR3rpemBYUoV7CQQcFizwqEDf-rEeV8szwiGxgs0AHdD3V83VlF4qsHiOF4

Daily News. (12 October 2020). LAMP PCR test kit from the Institute of Nanotechnology. Retrieved from http://www.dailynews.lk/2020/10/12/local/231247/lamp-pcr-test-kit-institute-nanotechnology?fbclid=IwAR20-opj0AMdkqapmMOB8m59aDLiwJgToIy1wmtPYJ9gMlPqrTrYAIyx1zY

Dodds, L. (13 April 2020). Amazon hires another 75,000 staff to cope with Covid-19 demand. *The Telegraph*. Retrieved from https://www.telegraph.co.uk/technology/2020/04/13/amazon-hiresanother-75000-staff-cope-covid-19-demand/ .

European Pharmaceutical Review. (01 April 2020). COVID19 update: Coronavirus and the pharmaceutical supply chain. Retrieved from https://www.europeanpharmaceuticalreview.com/article/116145/covid-19- update-coronavirus-and-the-pharmaceutical-supply-chain.

Govindan, K., Mina, H., & Alavi, B. (2020). A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19). *Elsevier Public Health Emergency Collection, 138*, 101967. doi: 10.1016/j.tre.2020.101967.

Hizbullah, Md. (20 April 2020). Beware of phoney PPE factories popping up around. *India Today*. Retrieved from https://www.indiatoday.in/

india/story/beware-of-phoney-ppe-factories-popping-up-around-1669126-2020-04-20.
https://www.onlanka.com/news/morison-opens-largest-pharma-manufacturing-facility-in-sri-lanka.html

Jara, M., Vyt, D., Mevel, O., Morvan, T., & Morvan, N. (2018). Measuring customers benefits of click and collect. *Journal of Services Marketing, 32*(4), 430-442. doi: 10.1108/JSM-05-2017-0158.

Jayakody, A. (1 May 2020). COVID-19 Pandemic: Will Sri Lanka experience a severe dearth of medicines? *Daily Mirror Online*. Retrieved from http://www.dailymirror.lk/news-features/COVID-19-Pandemic-Will-Sri-Lanka-experience-a-severe-dearth-of-medicines/131-187537.

Kano, L., Tsang, E.W., & Yeung, H.W.-C. (2020). Global value chains: A review of the multi-disciplinary literature. *Journal of International Business Studies, 51*, 577-622. doi: 10.1057/s4126 7-020-00304 -2.

Kilpatrick, J., & Barter, L. (2020). *COVID-19: Managing supply chain risk and disruption*. New York, USA: Deloitte Development LLC.

Leite, H., Lindsay, C., & Kumar, M. (2020). COVID-19 outbreak: implications on healthcare operation. *The TQM Journal, 33*(1), 247-256. doi: 10.1108/TQM-05-2020-0111.

Li, R., Liu, Y., & Bustinza, O.F. (2019). FDI, service intensity, and international marketing agility: The case of export quality of Chinese enterprises. *International Marketing Review, 36*(2), 213-238. doi: 10.1108/IMR-01-2018-0031.

Lindsay, C.F., Kumar, M., & Juleff, L. (2020). Operationalizing lean in healthcare: The impact of professionalism. *Production Planning and Control, 31*(8), 629-643. doi: 10.1080/09537287.2019.1668577.

Liu, Y., & Huang, Q. (2018). University capability as a micro-foundation for the Triple Helix model: The case of China. *Technovation, 76-77*, 40-50. doi: 10.1016/j.technovation.2018.02.013.

Liu, Y., Lee, J.M., & Lee, C. (2020). The challenges and opportunities of a global health crisis: the management and business implications of COVID-19 from an Asian perspective. *Asian Business and Management, 19*, 277-297. doi: 10.1057/s41291-020-00119-x.

Mollenkopf, D.A., Ozanne, L.K., & Stolz, H.J. (2021). A transformative supply chain response to COVID-19. *Journal of Service Management, 32*(2), 190-202. doi: 10.1108/JOSM-05-2020-0143.

Park, C.-Y., Kim, K., Roth, S., Beck, S., Kang, J.W., Tayag, M.C., & Griffin, M. (2020). *Global shortage of personal protective equipment amid covid-19: supply chains, bottlenecks, and policy implications*. Metro Manila, Philippines: Asian Development Bank. doi: 10.22617/BRF200128-2.

Perera, T. (28 April 2020). COVID-19: A wakeup call for increased manufacture of pharmaceuticals locally. *Daily FT*. retrieved from http://www.ft.lk/columns/COVID-19-A-wakeup-call-for-increased-manufacture-of-pharmaceuticals-locally/4-699342.

Razeek T. (19 April 2020). Local scientists overcome global COVID test kit shortage. Retrieved from https://ceylontoday.lk/news/local-scientists-overcome-global-covid-test-kit-shortage.

Salt.lk (2020). Atlas disrupts local stationery market with Sri Llankas first ever anti-bacterial-range. Retrieved from http://salt.lk/atlas-disrupts-local-stationery-market-with-sri-lankas-first-ever-anti-bacterial-range/?fbclid=IwAR2yCMoaDpKw2NkXuUCXcT-umCA_2980p8OphnrqovjG-SCcd8Yy10iSobQ

Sharma, A., Gupta, P., & Jha, R. (2020). COVID-19: Impact on health supply change and lessons to be learnt. *Journal of Health Management, 22*(2), 248-261. doi: 10.1177/0972063420935653.

Sharma, M. (15 April 2020). Coronavirus: Shortage of kits leads to delays in testing. *India Today*. Retrieved from https://www.indiatoday.in/mail-today/story/coronavirus-shortage-of-kits-leads-to-delays-in-testing-1667041-2020-04-15.

Taleb, N.N. (2010). The black swan: The impact of the highly improbable (2nd ed.). London, UK: Penguin Book.

Xinhua (15 August 2020a). Sri Lanka targets 50 percent self-sufficiency in pharmaceuticals: state minster. Retrieved from http://www.xinhuanet.com/english/2020-08/15/c_139292960.htm.

Xinhua (11 November 2020b). Sri Lanka to open pharmaceutical manufacturing zone to attract global companies. Retrieved from http://www.xinhuanet.com/english/2020-11/11/c_139509112.htm.

NATIONAL SCIENCE FOUNDATION

Section 10

Research and Inventions

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

Research and Inventions: Introduction

Ajith De Alwis

The societal response through inventions in trying times is the subject in this section. How we respond matters a lot in realizing what the Chinese saw in creating the character to describe "crisis" – "danger" and "opportunity". If you respond to the danger only, life for you and everyone else is a one of flight. If fight was the response, the situation, however bad it may look, might turn out be the finest hour. Inventions and Innovations and the process in between in Sri Lanka during the first wave of Covid-19 is discussed.

If we can learn from Alibaba, and of course Jack Ma in this regard. Alibaba was a 1999 start-up based on the online B2B business model. Today, it is a giant e-commerce company worth $ 470+ billion. It was SARS that helped Alibaba to bloom: not because of the virus itself but due to the way Jack Ma and his team took it on. When he sent his team home for a self-imposed isolation after one of his staff was stricken with SARS, they took their desktops – not laptops! – home, and with his core team holed up in his apartment, worked to change history. E-commerce was changed forever. He allowed people to post on his site free of charge for three years, and each transaction was not viewed with profits in mind. The capture of minds and growth was more important. Alibaba was not the only one; JD.com is another example from China. One or two big indigenous growth engines can do wonders to the economy, and Covid-19 situation is an opportunity. Sri Lanka's pioneer e-commerce player, even with successful demonstrations with drone deliveries, got it wrong. Hopefully this situation would be reversed. We also appear to have the other strategy of marking up-and-up when the iron is hot! Jack Ma built his strategy with responsibility to his community in mind. SARS led to more self-imposed isolations, people latched onto online ordering, a new normal was created, and Alibaba soared. Getting rid of eBay in China was just an event on the timeline.

On Sri Lanka and Covid-19 first wave from a medical perspective, we could be happy. I just wish that we did limit visitations to critical places. However, the situation should be fought – and that exactly is what we were doing instead of resorting to flight! – with survival and same life at the end of the tunnel in mind! This was an opportunity to do many things and force changes that the usual circumstances would not allow at all. Experience in many a country especially in the developed world is that crisis are made use of as opportunities and individuals or institutions have enabled significant progress to be made subsequent to overcoming the crisis. The innovations have been both used in overcoming the crisis as well as charting the economic development subsequent to the crisis. The crisis become opportunities when one is alive to that scenario. Decision makers who have been open to such opportunities have seen countries emerging as strong economies overcoming other established countries. The creativity and the drive come from ordinary members of the society and this is another observation.

The initial wave of Covid-19 in Sri Lanka similarly witnessed members of the public and institutions quite energetically delivering ideas and devices. Some were responding to formal mechanism that have been setup to elicit such responses. Individuals who have developed devices or systems in isolation where the only stimuli have been the crisis itself were also frequently seen. In all situations the interest and the energy of the inventor is not equally reciprocated by the system however, much of it is in crisis and in need of solutions. In search of standard solutions usually is the more prevalent scenario. The enthusiasm when met with little or no interest is actually a test of character of the individual. This situation and the requirement are not specific to Sri Lanka. Usually in a crisis of this nature it is the State that drives the process. The layers of public bureaucracy that one has to survive is a measure of the efficiency of decision making and one's interest in solutions.

The innovation session has 12 number of presentations and was one of the sessions that we had to have on both days as the submissions were many. The submissions however were quite a small number from the observed developments in the society. The interest in written communication is also another characteristic that distinguishes an inventor. Most of the individual inventors demonstrate a liking for action than written communications. Hence definitely the event lost out on significant number of inventions and some high-end developments as well. To remedy that deficiency a review paper for the period has been included into this proceeding. An Inventor when writing also addresses the issue differently to a standard research. A presentation covering an invention thus is different to the usual research paper which actually an end product of a more methodical process. Considering the importance of capturing at least some of the inventions that materialize – some from the professional community too – the editor considered what is included to be as invention communications. With inclusion of those a significant amount of activities that were a common day occurrences in that particular period had been identified. It is however hoped a more incisive research is undertaken by a researcher to understand and present both the characterization of the Sri Lankan inventor and researcher at the time as well the innovation eco-system that prevailed. Crisis had no opportunity to substantially change what was present and embedded. It could however be changed by individuals who can be innovating in the services. These two areas await further study.

Transforming inventions to impactful innovations in times of a pandemic: Lessons from Sri Lanka‡

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ABSTRACT

The global community has been facing an unprecedented challenge since the end of 2019, with the emergence of the Covid-19 pandemic, which affected the lives and livelihoods of people around the world. Despite the sudden lockdown of countries, a platform was created by Covid-19 to breed domestic inventions at a remarkable pace in a local and global context. Sri Lanka too has witnessed this trend. Many domestic innovations in the areas of public health, society, and economy have spurred particularly during the first wave and given due publicity. However, a gradual decline of spirit for innovative solutions/approaches was observed in subsequent Covid-19 waves in Sri Lanka. This paper aims to analyze inventions developed to combat Covid-19 with the hope of a resilient future during the first wave. However, the successful transformation of such was hindered due to barriers prevail in the Sri Lankan innovation ecosystem. The lessons should not be ignored and one must understand and take actions to mitigate the challenges for the betterment of the economy and the nation. The subject of this critical review is to highlight overarching issues and challenges which obstructed further development, market penetration of such inventions and, propose recommendations for overcoming such while focusing on innovation attempts, both success and, failures.

Key words: Business process innovations, Covid-19, Domestic inventions, Frugal innovations, Technological inventions, Sri Lanka

1. INTRODUCTION

The inventors exercise creative ideas to provide technical and, or non-technical solutions for existing problems during normal situations, at a time of recessions, or in times of crisis. This emanates at the individual level or at an organizational level where public sector institutions, private entities, and academic institutions contribute as actors to this endeavor. The Covid-19 pandemic was a crisis of the unprecedented magnitude that provided an opportunity space for innovative thinkers to voluntarily come up with novel approaches to cater to emerging needs. Many an example could be identified from a history of crises yielding inventors of highest quality. It appears that such situations are the necessary catalysts for such individuals to come out of their uneventful living.

Covid 19 has spread to be a pandemic, and has brought negative impacts directly on public health, and indirectly on economy, society, and

‡ **Invited Paper**

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politics. As a crisis of immense magnitude hit Sri Lanka, Covid-19 had paved the way for inventions and innovations. Invention landscape in tackling Covid-19 span over various areas; prevention, treatment, testing, emergency communication, humanitarian assistance, transport, data, education, supply chain, economic and workforce support, vulnerable groups, policy related, *etc*.

The inventions emanate at the individual, or the organizational level may be technological, leading to new product/process development or business processes. Especially, the business processes inventions tried to mitigate/ overcome the negative effects on businesses and to realign the economic consequences. Business process inventions are found to be successful in terms of implementation and gaining results compared to technological inventions. Business process inventions were mostly driven on IT platforms. The pace at which inventions grew was relatively high compared to inventions that came up during previous pandemics such as SARS and Ebola. As stated in the OECD report, in the first six months since the outbreak began, the US Food and Drug Administration (FDA) has approved almost 100 COVID-19 tests, in contrast to the three months the FDA took to approve the first Ebola test during the 2014 West Africa outbreak. Further, the first COVID-19 vaccine entered into human trials within a record-breaking 69 days of identifying the causative agent of the outbreak, whereas 25 months for the first vaccine to reach the human trial stage during the previous global coronavirus outbreak: SARS in 2002–04. These demonstrate the intensity of interventions towards the COVID-19 pandemic. In financial terms also, the same report highlights that USD 9 billion in seven months mobilized compared to total global funding disbursed for Ebola R&D, between 2014 and 2018 was USD1.9 billion.

During the 2020, Sri Lanka witnessed significant number of inventions coming through, addressing the needs of the aforementioned 12 categories, tackling Covid-19 by the public and private sector, civil society, and, academic institutions. However, successful transformation to impactful innovations requires enabling environment with multidimensional support; financial, physical resources, tax benefits, regulations, *etc*.

The Invention is 10% of the innovation value chain, where the rest 80- 90% lies with the transforming invention to impactful innovation. Innovation and economy are interdependent and well reflected by the Innovation matrix as explained in Figure 1. The two-dimensional aspect of innovation matrix explains the market change and the technology in four innovation quadrants, situational innovation, incremental innovation, disruptive innovations, and radical innovations. It is of interest to see, how Covid-19 local inventions can be mapped into these four quadrants and support exist in the Science, Technology, and Innovation (STI) ecosystem to translate for commercial yields. Therefore, it is imperative to carefully identify the spectrum of inventions that has emerged during the first wave of the pandemic aligning to two dimensions: market and technology.

Can the pandemic in an economy, literary transform the economy to a new state? Transforming an economy with industry 4.0 elements was an opportunity that the Covid-19 offered. There was an urgent need to keep working but the 'how' had to be different. Industry 4.0 technologies already on the market, were ideal to meet such expectations. This was another transformative opportunity that was available for Sri Lanka in this crisis.

2. METHODOLOGY

This study was conducted to identify domestic inventions in terms of the platform (individual/ organizational), type (technological/ business processes), areas (prevention, treatment, supply chain, *etc.*), and analyzing the rate of success/ failure, level of readiness to market. Unfolding the reasons for the success or failure of a particular invention is paramount to ascertain the factors and actors that should come into force, to create enabling environment to escape from the "Valley of

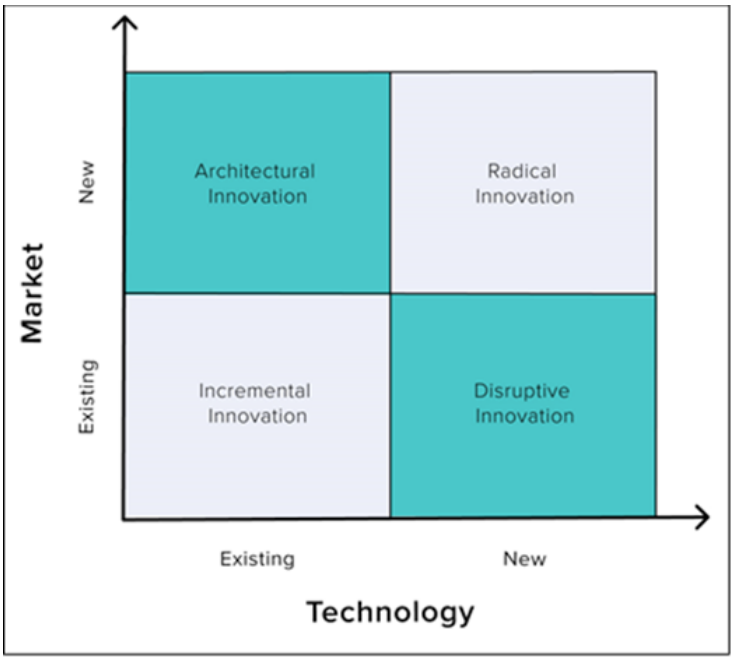

Figure 1. The Innovation Matrix

Source: https://ideadrop.co/innovation-management/different-types-of-innovation/

death" in the innovation value chain, especially under a crisis.

In this context, qualitative and quantitative methods are used to identify inventions which emanated from public & private institutions, academic institutions, and at individual levels. Acquisition of information was mainly conducted through online searches and direct contacts with the respective institutions were made at all possible times. For analysis, a case study based-approach is used to gather information on selected inventions from a cross-section of inventions.

A cohort of 392 inventions registered at the Sri Lanka Inventors Commission (SLIC), in response to the national call, was analyzed in detail. Inventions/ innovations which emanated from various academic institutions were also considered. Inventions from two main public sector R & D institutions, revealed in electronic media was obtained by navigating social media sites. Contribution by industry sector was also in focus. Inventions were classified as per the application area and further sub-categorized for a clear understanding of markets and the maturity of the technology.

3. RESULTS AND DISCUSION

Innovation efforts led by people in low-income countries (LICs) and middle-income countries (MICs) have been of vital importance to local and national responses to emerge from the coronavirus (OECD, 2021). Ascertaining this, during the first wave of Covid-19 pandemic, which hit Sri Lanka during the first quarter of 2020, and lasted till the end of second quarter of the year, led the platform to groom a multitude of inventions with multi-stakeholder participation. Voluntary efforts of the community are the *sine qua non* to the inventions spurred by the crisis.

The period of the first wave of Covid-19 in Sri Lanka was shown to have had a significant number of developments. Almost one year later it is interesting to consider the sustainability of these activities. Has Sri Lanka seen the development of inventor-led businesses or invention transfers to businesses to drive economic growth? Have the elements of Industry 4.0 activities that were getting

demonstrated across the country in different sectors had success in transforming the sectors to adopt more of such technologies and for a more sustained fusion?

3.1. An Opportunity to Transform

As Covid-19 wreaked havoc, and economic transformation that was much talked about was the fourth Industrial Revolution (IR) and the discussions were on in Sri Lanka too. The technologies that were to enable this industrial revolution were all-present and were developing fast – Artificial Intelligence, Internet of Things, Big Data, Robotics, Additive manufacturing, Sharing economy, *etc*. There had been many discussions and planning by many to enter into this new era of growth. Education systems were getting a makeover to enable students to start young and early. Coding, robotics, *etc.* were getting into primary classrooms in real physical spaces. It was possible to observe how some of the ideas were getting adopted due to sheer necessity in many economies. The education space perhaps was an outstanding example of digital transformation in the Covid-19 first wave.

In Sri Lanka too the 4th IR had been on many an agenda over the past years. Robotics to the young and opening up coding experiences for children has seen some developments in cities. The education system considered the need for accelerated Science, Technology, Engineering, and Mathematics (STEM) integration to accommodate these emerging scenarios. Ministry of Health had a major convention discussing 4th IR and Health in 2018. A National Policy for Artificial Intelligence was emerging. A direction that was thrust on economies by Covid-19 was the need to embed manufacturing in an economy. Relying on trade excessively was shown immediately to be a fallacy.

Fast-forwarding to Covid-19 experience in the country it is easy to see that many have come forward with technologies offering solutions that are part of the 4th IR. For example, at the very early stages service robots were deployed in a hospital with Covid-19 patients to ensure the safety of medical personnel.

3.2. Inventions and Institutions

Multiple institutions have promoted creativity to be showcased during the first wave of Covid-19 in Sri Lanka. Sri Lanka Inventors Commission, Sri Lanka Telecom, Citra Social Innovation Lab, Chartered Institute of Transport and Logistics (CILT). The latter three engaged with hackathons. The national level initiative was led by the Sri Lanka Inventors Commission (SLIC).

Corona outbreak has created numerous gaps between Public-Government relationships, social groups, institutional relations, businesses, and different sectors of industries, even in the food supply as well as in medical facilitation, *etc*. The disruptions in supply chains caused significant problems to the country. There was the need for creativity across multiple fronts and all institutions doing things differently was almost an imperative.

3.3. SLIC Program

Sri Lanka Inventors Commission, functioning under the purview of State Ministry of Skills Development, Vocational Education, Research and Innovation, gave a start, by inviting inventors in different platforms; organizational, or individual opened up with a direct funding campaign of Covid-19 inventions. SLIC is the key state organization and responsible statutory body which promotes and encourages the creative talents of Sri Lankan inventors. The analysis showed that SLIC has given the leadership to leverage the fruitful innovative talents of Sri Lankan Inventors and innovators to avoid/overcome prevailed COVID 19 pandemic situations in Sri Lanka. The influx of local inventions for this call was significant.

Bridging those gaps and bringing talented solutions to balance the demand and supply side of a crisis was a challenge with a high rate of risk of success, at a time of fragmented STI ecosystem. Commission has played a significant role to open up the results without further

delay, amidst interruptions that occurred in the global supply chain.

SLIC's objectives were multifold;

- to coordinate and assist each invention or useful product with close supervision and monitoring to convert them as effective practical solutions for the said requirements
- to promote and socialize, recognize and also to commercialize as well as publicize while securing Intellectual Property Rights where possible.

Ending up with almost 392 inventions in the areas of prevention, treatment, testing, emergency communication, transport, data, education, supply chain, economic, and workforce support during the first wave, under one roof, was a challenging task for a public sector institution. The operational plan executed to handle the situation was multifaceted;

- used possible ways to link each other remotely and minimize the communication gaps between SLIC and the general public (limited facilities and alternative options to get used to reach each requirement and also did not have sufficient time to test or run pilot approaches to check whether the suggested/introduced systems).
- SLIC staff linked together where possible to grab generated ideas from communities all over the island.
- Each staff member was allocated with every single piece of idea and that idea was followed up by the relevant officer until it reached the desired level and entered the commercialization stage.
- SLIC created a specific online database that could be accessed by every member of the SLIC who has been granted with necessary permission and updated every single piece of action that is taken to develop or in moving forward.
- Advertising campaign through electronic and printed media and on social media platforms such as Facebook, YouTube, *etc*. which belonged to the SLIC as well as the official web page of the Commission., invitations were extended to universities and R & D institutions

The above encompasses the attributes of an enabling facilitator; human resource deployment, rapid operational adaptations, infrastructure facilities for online operations, *etc.* In this situation, multiple requirements are needed to be addressed urgently in the country.

Especially there were requirements for the general public and health sector to address preventive solutions, needy medical equipment to use in emergencies, that arise, and also to fulfill the requirement of minimizing spread among the community. In order to address these requirements, the SLIC has created a conducive environment for the local inventors and innovators to provide innovative ideas and alternative, economical and potential solutions for existing technologies and recreations.

For the purpose of this study SLIC inventions were categorized under main areas; prevention, treatment, testing/ diagnostics, and miscellaneous under which all inventions indirectly support maintain hygienic practices, contact tracing, communication methods, etc., are listed.

The analysis revealed that the reported inventions were dominated in the area of prevention, which accounted for 71% of total inventions. Out of reported 390 inventions during the first wave, 382 were directly related to Covid-19 and thus this study is mainly confined to these 382 inventions. Illustrated percentages are attributed to each area is in Figure 2.

As per the above figure, Inventions related to treatment accounts for 14%; testing & diagnostics 6%; miscellaneous 9%.

Amongst many bits of advice given by the WHO to the public in the prevention of getting contaminated, three golden rules were: maintaining distance, wearing a protective

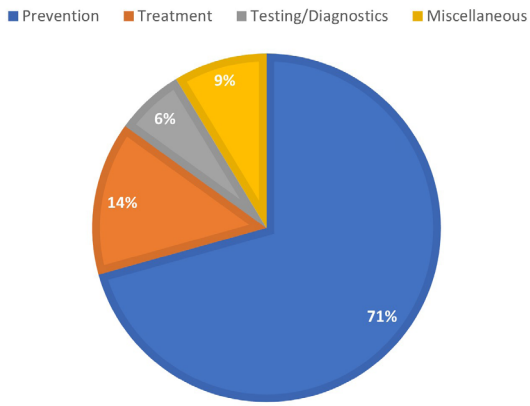

Figure 2. SLIC inventions by area

device, maintaining self-hygiene. Inventions of 70% in the area of prevention, contentedly manifested the general perception of the community, towards the necessity of products to keep self-hygiene.

Sub-categories of inventions under this group covers protective devices, masks, Personnel Protective Equipment (PPEs), disinfectant chambers, sterilizers, steamers devices/ materials for maintaining hygienic conditions, nutraceuticals/ herbal preparations: for internal & external applications; and other supportive devices/ items.

It is noted that inventive work pertaining to sanitizers/disinfectants/disinfectant chambers, took promising figures (37.8%) compared to face masks/ PPEs (16.3%). However, the technological intensity of these inventions was found to be at a lower scale signifying the incremental nature of such innovations .As an exception to this, some inventions in disruptive type evolved from Universities. Rather than creating an economic impact, these inventions were aligned to respond to the needs of the health care sector. But developing processes incorporating advanced features, such as in the mask "RESPIRON AV99", which would be discussed under academic inventions, successfully moved across the value chain; manufacturing, trading, selling while non-exclusively transferring the knowledge to global players in the apparel industry to create value for their products.

Demand for masks during the first wave was significant with demand exceeding the supply so unfair trade practices were observed, for which National Medicines Regulatory Authority (NMRA), has issued an Extraordinary Gazette stipulating the prices.

In parallel to the global context, creative minds were focused on tools for surveillance, supply chain management, clinical trialing, and then onto solutions for diagnosing patients and developing vaccines (Martina et al., 2020).

The phenomena were different in the domestic setup, inventions in the preventive area dominated other domains (Figure 3).

Interestingly, 102 (37.8%), numbers of supportive devices addressed many different user requirements. Table 1, enlist a few. Another 8.1% of inventions were in the line of herbal preparations as external or internal applications or as nutraceuticals.

Table 1. SLIC inventions – supportive devices for prevention

	Invention type
1	Foot operated/ automatic taps
2	Spraying devices
3	Heat dustbin/ smart garbage bin
4	Masks and glove reuse machine
5	self-sanitizing door
6	Sanitizing machines
7	Cash disinfecting units
8	Sanitizing ekle brooms
9	Distance maintaining barriers

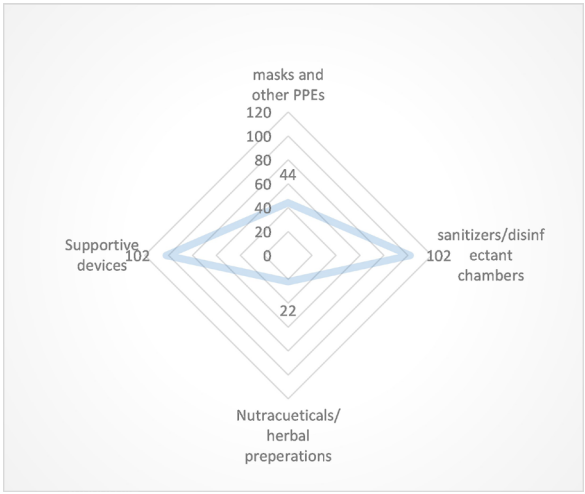

Figure 3. Percentage distribution of SLIC inventions under sub categories of prevention

The trend in treatment-related inventions spans over medicines/ drugs, ventilators, and devices for clinical care support. Medicines were dominated by herbal formulations, but neither standardized nor proper regulatory approvals were immediately forthcoming. Ventilators were promising, which have emanated from local universities as well. In this sector, technologically advanced features can be observed, in particular to ventilator systems. Devices which are not directly relevant to patient treatment, but provide indirect support, are grouped as "clinical care support" (Figure 4).

Exponential growth and demand in the global ventilator market had been created due to Covid-19 pandemic, resulting in a growth rate of up to 172% in 2020. The USA, China, and India were in lead in need of ventilators. In the management of this situation, in the global arena, measures were taken by regulatory authorities to define the use of a "ventilator" with required technical specifications. Accordingly, in March 2020 FDA declared authorized anesthesia gas machines, continuous positive airway pressure (CPAP), and other sleep apnea devices as alternative ventilators under emergency use authorization –EUA- halted imports and flight restrictions, countries like India ran into homegrown developments making more than 40,000 ventilators in six weeks.

Ventilators are for emergency need, ICU use, or life-saving purposes. Ventilator modes such as conventional Ambu-bag, microprocessor, or alternative forms can be used to cater to these purposes. The ventilators developed in the local context cover all these

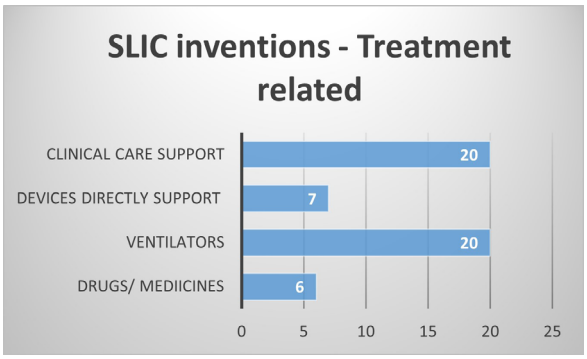

Figure 4. SLIC inventions treatment related

aspects, but most developed in a silo, rather collaborative efforts to bring the systems to run at a large scale in the domestic market. Indian approach was quite good and maybe a role model; bringing many unrelated industries together to manufacture and market ventilators. Mahindra and Mahindra having expertise in aerospace to state of the art automobiles, partnered with Skanray Technologies, a leader in medical equipment to realize the country's needs. Parts for ventilators were obtained from vendors of automotive component suppliers. Another case was. AgVa health with Maruti Suzuki India Limited. Case of HP Inc., Redignton India, and AgVa Health was a successful tripartite collaboration in manufacturing and supplying ventilator parts employing 3D printing. The emergency need was catered through advance manufacturing technologies such as 3D printing.

Harnessing local potentials to take domestic efforts; 4% of inventions related to ventilators out of all SLIC inventions, to that scale, is a necessity in making the invention impactful at the macro level.

Multifunction beds, ICU beds, speaker beds, patient monitoring systems, e-health systems, *etc*. were grouped as clinical care support. Video laryngoscopes, mechanical cardio-pulmonary resuscitators, pulse-oximeters, embodied with advanced features, and for such attempts inventors should be acknowledged for bringing technologically sound innovations.

Notwithstanding these, there are many more inventions bringing solutions to different needs, were reported in higher numbers. This mainly aids in patient and doctor support (especially robots, trolleys), contact tracing/ tracking (drones/ curfew pass), communications, trade-related (e-shops), *etc.* Use of Robots/ Robotic technology in this section was striking which takes 39% and shows the competency of Sri Lankan inventors and trends towards the application of advanced technology in combating Covid-19. ICT-based platforms were also developed in constructing devices for contact tracing, tracking, and trade related matters. When Covid-19 first wave hit Sri Lanka there had been a fair amount of sensitization of the public through the coverage of developments in China, Italy, France, UK *etc*.

However, it is noticeable that the majority were frugal innovations coming from the bottom of the pyramid, to serve more, under resource constraints, which is inherent in many low and middle-income countries (Matthew et al., 2020). Though frugal innovations predominantly features affordability and low cost, the quality and ability to provide safe health care, would be a better option under the prevailing supply chain issues. Totally 59 inventions (15% from Covid-19 related inventions) which had been selected to provide financial assistance, technical assistance, and product developments including testing facilities through SLIC. The sum of financial value to be incurred by the commission on them for said assistance is over Rs. 12 million. Nearly 50 entrepreneurs are expected to be generated through this project and necessary scaling up supports have already started to provide facilities such as interest-free loan facilities and links with business partners, *etc*. Out of the total products, more than 35 inventions have taken necessary actions to secure their intellectual property rights currently and follow-up actions are progressing on the same (Table 2).

Considering the innovative products that moved forward through developing and implementation stages, the number of successful outcomes can be pointed out as follows.

3.3.1. Protective Ventilation Suite for Healthcare Personnel by inventor Mr. Nalaka Chandrawansha.

This equipment is useful as a protective cloth against airborne infectious diseases such as Covid-19. It is very convenient equipment for healthcare workers as it is easy to wear and avoid sweating, which is beneficial during the clinical or surgical environment. It has a ventilation system that facilitates the air while the healthcare worker can continue his work without any difficulty. The developed version of

Table 2. The summarized details of the program activities are mentioned below.

		1 Evaluation 06/04/2020	2 Evaluation 10/04/2020	3 Evaluation 16/04/2020	4 Evaluation 21/04/2020	5 Evaluation 27/04/2020	6 Evaluation 04/05/2020	7 Evaluation 02/06/2020	8 Evaluation 27/07/2020	9 Evaluation 27/07/2020	Total
1	No. of Inventions Evaluated	18	7	11	26	16	32	43	19	10	182
2	No. of Inventions selected for financial/ other assistances	13	6	4	16	6	11	3	10	3	72
3	Value of Financial Assistances given/ progressing by SLIC (Rs.)	4,350,000.00	1,782,865.00	45,275.00	1,604,500.00	835,000.00	1,874,600.00	-	-	47,000.00	10,539,240.00
4	No. of Entrepreneurs Expects to be Generated	10	5	4	13	2	11	3		3	51
5	No. of Patent Applied										33
6	No. of Inventions Reported										392

the product contains a ventilation system for the head region and there is no need to wear a mask and goggles as in the conventional PPE and it also consisted of lightweight covered components, a long-life battery pack, and battery life indicator.

3.3.2. Microorganism Diverting and Clearing Device (MDCD) by inventor Dr. Shashika Ariyarathna.

This device is designed to collect respired air from a patient who is connected to a conventional Ambu bag or a ventilator without exposing the infected air to the surroundings which may cause infection to other people as well. The device consists of three main treating methods to disinfect microorganisms in the collected respired air. This device obtained the first patent in Sri Lanka with respect to the devices made to fight against COVID 19 and it was assisted by SLIC. The latest version included the Carbon Dioxide sensor which is important to acknowledge the required breathing rate of the patient and the facility currently not available in an Ambu ventilation.

3.3.3. Microorganism killing and filtering Air Conditioner by inventor Mr. Thushan Karunarathna.

This device consisted of a filter system including a "HEPA" filter and also included a heat chamber to destroy living microorganisms in the inlet air. The device can clean the air which circulates in a closed environment efficiently in order to minimize the risk of infections from airborne viruses. The developed version included many facilities such as oxygen rate controlling mechanism and humidity controlling system in the dispatch air, advanced microorganism destroying system by activated radiation mechanism, and filter service requirements indicator system. The device has three types

suitable for small size closed areas, medium or large size closed areas as well as a possibility with application in mobile services such as ambulances, train compartments, and buses *etc*.

3.3.4. Face Mask made with Natural Herbal Medicine by inventor Mr. Saman Hettiarachchi

This face mask is produced with an initial step by inserting medical compounds which can filter air-borne viruses and microorganisms while enriching the body immunity from the air coming through the medicinal ingredients to the human respiratory system. The product had a good demand overseas as well.

3.4. Inventions in Universities

University researchers are yet another cross-section who contributed to local and global efforts in combatting Covid-19. Like other parts of the world, relentless efforts have been made by Sri Lankan academics to bring an innovative solution, amidst restricted mobilization and limited access to laboratory facilities, under lockdown conditions. As universities were not considered as essential services, the lockdown prevented activities to a significant extent as staff and students were all displaced. The developments noted here came from teams who were active despite these restrictions.

Key features of academic inventions:

- Multidisciplinary nature
- Scientific and technological merits
- Use of advanced manufacturing technologies
- Industrial collaborations
- Successful Implementation/ application

Presented in Table 3, few reported and promising developments, during the period from March-May 2020.

Development of technology related to novel and improved face mask materials by the University of Peradeniya, attracted the key players in the apparel sector and invited the experts to improve the quality of mask materials, already produced at some reputed garment industries like MAS holding and Kayak Surgi Pharma (Pvt.) Ltd. Project has been started at a commercial scale with the request of reputed textile industries like Teejey Lanka. A set of masks were produced and donated to the Temple of Sacred Tooth Relic (Sri Dalada Maligawa), Kandy.

Since the outbreak of the pandemic, global usage of the single-use plastics, have been escalated, and estimated at 1.6 million tonnes/ day, whilst approximately 3.4 billion single-use facemasks/face shields are discarded daily as a result of COVID-19 (Nsikak *et al.*,2021). RESPIRONE NANO AV 99 face mask from the University of Peradeniya, addressed this issue at a global context; daily disposal of masks at an unprecedented rate, by introducing the three-layered mask, which is made up of biodegradable fabric material, and enabling re-use. Competitive advantage gained due to the advent of the advanced technology paved the way for inventors to find suitable manufacturing partner: Sarasavi Industries (Pvt) Ltd and later to launch the product through State Trading Corporation and to make it available for the public through Sathosa (CWC), with the government intervention.

With the emergence of the Covid-19, disposal of polythene/ plastic waste has exponentially increased, marking a threat to the environment. A biodegradable sanitizer bottle from three undergraduates from the University of Peradeniya shows the thoughtfulness of developing environmentally benign products. The product itself is not a solution at the local level but addresses a global issue.

The diagnosis of Covid 19 and the release of results within a short duration is a major problem faced by health authorities all over the world. A team of researchers from the National University of Singapore (NUS) has come up with a portable PCR test kit named "Epidax," based on a microfluidic chip-based diagnostic system that enables the release of

Table 3. A snapshot of academic inventions

Product type	University/ collaborators	Product description
Ventilators	Kothalawala Defiance University RIO Electronics, TECH Automation (Pvt) Ltd	KDU Ventilator-2020 Ver. 1.0 Pneumatically driven, time-cycled ventilator with user-determined volume and flow rate selection capability. The system is a matched integration of a compressed air tank, air and oxygen inputs, a set of electrically operated valves and tubes, and a patient circuit of tubing.
	Kothalawala Defence University Students of SLINTEC and University of Sri Jayawardeneura	KDU VentilatorPro KDU Ver. 1.0 Build using locally sourced materials and components. This prototype functions on AC/CMV, SIMV, Spont, CPAP, PEEP modes and supports backup ventilation. It is built to minimize aerosol generation during ventilation. The self-sterilization process is also embedded to reduce the lead time taken for the next patient.
	University of Sri JayawardenepuraU Industrial Development Board	Ventilator (Prototype Innovation) Works on a pressure-controlled respiration mode. The ventilator takes over the body's breathing process when a disease has caused the lungs to fail.
	University of Ruhuna	Low cost remotely operated ventilator Proven its success as Volume Control Ventilator (VCV) method. Source:
Robotic platforms	University of Peradeniya CodeGen Int. Pvt. Ltd.	Robotic platform for patient monitoring and treatment A unit was donated to the COVID-19 ward of the Kandy National Hospital Sri Lanka.
	Kothalawala Defense University	2KDU MEDICARE Robot-2020 Ver. 1.0 Allows the control of all vital parameters during ventilation, functions on AC/CMV, SIMV, Spont, CPAP, PEEP modes, supports backup, ventilation *etc* The prototype features include the ability to deliver food containers & medicine to 8 patients at the same bed level by a single cycle, capability to spray sanitizer as per requirement by robotic hand on top of the system, two-way communication for doctor and the patient for real-time medical inspections, ability to handle the robot remotely and obstacle detection along the way, inbuilt UV sterilization in all dispensers. The product development cost was LKR 250,000.00
	University of Moratuwa	Hospital Assisted Robot A robot was handed over to Kandy Hospital
Clinical care	University of Peradeniya	Real-time Remote COVID-19 Patient Vital Monitoring System for isolation wards Able to monitor Respiratory Rate, Body Temperature, Non-Invasive Blood Pressure. Equipped with alarm systems. Integrating real-time analytics and AI
	Kothalawala Defense University	Curec: Doctor Patient Communication Platform Key features of Curec are the real-time video calling facility and the location tracker. The App also provides a Symptoms Log for the patient to monitor his history and decisions given by previous doctors.
	Kothalawala Defense University	MEDBED Ver 1.0" Intensive Care Unit Bed Bed is capable of basis five motions and lateral bed movement.
Test kits	University of Peradeniya Medivesta Remedies (Pvt) Ltd	Novel test kit to diagnose SARS-CoV-2 IoT is based on the Reverse Transcription-Loop Mediated Isothermal Amplification (RT-LAMP) principle and patients are detected. Final results can be provided within 2 hours

	University of Sri Jayawardenepura	Portable Single Person Operating COVID -19 Sample Collection Chamber Single health care worker can easily take the sample, disinfect the anterior side of the chamber, send the next sample collecting bottle to the outside through the channel with patient details on it and obtain the next sample. The chamber has its lighting system to light the patient's face to visualize the interior of the mouth. Also, it has an air cooling system to reduce the heat and the humidity inside the chamber. The machine was handed over to IDH.
Germ killers	Kothalawala Defense University	UV Air Purifier capable of destroying airborne pathogens using UV-C light.
	Kothalawala Defense University Dankotuwa Porcelain (Pvt) Ltd.	Steam Inhaler The spout of the device has uniquely design that helps inhalation in patients who have nasal congestion, runny nose, 'sinus' type headaches, intractable cough and respiratory- related issues.
	University of Peradeniya	Bio-Degradable Sanitizer bottle and Sanitary wipe package Banana stem as the main ingredient. Net zero environmental impact.
	University of Rajarata	Automatic hand sanitizing spray Sanitizing liquid automatically released. *Source:https://www.facebook.com/391992721210480/photos/a.421179761625109/797804667295948/?type=3&theater*
PPEs	University of Peradeniya	Novel and improved face mask materials:
	State Trading Corporation Sathosa	Face mask material with super hydrophobic outer layer having additional features: viricidal activity, enhanced electrostatic, and physical filtration.
Treatment	University of Colombo	MCPR (Mechanical Cardiopulmonary Resuscitation) Machines This machine can be used to provide chest compressions to COVID-19 patients

results with an hour. The local product by the University of Peradeniya, a novel test kit for the diagnose SARS-CoV-2", thus would be an equal competitor, in the global market, even though the difference exist in the base technology. The "Epidax", stays in front by eliminating an intermediate step of RNA extraction, bringing down the waiting time to one hour. However, the local product integrated with the Reverse Transcription-Loop Mediated Isothermal Amplification (RT-LAMP), takes 2hrs to complete the task. Nevertheless, both the products are in hand in hand with respect to the marketing model for commercialization through an industry partner.

A wide array of inventions addressing the real needs in the health sector, from high-tech areas were dominant, and many have already transferred to the user level at the first instance, without hope or strategic move towards manufacturing at a commercial scale. The platform technologies for the business process improvements were hardly seen from this group.

3.5. Inventive efforts from Research Institutions

Despite the grave challenge towards the research work, some of the local research institutions had taken a pivotal role in implementing research to bring marketable products. Sri Lanka Institute of Nanotechnology (SLINTEC), and Industrial Technology Institute (ITI), are at the forefront.

- SLINTEC-Multilac Novid® Antibacterial Antiviral Spray

Multilac-SLINTEC Novid spray, with its unique anti-viral technology, eradicates bacteria on the surfaces, once sprayed as well as in the surrounding air

- BreathTech-S^3

The World's first sustainably designed face mask to use respiration sensor technology. Mask function in a way, where a smart sensor, monitors breaths per minute, Mask fit analysis, Mask CO_2 build-up, Connected Application, left behind mask alerts, Wash or Replace Mask notifications, Proper mask recycling guide

- Atlas Antibacterial Stationery Collection (co-developed with SLINTEC)

Antibacterial Exercise Books, Practical Books, Drawing Books and Pens

- SLINTEC Swabs

The Nylon flock swabs with excellent absorption and elution of specimens.

- Loop-mediated isothermal amplification kit (LAMP-PCR), to enhance the national Covid-19 testing facility

Cost effective Covid-19 diagnostic test kits, including gold nanoparticles and graphene-based strips, or electrodes to detect viral antigen, and RT-LAMP PCR to detect viral RNA.

Industrial Technology Institute (ITI) is mainly involved in developing prevention care products. such as sanitizers, sanitizing sprays, automatic hand sanitizer dispenser, air-sanitizer, hand wash, foaming hand wash, herbal mouth wash, coconut oil-based surface disinfectant, coil-based surface sterilizing fruits & vegetable wash, Transparent soap, Bio wet wipes, Body & hand cream/lotion, Immunity boosters, and energy boosters.

The state-affiliated Ceylon German Technical Training Institute (CGTTI), has developed a walkthrough disinfection unit which was installed at the Ministry of Labour premises. Multiple parties developed these units using different solutions for the disinfecting process which included ozonated water. The initial demand for walkthrough disinfection units' use was subsequently discontinued after identifying multiple shortcomings of this application.

3.6. Industry sector innovations

Industry, the third main actor in Science, Technology, Innovation (STI) system was at a vulnerable position due to cascading negative effects on economy due to limited or prohibited business operations, restricted cross – border mobility and the prevailing disconnected ecosystem, especially during first wave. There was a significant contraction of economy by 3.6% in real terms in 2020, as performing of all economic sectors were severely hampered; agriculture, forestry and fishing by 2.4%, industry by 6.9%, and services by 1.5% compared to the previous year (Annual Report, Central Bank,2020). Apparel sector being the main subsector in the industry sector was also subjected to downfall, though many big players turned around to translate complexity to competitiveness by delivering altered needs of the consumer market; garments to PPEs. This change does not suffice to catch up the irrecoverable disruption. By May 2020, Sri Lanka's apparel industry had attracted over 500 million U.S. dollars' worth of orders for the production of personal protective equipment (PPEs), and was expected to increase the numbers to a value of 1-billion-dollar mark with 33 factories operating at the time.

Given this backdrop, many Sri Lankan industries advanced technological inventions and business process inventions, as responsible entities, at a national crisis to reverse economic setbacks experienced.

As Covid-19 wreaked havoc, and economic transformation that was much talked about as the fourth industrial revolution happened in Sri Lanka too. The technologies that were to enable this industrial revolution were all-present and were developing fast – Artificial Intelligence, Internet of Things, Big Data, Robotics, Additive manufacturing, Sharing economy *etc.* There had been many discussions and planning by many to enter into this new era of growth.

3.7. Technological Inventions from Local Industry

Vega Innovations (the subsidiary of CodeGen Group of Companies) has developed

a low-cost and scalable medical ventilator in 10 days at USD 650 per unit. This ventilator is designed for treating the Coronavirus patients at a critical stage and operates in a Volume Controlled – Continuous Mandatory Ventilation (VC-CMV) mode, eliminating the drawbacks of Ambu bag-based design, and tested under the supervision of a Consultant in Anesthesiology, Intensive Care and Pain Medicine at the Ministry of Health of Sri Lanka. The expected economic impact from a unit would be 29,360 USD, as 2020 estimates, as the cost of a typical medical ventilator would be at 30,000 USD.

The Sri Lankan stationery manufacturer Atlas stationery has developed an Automated Guided Vehicle (AGV) robot to aid medical personnel in the battle against COVID-19. The AGV can transport food and medicine, carry out temperature checks, and aid doctors in monitoring and communicating with patients. The robot was donated to the Homagama Hospital and was one of the first robots of such nature to deploy in Covid-19 treatment wards.

The "Ideathon", was launched by the Chartered Institute of Logistics and Transport Sri Lanka (CILT SL) in April 2020 to collect ideas to tackle issues faced by the Supply chain, logistics, and transport industry, in the pandemic.

The business process innovations spearheaded the technological innovations in terms of relatively low lead-time for implementation and gaining financial returns. A paradigm shift in Colombo Tea Auction and the Coconut Auction were two successful groundbreaking processes established, at a time many economic sectors were shrinking. Both tea and coconut auctions have transformed from a life-long manual process to a digital one. During the Covid-19, the Colombo tea auction, the oldest auction, went digital to keep the industry going.

3.8. The Colombo Tea Auction

The Colombo Tea e-Auction platform went live on April 5, 2020, following the first lockdown due to the COVID-19 pandemic. Before that, it was a face-to-face manual outcry auction held for two days per week. This transformation has eliminated cry-outs in the auction premises and submission of bids while keeping the livelihood of people in the tea industry alive.

As reported, the Colombo Tea e-Auction platform is used by all eight tea brokering companies in Sri Lanka, and over 300 tea buyers and exporters by joining via five concurrent virtual auction rooms. Users of the e-auction have accessed to power analytics and digital dashboards. CICRA Solutions, a local IT service provider supported the Colombo Tea Traders Association to develop a Minimum Viable Prototype (MVP) within a week.

Digital transformation of the Auction enabled prices to increase from LKR 546.67/ Kg recorded in 2019 to LKR 633.85/ kg during 2020 (Central Bank of Sri Lanka, 2020).

3.9. The Colombo Coconut Auction

A twenty-six year old, Sri Lanka's coconut auction is usually conducted in Colombo and Kuliyapitiya by the Coconut Development Authority (CDA). The online auction has connected auctioneer, brokers, and suppliers on one platform, who usually meet up at 10 am every Thursday. The Covid 19 pandemic has brought it to a turning point, where from 2020 it has been operating online. Drop in price of 1000 nuts to LKR 38,215 on the first day was recovered in subsequent auctions. The average auction price of coconut at the Colombo Coconut Auction also increased to LKR 48.89 per nut from LKR 27.55 per nut in 2019.

This manifested that timely adoption of technology-based process improvements enabled the industry to thrive, in a desperate situation.

An interesting industrial innovation was a virtual reality (VR) program to a factory in Sri Lanka by Haycarb Ltd. for their trading community. Haycarb is a global leader in activated carbon production and supply,

especially using a renewable raw material. As the customers usually want to inspect the facility and processes before placing an order, the company developed this VR scheme which proved to be a significant success.

3.10. Innovation Matrix and Domestic Inventions

The Innovation matrix depicts a two-dimensional aspect; technology and the market. Understanding the status of local innovations emanating in the pandemic would reflect where we are standing, while shedding light on where we want to be to compete with the global counterparts (Figure 5).

It is observed that the majority of the innovations reside in the "disruptive" innovation quadrant, opening many investors to pick up for commercial exploitation. The application of technologies of 4IR is also a favorable fact, as it may create value in the market in future. These disruptive inventions came from universities, or from individuals, thus the success or further scaling up, or emerging as a marketable product is in question. The whole scenario is depending on the environment in which these grew up.

Transforming these inventions to impactful innovations should be supported with a conducive environment backed by the actors and factors in the STI system: robust infrastructure facilities, financial instruments, legal frameworks, critical mass, networking, regulatory measures in place, uninterrupted supply chain, *etc*. The pandemic situation has created a fragmented environment far-reaching for each of the above elements. On the other hand, for innovations to be impactful, they should cater to the global and local market needs and the IP should be properly secured.

It is noted that many inventions/ innovations placed in this paper are embedded with technologies of 4IR, in convergence with main economic sectors, signaling the potential of its contribution to creating an economic impact.

The following summary observations from the first wave period could be associated with 4IR technologies.

- Inventive Developments in the Manufacturing Sector of Sri Lanka
- Consider the following innovative developments that materialized with direct opportunities for the manufacturing sector.
- Robotics for medicine and food delivery in wards
- Robotics for patient interfacing with medical personnel through vision and voice applications
- 3D Printing of Ventilator parts and face shields
- 3D Printing of face masks

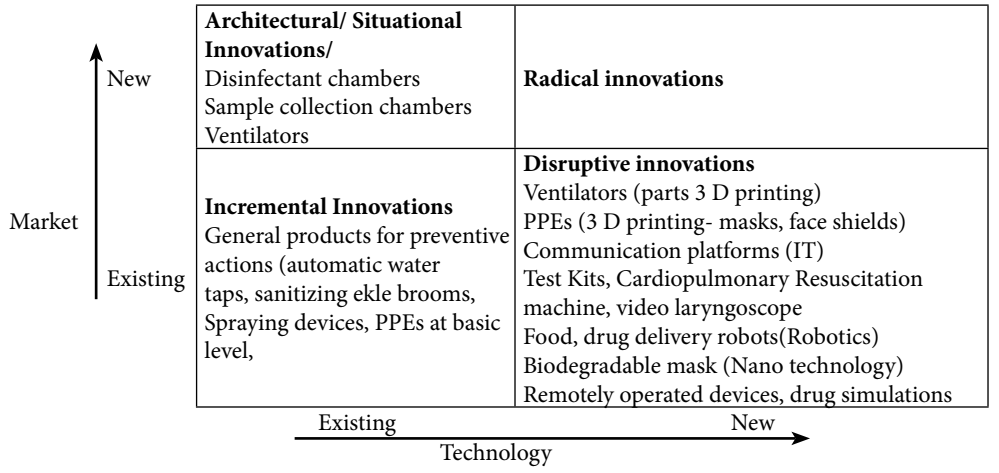

Figure 5. Domestic inventions in the innovation Matrix

- Robotics for disinfection
- Robotics for communications
- Systems for supporting physical distancing of incoming patients and medical investigators
- Remotely operated hospital equipment (ICU beds, patient turning mechanisms)
- Nanotechnology coatings
- Hematology and computer vision
- Bioinformatics and computational drug discovery – drug simulations

3.11. Inventive Developments in the Services Sector of Sri Lanka

Consider the following innovative developments that materialized with direct opportunities for the service sector. Some of the demonstrated developments have both manufacturing and service sector implications.

- Robotics for patient interfacing with medical personnel through vision and voice applications
- Mobile tracing and tracking applications
- Distant virtual communications and meetings – learning spaces
- Drone based observations and service deliveries
- Remote sensing applications
- Big data applications
- RT-PCR techniques and antibody testing
- Medical sampling and transportation
- e-Auctions
- Digitalization of services
- Flexi working

4. CONCLUSION

Quite a few lessons could be derived from the observations over the period. With a year gone and two additional Covid-19 waves later, these lessons are quite important. Inventions covering multiple areas have emerged and all with commercial potential. While many are locally relevant there had been a few inventions with much broader market potential. As it was mentioned in the beginning Inventors had their share of issues in getting to the next level. A greater majority of the inventors unfortunately performed with the mindset of that their development is a world's first. They were not quite aware of the process of understanding prior art. There was the widely held belief with media unfortunately contributing heavily as well, that the inventor almost always deserves a patent the moment of declaration. This is a significant gap in the process of innovation in Sri Lanka and was displayed in this instance too. Media should understand the process of innovation in their communications or otherwise, we would be forever doing a great disservice to the inventors as well as to the society.

Inventors did find difficulties in realizing prototypes. With state money to be disbursed, SLIC was not able to use all available avenues to support inventors. Most of the prototyping work had to be carried out by the NERDC and the lockdown did not help. The procurement process is not the most useful when it comes to supporting creativity. The delays caused many difficulties to the inventors. This deficiency of the procurement system in existence in the state sector is not at all helpful to push inventions. There is no understanding of the fact that all inventions definitely would not result in commercial enterprises but almost all of them do need support in moving forward. Unless this process is taken care of, the ecosystem for supporting inventors and intellectual property development is unlikely to materialize.

Lack of standardized testing facilities was a significant problem. As an example, masks had to be tested and suitably approved. There was no mechanism available to study viruses in the country as the required biological safety standards were not available in the available research settings. Covid-19 was all about a virus and bacterial testing is not exactly relevant. Most of the masks were trialed with bacterial testing which is not exactly what is required. Testing facilities proved to be a significant problem to many an inventor and this need has to be realized.

The service sector inventions did move into implementation and are seen to have been sustained. The education sector developments are now evolving to accept hybrid approaches and flip classroom systems. The deficiency is

that poor service level quality prevails across the country. This needs to be consciously addressed.

Sri Lanka has faced a novel virus during the first wave with some inventive courage. Many an opportunity that did emerge during the period has not been successfully converted, leaving behind some important lessons to take.

REFERENCES

Central Bank of Sri Lanka. (2020). Annual Report, https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/annual_report/2020/en/5_Chapter_01.pdf

OECD. (2021). COVID-19 Innovation in low and middle income countries: Lessons for Development Co-operation, OECD policy Papers (April) 2021, No.39.

Nsikak ,U. Benson. David. E., Bassey, Thavamani. Palanisami.Benson., et al. (2021). COVID pollution: impact of COVID-19 pandemic on global plastic waste footprint, (https://reader.elsevier.com/reader/sd/pii/S2405844021004485?token=7BB73F8A52DC02BACFA257756C140F7BD325364D5A7E5FFAD1D09ECB37518A5F0440B1DBA6DD3C368AF1F8231D2F6014&originRegion=eu-west-1&originCreation=20210610152739)

Matthew, H., Yasser, Bhatti, J. B., Sharma, D. (2020). Fast and frugal innovations in response to the COVID-19 pandemic, *Nature Medicine*, 26, 814–817.https://www.nature.com/articles/s41591-020-0889-1

Martina, M., Susann, R., Fazilah, S., Allaudin. (2020). Public Health innovations for Covid 19, ADB Sustainable Development Working Paper Series; No.70.

BIBLIOGRAPHY

https://www.oecd.org/coronavirus/policy-responses/innovation-development-and-covid-19-challenges-opportunities-and-ways-forward-0c976158/

http://slic.gov.lk/itnsliccovid/

https://covid19innovationhub.org/categories.

https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public,

http://www.ce.pdn.ac.lk/2020/05/07/innovative-engineering-in-the-battle-against-covid-19/

http://www.ce.pdn.ac.lk/2021/06/02/third-year-undergraudate-in-the-award-winning-team-for-work-on-cloud-atlas-an-innovative-project-to-build-biodegradable-sanitary-products/

http://eng.pdn.ac.lk/news/covid19-robot.pdf

https://www.pdn.ac.lk/news/news.php?id=presentation-of-the-respirone-nano-av-99-face-mask-and-the-novel-low-cost-covid-19-detection-kit-at-the-cabinet-meeting

https://www.kdu.ac.lk/general-sir-john-kotelawala-defence-university-invents-a-number-of-products-useful-in-combating-covid-19-pandemic/

https://www.eurekalert.org/pub_releases/2020-06/nuos-nrt062820.php

https://www.ft.lk/business/CILT-launches-ideathon-to-tackle-supply-chain-challenges-faced-during-COVID-19/34-699122)

http://www.colombopage.com/archive_20A/Jan29_1580314685CH.php.

https://www.businessnews.lk/blog/2020/04/02/low-cost-medical-ventilator-manufactured-by-vega-innovations-to-support-covid-19-outbreak/

https://www.sjp.ac.lk/technology/japura-technology-student-ashan-invents-ventilator-treat-covid-19-patients/

http://www.medical.sjp.ac.lk/index.php/news-141

https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/annual_report/2020/en/6_Chapter_02.pdf

https://roar.media/english/life/in-the-know/sri-lanka-tea-auction-digital

https://economynext.com/sri-lanka-coconut-auctions-go-online-69908/

http://www.xinhuanet.com/english/2020-05/22/c_139079934.htm

http://www.colombopage.com/archive_20A/Jan29_1580314685CH.php

https://www.prnewswire.com/news-releases/global-ventilator-market-analysis-and-forecast-2021-2030-market-to-reach-3-110-million-by-the-end-of-2020-due-to-covid-19-pandemic-301191139.html

https://www.oecd-ilibrary.org/sites/75f79015-en/1/3/1/index.html?itemId=/content/publication/75f79015-en&_csp_=408df1625a0e57eb10b6e65749223cd8&itemIGO=oecd&itemContentType=book

https://www.ft.lk/ajith-de-alwis/Inventions-coming-and-going-When-the-dust-settles-what-may-we-have/4-701136).

https://www.nature.com/articles/s41591-020-0889-1/tables/1

https://www.investindia.gov.in/siru/helping-india-breathe-ventilator-manufacturing-during-covid-19

https://www.facebook.com/pg/EfacUOR/photos/?tab=album&album_id=10157084999527967&__tn__=-UC-R

https://ideadrop.co/innovation-management/different-types-of-innovation/

https://www.ft.lk/ajith-de-alwis/Coronomics-Plan-your-eggs-and-the-basket/33-695109

Development of novel therapeutics for COVID-19

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ABSTRACT

Angiotensin converting enzyme 2 (ACE2) is the driving force of the protective arm of the renin angiotensin system (RAS). ACE2 plays an unequivocal role in counter-balancing the deleterious effects of the classical RAS comprising ACE. A protective role for ACE2 in antagonising tissue injury and fibrosis has been well characterised in mouse models of cardiac, pulmonary and liver diseases. Despite its highly protective role in disease pathogenesis including in lung epithelial injury, ACE2 has been hijacked by severe acute respiratory syndrome-coronavirus (SARS-CoV) and SARS-CoV-2 to gain entry to alveolar epithelial cells, causing severe respiratory disease in humans. Often SARS-CoV-2 infection causing COVID-19 becomes life-threatening in elderly or people with other medical conditions due to highly virulent and contagious nature of SARS-CoV-2 compared with SARS-CoV. Given an unprecedented number of COVID-19 patients that have been affected globally, there is an urgent need to discover therapeutics targeting the interaction between the receptor binding domain (RBD) of the viral spike protein and the receptor, ACE2. Development and/or identification of already existing drugs used for other medical conditions to treat COVID-19 patients is vital at this stage since long-term efficacy of the vaccines that have been developed for COVID-19 are not yet known. Thus, this paper discusses about the role of ACE2 in recognising and binding of SARS-CoV-2 and provides novel therapeutic interventional strategies to prevent SARS-CoV-2 infection.

Key words: COVID-19, SARS-CoV-2, ACE2, Viraemia, Lung infection, Novel therapeutics, Spike protein

1. INTRODUCTION

Emerging in December in 2019, in Wuhan, China, the novel coronavirus 'severe acute respiratory syndrome-coronavirus-2' (SARS-CoV-2), has rapidly spread across 191 countries with over 108 million positive cases and 2 million and 399,793 deaths by 15th February 2021 (Johns Hopkins CR Centre, 2020). This novel disease was recognized as a pandemic by the World Health Organization

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(WHO), and continues to cause an enormous global health, social and economic impacts. Coronavirus is common and it makes up to 30% of common colds (Mesel-Lemoine et al., 2012). However, this is the third member of the coronavirus family to have caused a pandemic since the turn of this century (Pitlik, 2020). The first coronavirus that crossed this barrier and infected humans in the year 2002 was SARS-CoV which was identified in Guangdong province of Southern China, spreading across 26 countries with more than 8000 infections and 774 deaths (WHO, 2004). The second coronavirus, MERS-CoV (Middle East Respiratory Syndrome Coronavirus), which emerged in 2012 in Saudi Arabia has spread across 27 countries with 2494 infections and 858 deaths (WHO, 2019). It is thought that all these coronaviruses are closely related and came from a common origin in bats (Andersen et al., 2020). However, in contrast with the two other members of the family to have crossed the species barrier and caused a pandemic, SARS-CoV-2, which causes coronavirus disease-2019 (COVID-19), is highly virulent and contagious (Zhu et al., 2020). Despite its devastating global impact on human health and socioeconomic endpoints, a cure for this highly lethal virus has not been established. Therefore, there is a major need to develop novel therapeutics for the prevention and treatment of COVID-19.

2. PATHOGENESIS OF COVID-19

2.1. SARS-CoV-2

SARS-CoV-2 is a single-stranded RNA virus containing ~30 kb genome that consists of up to 14 open reading frames (ORFs) flanked by 5` and 3` untranslated regions (UTRs) (F. Wu et al., 2020). The vital structural proteins of the viral envelope are mainly composed of highly glycosylated spike (S) protein, membrane/matrix protein (M) and envelope protein (E) which are embedded in a lipid bilayer (Wu et al., 2020). Whilst these structural proteins together with nucleocapsid (N) protein are important for virus assembly during viral replication, the subunit proteins of the S protein which exit as a trimeric prefusion state play the leading role in receptor recognition, binding and entry into host cell. Thus, receptor binding domain (RBD) of the subunit 1 (S1) protein binds to the receptor, ACE2, leading to destabilization of the prefusion trimer which results in the cleavage of S1 subunit by host proteases including transmembrane protease serine 2 (TMPRSS2) (Hoffmann et al., 2020). This exposes the S2 subunit containing a fusion peptide sequence which undergoes a conformational change to acquire a stable fusion-able state, leading to host cell membrane fusion and viral entry (Walls et al., 2017; Wrapp et al., 2020).

2.2. SARS-COV-2 cellular receptors

It has been reported that there are multiple receptors involved in recognising SARS-CoV-2. This includes cell membrane proteins angiotensin converting enzyme 2 (ACE2), basigin (CD147) and neurophilin-1. It is possible that basigin may serve as either a co-receptor or it may be of importance in COVID-19 disease pathogenesis through virus dependent functional activation of associated pathways (Faghihi, 2020; Hamming et al., 2004; Helal et al., 2020; Liu et al., 2020). On the other hand, neurophilin-1 which has been shown to bind SARS-CoV-2 in the neuronal system may be important in neuron-specific infection by the virus (Daly et al., 2020). However, in comparison with basigin and neurophilin-1, there is strong evidence to suggest that ACE2 is the leading candidate molecule that directly binds to the SARS-CoV-2 (Li et al., 2003; Turner et al., 2004).

Angiotensin converting enzyme 2 which was discovered in the year 2000 (Donoghue et al., 2000; Tipnis et al., 2000) is a crucial enzyme in the protective arm of the renin angiotensin system (RAS). The RAS is a well characterised essential hormone system with pivotal roles in vascular biology, blood pressure regulation, the nervous system, electrolyte homeostasis, tissue injury, neoplasia and lipid homeostasis (Afsar et al., 2020; Grace et al., 2012; Herath et al., 2007; Putnam et al., 2012). It is now well accepted that the protective RAS has been evolved to counter-regulate the deleterious effects of the classical RAS which consists of the profibrotic and vasoconstrictor peptide angiotensin II working through its G protein-

coupled receptor (GPCR) angiotensin II type 1 receptor (AT1R) (Figure 1). Whilst the effects of the classical RAS are elicited via the activation of the AT1R, ACE2 of the protective RAS elicits its effects by activating distinct GPCRs, Mas receptor and Mas-related G protein-coupled receptor type D (MrgD) (Gunarathne et al., 2019; Paz Ocaranza et al., 2020; Santos et al., 2003; Tetzner et al., 2016).

The effects of the renin angiotensin system (RAS) are determined by the balance between its classical arm and the protective counter-regulatory arm. Classical arm consists angiotensin converting enzyme (ACE), angiotensin II, angiotensin II type 1 receptor (AT1R), which mediate vasoconstriction, cell proliferation and proinflammatory and profibrogenic pathways. The protective counter-regulatory arm consists angiotensin converting enzyme 2 (ACE2), angiotensin (1-7) and the Mas receptor, directly opposing the deleterious effects of the classical RAS.

Over decades of widespread interest in the RAS has resulted in the development and availability of effective pharmacotherapies which target hypertension, cardiovascular and liver disease (Gheblawi et al., 2020; Grace et al., 2012; Mak et al., 2015; Rajapaksha et al., 2019).

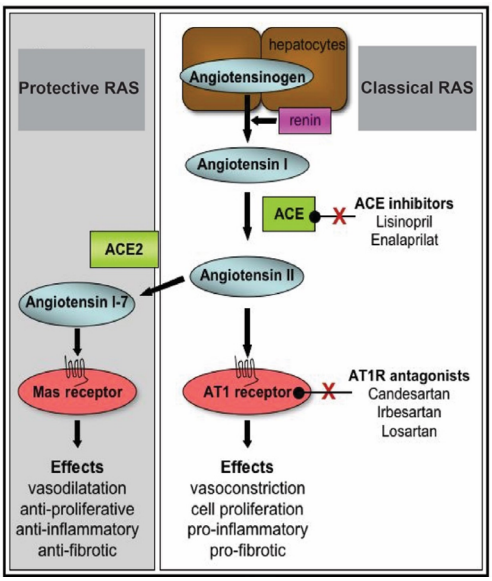

Figure 1. Overview of the renin angiotensin system

Therapeutics that act on the RAS including the angiotensin converting enzyme inhibitors and angiotensin receptor blockers (ARBs) are commonly used in current medial practice. Additional interest in the RAS has been driven by a recognition of the essential roles of this hormone system in tissue injury including pathologies as diverse as the remodelling of cardiac tissue after myocardial infarction, the development of the vasculature in malignancy and progression of tissue fibrosis such as liver fibrosis which can result in cirrhosis (Gheblawi et al., 2020; Warner et al., 2007). With discovery of ACE2, it is now recognised that this enzyme determines the balance between the classical and protective RAS (Santos et al., 2018; Warner et al., 2007). Nevertheless, liver-specific over-expression of ACE2 in mice with liver fibrosis has proved to be highly effective in antagonising liver injury and fibrosis progression and has been suggested to be a potential therapy for liver disease (Mak et al., 2015; Rajapaksha et al., 2019). However, ACE2 has received a great deal of interest as it is the viral entry receptor for the coronaviruses that cause severe acute respiratory syndrome (SARS) (Li et al., 2003; Turner et al., 2004). Thus, despite its highly protective role in disease pathogenesis, ACE2 by serving as a cellular receptor for highly infectious and lethal SARS-CoV-2 contributes to COVID-19, a severe respiratory disease in humans (Hoffmann et al., 2020).

2.3. ACE2 binding of SARS-COV-2

Since viral S protein of both SARS-CoV-2 and SARS-CoV dictates the host cell infection by binding to cell surface receptor, ACE2, which is expressed at relatively high level in lung alveolar epithelial cells (Hamming et al., 2004), the amino acid sequence of the S protein is key to develop drugs and vaccine. Whilst the S subunits from both SARS-CoV-2 and SARS-CoV share a high degree of structural similarity, the binding affinity of the S1 subunit of SARS-CoV-2 to ACE2 is ~6- to 22-fold higher compared to that of SARS-CoV S1 subunit (Lan et al., 2020; Wrapp et al., 2020). The difference between the affinities of the two related viruses may be explained by the observation that although the N-terminal

amino acid residues (SARS-CoV-2$^{331-429}$/ SARS-CoV$^{318-416}$) of the RBD is relatively well conserved, the C-terminal amino acid residues (SARS-CoV-2$^{430-527}$ / SARS-CoV$^{417-513}$) containing the residues of the receptor binding motif (RBM) that interact with ACE2 is more variable (Jaimes et al., 2020). In support of the sequence differences at the C-terminal residues of the RBD of S1 subunit that likely influences the binding affinities, atomic details of binding interface studies provide evidence that natural substitution of key amino acid residues of SARS-CoV-2 RBM led to higher affinity for ACE2 binding with relatively higher Van der Waals bonds than SARS-CoV (Wang et al., 2020). A stronger interaction between ACE2 and the RBM of SARS-CoV-2 as compared with SARS-CoV is further reflected by findings of structure-guided sequence alignment studies which showed that glutamine residue at 493 (Gln493) of the SARS-CoV-2 RBM not only interacts with 3 amino acid residues of ACE2 (Lys31, His34 and Glu35) which are considered as virus binding hotspots (Li, 2008; Wu et al., 2012) but it also forms a hydrogen bond with Glu35 whereas the comparable residue of the SARS-CoV (Asn479) interacts only with His34 of ACE2 (Lan et al., 2020). This concept was further strengthened by studies in which the crystal structure of the RBD of SARS-CoV-2 in complex with ACE2 showed the formation of a hydrogen bond not only between Gln493 of SARS-CoV-2 RBM and Glu35 of ACE2 but also with Lys31 of ACE2 (Shang et al., 2020). A detailed characterization of the structure of the interface between the S1 RBM of SARS-CoV-2

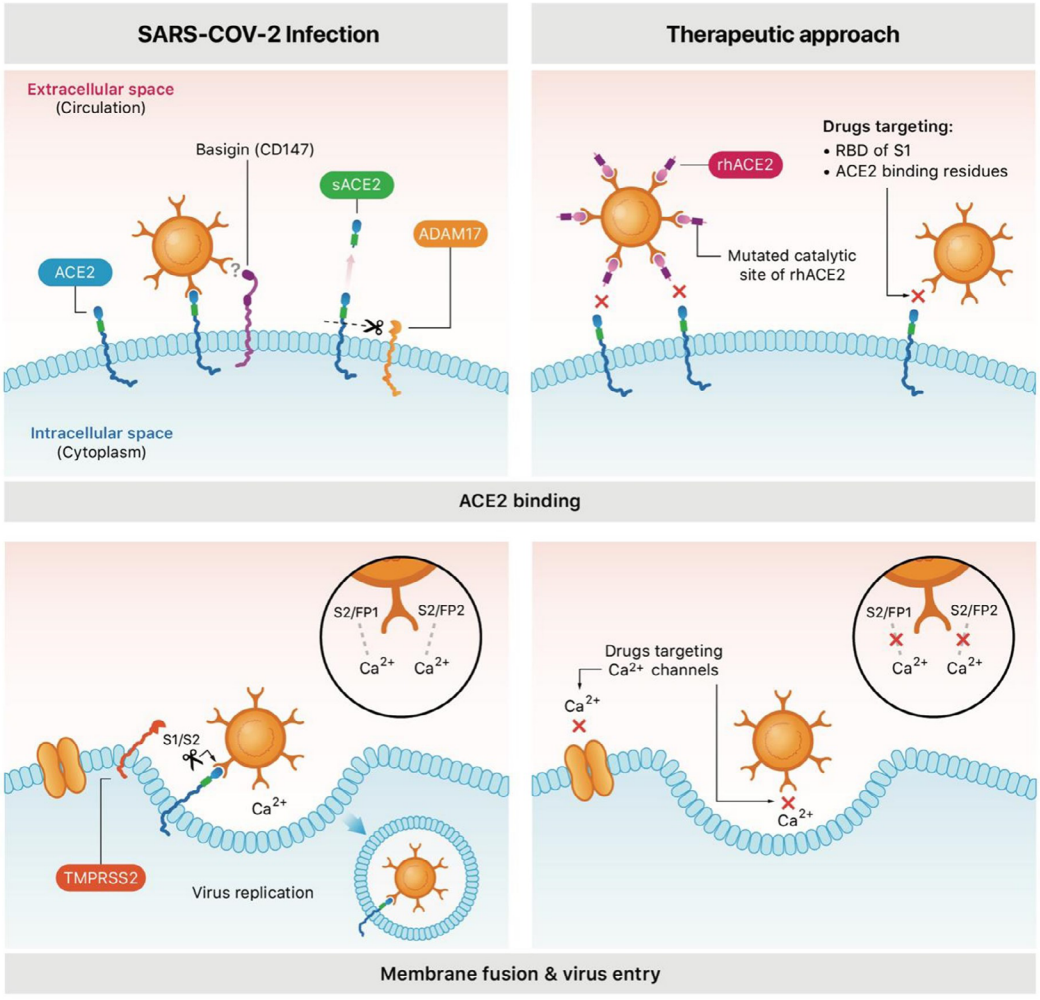

Figure 2. Role of ACE2 in SARS-CoV-2 infection and therapies targeting receptor binding and membrane fusion

and ACE2 residues provides numerous avenues to develop promising therapeutic strategies which may include *insilico*-screening of small molecule drugs targeting the interface between the virus and the receptor.

Left: Spike (S) protein of SARS-CoV-2 (S1 subunit) binds to cellular ACE2 receptor (top), followed by host cell membrane fusion using fusion peptide (FP) of S2 subunit (bottom), leading to endocytosis of the virus and loss of cell surface ACE2. Right: Treatment with recombinant human angiotensin converting enzyme 2 (rhACE2) is expected to mop up SARS-CoV-2 in the circulation by competing with cellular ACE2 for binding to S1 protein (top). Drugs that can be used to target the interface between the ACE2 and the receptor binding domain (RBD) of S1 protein to prevent viral entry to host cell (top). Ion channel inhibitors can be adopted to deplete intracellular and extracellular Ca2+ concentration to prevent the host cell membrane fusion of FP of S2 protein (bottom). Abbreviations: sACE2, cellular ACE2 is shed into the circulation by the activity of metalloproteinase ADAM17; TMPRSS2, transmembrane protease serine 2 cleaves S1 subunit, leaving S2 subunit for host cell membrane fusion.

2.4. Host-cell membrane fusion of SARS-COV-2

Whilst the observed differences between the SARS-CoV and SARS-CoV-2 in binding to ACE2 receptor is relatively well characterized, host cell membrane fusion of S2 subunit shows some striking similarities between the SARS-CoV and SARS-CoV-2 (Millet & Whittaker, 2018; Straus et al., 2020). Proteolytic cleavages at the S1/S2 subunits and S2' site upstream of fusion peptide domains by host proteases such as TMPRSS2 expose two fusion peptide sequences immediately downstream of S2` site, allowing the insertion of the fusion sequences into the host cell membrane (Cannalire et al., 2020; Gierer et al., 2013; Hoffmann et al., 2020; Shirato et al., 2013).

In this membrane fusion process, it has been proposed that Ca^{2+} ions play a dominant role in the ordering of FP domains of most enveloped viruses, thus facilitating the merge of FP domains with host cell membrane (Dube et al., 2014; Lai et al., 2017; Millet & Whittaker, 2018; Nathan et al., 2020). As in host cell membrane fusion of Rubella virus, a strong Ca^{2+} dependency of SARS-CoV FPs has been suggested to be prerequisite events for membrane-ordering effects of the two FP domains with lipid bilayer (Dube et al., 2016; Dube et al., 2014; Lai et al., 2017; Millet & Whittaker, 2018). The requirement for two Ca^{2+} ions to make salt bridges by binding to conserved negatively charged hydrophobic residues in the FPs such as aspartic and glutamic acid residues, has been suggested to promote greater membrane ordering and host cell membrane fusion (Millet & Whittaker, 2018; Nathan et al., 2020). Straus and colleagues in their studies using mutant FP residues and electron spin resonance spectroscopy demonstrated that negatively charged E891 (Glu891) of MERS-CoV FP domain 1 is a critical residue for Ca^{2+} binding, membrane ordering and fusion (Nathan et al., 2020). They further provided evidence using pseudo viral particles decorated with MERS-CoV S subunit protein that the infectivity of Huh-7 cells by pseudo particles was attenuated by depletion of intracellular or extracellular Ca^{2+} concentration whereas intracellular Ca^{2+} depletion completely abrogates SARS-CoV infectivity (Lai et al., 2017). This difference in the ability of membrane fusion and infectivity of the two viruses is supported by isothermal titration calorimetry studies, which in agreement with previous reports (Lai et al., 2017), suggested that unlike MERS-CoV FP which requires one Ca^{2+} ion for membrane ordering, SARS-CoV binds two Ca^{2+} ions, forming a salt bridge with each of the two FP domains (Lai et al., 2017; Nathan et al., 2020). These findings reinforce the importance of targeting Ca^{2+} channels for the design and development of new drugs or repurposing drugs currently in clinical practice to treat patients with COVID-19. Nevertheless, these drugs help prevent the virus from attacking other vital organs in those patients who are in early stages of disease progression.

3. NOVEL THERAPEUTICS FOR COVID-19

3.1. Patients with COVID-19

Among diverse physiological roles of ACE2 in many tissues and vascular beds, the protective role of ACE2 against lung injury is paramount since this multifunctional protein lies in the interface between exterior air and alveolar cells (Imai et al., 2005; Samavati & Uhal, 2020). Intriguingly, despite its protective role in the lung, ACE2 has been hijacked by SARS-CoV and SARS-CoV-2 to gain entry to alveolar epithelia cells, causing severe respiratory disease in humans (Hoffmann et al., 2020; Kuba et al., 2005; Lan et al., 2020; Li et al., 2005; Li et al., 2003). What is remarkable in this process is that not only the virus gain entry into alveolar epithelial cells, but at the same, it destroys the protective machinery driven by ACE2, thus causing dual negative impact in the lungs.

It is likely that the driving force in many gravely ill patients' secondary complications following the appearance of respiratory symptoms is a disastrous overreaction of the immune system known as a 'cytokine storm' where immune cells start to attack healthy tissues (Moore & June, 2020). This phenomenon may lead to blood vessels leak, dropping blood pressure, clot formation, possibly leading to catastrophic multiorgan failure such as stroke, heart and kidney failure (Huang et al., 2020; Klok et al., 2020; Shi et al., 2020; Zou et al., 2020). Whist the lung is the primary battle zone disrupting healthy oxygen transfer with subsequent damage to lung vasculature triggered by cytokine storm, it is highly likely that lung alveolar epithelial cells release a large fraction of the virus into the circulation, leading to viral-mediated direct effects on other major organs such as the kidneys, heart, brain and intestines (Farcas et al., 2005). Indeed, autopsy of dead patients showed viral inclusion bodies and particles in the kidneys, and inflammatory cells and apoptotic bodies in the heart and small intestine, implying that the virus could directly invade other organs (Farkash et al., 2020; Lamers et al., 2020; Puelles et al., 2020; Varga et al., 2020; Zou et al., 2020). This is not surprising given that along with vascular endothelium across the body, these are the organs that highly express ACE2 receptor in both humans and rodents and thus potentially vulnerable to infection (Gembardt et al., 2005; Hamming et al., 2004; Zou et al., 2020). Moreover, the possibility that the virus can directly infect nerve cells, particularly neurons in the medulla oblongata of the brain stem that controls the functioning of the heart and the lungs, and the reported loss of sense of smell and taste in COVID-19 patients, suggests neurological damage and rapid deterioration of patients' condition (Iadecola et al., 2020; Lechien et al., 2020; Liu et al., 2020; Zou et al., 2020).

The strong body of evidence suggests that a significant percentage of COVID-19 patients are transferred to the intensive care unit (ICU) around median day 8 (day 5 to 14) from first admission to the hospital (Huang et al., 2020; Xu et al., 2020) and the median duration from admission to the ICU to death is 7 days (Yang et al., 2020). It could be argued that the latency period between hospitalisation and ICU admission may be enough for the virus to enter and destroy other vital organs including the kidney, heart, liver, gut and neuronal system. Therefore, it appears that secondary invasion of the virus targeting other major organs may be expected to cause catastrophic multiorgan failure (Klok et al., 2020; Shi et al., 2020; Zou et al., 2020).

3.2. COVID-19 in Sri Lanka

On the other hand, a close look at global spread of the SARS-CoV-2 reveals an interesting phenomenon (JHCR Centre, 2020). As of 15th February 2021, India and USA are countries that ranked in the top with ~8% and 8.3% positive cases relative to its population compared to the UK (~6%). Despite its high prevalence in India, death rate of positive cases is low (~1.4%) compared to the USA (1.8%) and the UK (2.9%). What is phenomenal is however that in Sri Lanka positive cases (~0.4%) and death rate (~0.5%) are surprisingly low. This raises an interesting question as to how infection and death rate are reduced in

Sri Lanka? Likely explanations are that in Asian population (1) genetic make-up that triggers an effective surveillance on pathogens including SARS-CoV-2 appears superior; (2) the frequency of occurrence of mutated SARS-CoV-2 variants is low compared to Europe and USA where the variants can escape immune surveillance, resulting in increased number of positive cases and mortality rate, (3) BCG vaccination that triggers a trained immunity may provide a protection against non-specific pathogens such as SARS-CoV-2, and (4) high temperatures and humidity may restrict viral infection.

The genetic background in Asian population may be considered as a possible factor that determines a strong immune surveillance to reduce the lethality of the SARS-CoV-2 infection. Although the infectivity or the spread of the virus in Asian population and in particular in Sri Lanka is considerable, but relatively low compared to the Western world, what matters is the pathogenicity of such infection which determines the severity of illness and mortality in infected patients which is comparatively very low in Sri Lanka. Another possible factor for a low lethality of the virus may be the absence of the occurrence of mutated SARS-CoV-2 variants in Sri Lanka and this includes newer variants found in the UK, Italy and Brazil (Caccuri et al., 2020; Kirby, 2021; Paiva et al., 2020; Tang et al., 2020). Whilst it is yet to be confirmed, it is also possible that BCG vaccination which is performed in most Asian countries including Sri Lanka for tuberculosis may provide some protection against non-specific pathogens such as SARS-CoV-2 (Covian et al., 2020). This phenomenon is known as 'trained immunity' which is defined as an enhanced non-specific immune response to a secondary infection mediated by trained innate immune cells such as monocytes, macrophages and natural killer cells which is characterised as being independent of T and B cell responses (Kleinnijenhuis et al., 2015; Netea et al., 2011).

3.3. Therapeutic strategies for COVID-19

It is imperative that the development of an effective vaccine is key to combat COVID-19. There are many institutions and pharmaceutical companies that are racing to develop and deploy safe and effective vaccines for this highly contagious disease. At present, there are more than 50 COVID-19 vaccine trials around the world. Of which, Pfizer which uses nucleoside modified mRNA and AstraZeneca (Oxford) which uses a recombinant replication defective chimpanzee adenovirus expressing the SARS-CoV2 S surface glycoprotein were the first to make effective vaccines. These vaccines have proved to be effective in clinical trials and several countries have already begun the vaccination. However, it will require a close follow-up in vaccinated individuals for an extended period of time to re-evaluate the long-term effectiveness and safety of the particular vaccine. The crucial question however is that how long a specified vaccine will provide an effective immune protection. This is not surprising as newer variants of the SARS-CoV-2 are being discovered and it is unknown whether these mutated variants can escape the immune surveillance and antibodies produced following vaccination. However, a mutation(s) in the genomic region of the SARS-CoV-2 that contains non-structural genes responsible for virus replication and assembly within host cells such as those occurring in the ORF1ab region may not be expected to confer an advantage for the virus to escape antibodies in vaccinated individuals (Rouchka et al., 2020; Sun, 2020). However, if a mutation(s) occurs in the genomic region that encodes for amino acid residues of the S protein could pose a threat as the current vaccines are being developed to target viral S proteins. This raises a question of whether individuals may require seasonal vaccination against COVID-19 as new variants are found from time to time, a much more similar scenario to that of annual FLU vaccination program. The development of a universal vaccine against COVID-19, which could potentially change the face of a possible seasonal pandemic COVID-19 prevention, is a huge technical challenge. In the backdrop of this scenario as well as future inevitable

coronavirus pandemics due to the recurrent spill over of the virus into humans from their reservoir in bats, it is therefore paramount importance of developing novel therapeutics to treat COVID-19 patients.

Despite many clinical trials undertaken in COVID-19 patients worldwide, an effective treatment for this highly contagious disease is yet to be identified. In addition, there is no accepted *in vitro* model or animal model to screen approved drugs that could be repurposed to treat COVID-19 patients. In our search for novel drugs for COVID-19, it is imperative that potential drug candidates need to be selected by screening large databases of small molecules which will be expected to undergo a rigorous *in vitro* and/or *in vivo* testing for their effectiveness against SARS-CoV-2 infection. The *in vitro* model adopted by Monteil and colleagues used native SARS-CoV-2 on Vero-E6 cells, and organoids derived from human embryonic stem cells (kidney organoid) and induced pluripotent stem cells (capillary organoid) to investigate the effectiveness of recombinant proteins on infectivity of SARS-CoV-2 (Monteil et al., 2020). Whilst this model provides an ideal flatform to investigate the therapeutic potential of drug candidates, the use of native SARS-CoV-2 is apparently not possible in many laboratory settings. Therefore, a simple and robust in vitro-based platform utilising SARS-CoV-2 viral like particles (VLPs) will enable fast, reliable and rapid screening of existing as well as potential new therapeutics in a physical containment 2 (PC2) laboratory setting (Xu et al., 2020). In addition, the recurrent spill over of coronaviruses into humans from their reservoir in bats strongly suggests that future zoonotic transmission events are inevitable and supports the need for ongoing and robust methods of antiviral drug screening and development.

Repurposed drugs or novel drug candidates can be tested to block entry of SARS-CoV-2 to host cells, particularly in those patients who are in the early stage of disease progression such as those patients who only show respiratory illness. It is now clear that therapies targeting the SARS-CoV-2 infection can be implemented at three levels. This includes an early stage of prevention of the virus binding to cellular ACE2 receptor and host cell membrane fusion, and late stage of virus replication within the cell. However, as discussed above, strategies that target the prevention of ACE2 binding and host cell membrane fusion is of paramount importance since these approaches essentially eliminate the viral invasion of vital organs other than the lungs in infected patients. In fact, a combined treatment targeting both receptor binding and membrane fusion is expected to block a higher proportion of the virus from entering target cells. Combined treatments have been successfully adopted for viral diseases; for example, the hepatitis C virus is now being treated using a combined treatment with two antiviral drugs directed at viral replication (Falade-Nwulia et al., 2017).

3.4. Impact of loss of cellular ACE2

Whilst circulating RAS plays a pivotal role in blood pressure regulation and fluid homeostasis in normal physiology (Ferrario et al., 2005; Wu et al., 2018), it is now well recognized that the local tissue RAS plays a predominant role in disease pathogenesis in many organs including liver disease (Crackower et al., 2002; Mak et al., 2015; Rajapaksha et al., 2019; Yang & Xu, 2017). It has been argued that loss of cellular ACE2 due to the endocytosis associated with SARS-CoV-2 infection poses a great risk to patients with COVID-19 as the loss of ACE2 is expected to shift the balance between the two arms of the RAS towards the classical RAS, exacerbating the condition in which Ang II-driven cytokine release can be enhanced (Grace et al., 2012; Mak et al., 2015; Rajapaksha et al., 2019). Moreover, the loss of ACE2 also expected have adverse effects on RAS-independent functions of ACE2 such as the regulation of neutral amino acid transport in the gut epithelial cells (Hashimoto et al., 2012). The possible impact of tissue ACE2 loses in patients with COVID-19 including the impact on those COVID-19 patients who have secondary complications such as type 2 diabetes, heart and kidney diseases, and gut

dysbiosis has been reviewed recently (Gheblawi et al., 2020).

3.5. Recombinant ACE2

The first approach to inhibit the interaction between the host cell membrane ACE2 and the S1-RBM of SARS-CoV-2 can be accomplished by utilising recombinant human soluble ACE2 (rhsACE2). Thus, the approach adopted by Monteil and colleagues using parenterally administered rhsACE2 which competes with SARS-CoV-2 for binding to cellular ACE2 (Figure 2) has a therapeutic potential in patients with COVID-19 (Monteil et al., 2020). Direct translatability of rhsACE2 is highlighted by the finding that this form of ACE2 administered intravenously to healthy volunteers produced no adverse effects and well tolerated (Haschke et al., 2013) Supporting this, work from our laboratory reported that up to 6000-fold over-expression of cellular ACE2 in the liver of healthy mice had no adverse effect (Mak et al., 2015). Although rhsACE2 has been reported to reduce the cellular uptake of the SARS-CoV-2 by up to 5000 folds (Monteil et al., 2020), this has not been tested in *in vivo* model due to a lack of an appropriate *in vivo* model.

Approaches that utilise exogenously administered rhsACE2 may compromise blood pressure since circulating rhsACE2 is expected to breakdown potent vasoconstrictor peptide Ang II, likely causing systemic hypotension and renal failure (Ferreira & Raizada, 2008). The effect on blood pressure can be further impacted by the production of vasodilator peptide, Ang-(1-7), the product of Ang II breakdown (Grace et al., 2012; Mak et al., 2015; Rajapaksha et al., 2019). This potential problem on blood pressure can be circumvented by introducing mutations into the catalytic domain of rhsACE2 (Figure 2) (Guy et al., 2005; Turner et al., 2002). The canonical function of ACE2 is to function as a carboxypeptidase (Guy et al., 2003). On the basis of the ability of ACE2 to cleave biological peptides, a consensus sequence of Pro-X-Pro-hydrophobic has been derived as the target for the ACE2 catalytic activity (Guy et al., 2003). Furthermore, this catalytic activity has been narrowed down to a number of residues located within the catalytic domain of ACE2 (Guy et al., 2005). Particularly, Arg273 has been identified as a critical residue for substrate binding (Guy et al., 2005). Site-directed mutagenesis to replace the arginine with a glutamine residue (R273Q) that represents a positive to neutral change in the side chain while maintaining most of the hydrophobic surface area has demonstrated that the loss of positive charge on the side chain at residue 273 has a profound effect on the substrate binding (Guy et al., 2005). Furthermore, mutations on H345A/L and H505A/L also results in enzyme activity being dramatically reduced. Further investigations have revealed that His345 as the hydrogen bond donor/acceptor during the formation of the tetrahedral peptide intermediate (Guy et al., 2005). Thus, these residues of ACE2 are highly critical for the catalytic activity. Therefore, if the choice is to use rhsACE2 as a therapy in COVID-19 patients, it is important that these critical residues will need to be mutated to make rhsACE2 catalytically inactive to prevent an increased breakdown of circulating Ang II and subsequent effect on blood pressure (Ferreira & Raizada, 2008). Catalytically inactive rhsACE2 could compete with the host ACE2 for binding to the S1-RBM of SARS-CoV-2, thus preventing or reducing the 'effective viral load' in the circulation that is available for host receptor engagement. Because rhsACE2 administration should be performed as an intravenous treatment, this therapy could only be applicable to those patients who are currently admitted to a hospital. Furthermore, since the treatment is a short-term treatment, the risk of developing anti-rhsACE2 antibodies is also minimum.

4. TARGETING ACE2 BINDING INTERFACE

Coronaviruses have been known to use membrane bound ACE2 as a point of entry to the host cell (Bourgonje et al., 2020). The arch shaped α-1 helix on the ACE2 peptidase domain (PD) mainly interacts with the RBM of the S1 protein while α-2 helix and the β3-4 loop of the ACE2 make limited contacts (Huang et al., 2020). The crystal structure of this

interaction (Huang et al., 2020) provides an excellent opportunity to inhibit the viral entry by inhibiting the ACE2-S1 interaction. Binding of the S1 RBM on ACE2 is mainly hinged on the arch shaped α-1 helix of the ACE2 (Huang et al., 2020). Therefore, the surface of the RBM interacts over a significant surface area on the ACE2. This provides two options for the inhibition of SARS-CoV-2 binding to the ACE2; (a) designing small molecule inhibitors that bind to the S1-RBM and inhibit the interaction with the ACE2 (Benítez-Cardoza & Vique-Sánchez, 2020; Hanson et al., 2020), and (b) use the ACE2 residues that interact with the S1-RBM as the target for the drug binding and inhibit the interaction with the SARS-CoV-2 (Figure 3).

The SARS-CoV-2 S1 receptor binding domain (RBD) interaction with the ACE2 is shown as a ribbon diagram using the crystal structure PDB:6m17 (Yan et al., 2020). The right panel shows the residues on ACE2 (Q24(Glu), H34(His), Y41(Tyr), Q42(Glu), M82(Met), K353(Lys), R357(Arg)) interacting with the residues on S1-RBM (K417(Lys), Y453(Tyr), Q474(Glu), F486(Phe), Q498(Glu), T500(Thr), N501(Asp)) (Yan et al., 2020).

Whilst repurposing the approved drugs provides fairly rapid solutions, *insilico* drug screening with molecular dynamics simulations could also be employed to screen and identify novel drug candidates that can be used to inhibit the receptor binding and/or the host cell membrane fusion of not only SARS-CoV-2 (Huang et al., 2020) but also of coronaviruses of future pandemics. Based on the co-crystal structure of the RBD and the ACE2, the S1-RBD forms a pocket around the residues R403(Arg), D405(Asp), Q409(Glu), K417(Lys), I418(Ile), L455(Leu), Y453(Tyr), Y495(Tyr), F497(Phe), N501(Asp) and Y505(Tyr). This pocket is about 17Å long and about 9Å in width and lined with hydrophobic residues. This could be utilised as a drug binding pocket and screen for molecules that bind to this region at a high affinity (Figure 3). Binding a molecule to this pocket could significantly reduce the interactions between the S1-RBD and the ACE2 resulting in lowering the affinity between the virus and the receptor.

Similarly, the same approach can be taken to screen for molecules binding to the ACE2 surface and prevent the RBD interaction with the host receptor. However, the RBD interacting surface of ACE2 does not appear to possess any druggable pockets. Therefore, screening for small molecules that could bind to the ACE2 surface to inhibit the interaction with RBD could be far-fetched. However, if

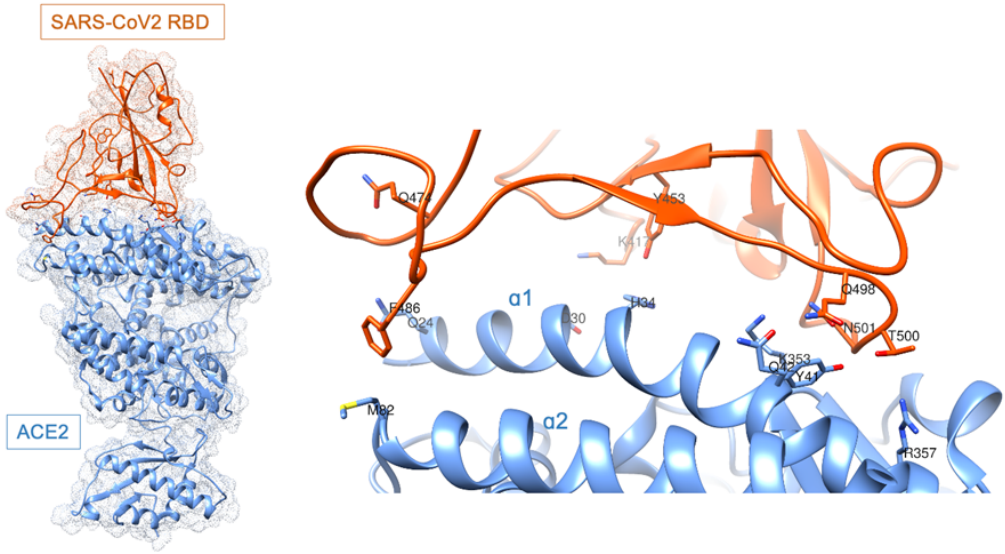

Figure 3. ACE2 interaction with the RBD of the SARS-CoV-2 spike protein

a peptide can be derived from ACE2 RBD interacting surface, this peptide could be used to inhibit the interaction between the ACE2 and S1-RBD. In situations where the protein surfaces do not facilitate small molecule inhibitors, peptide-based inhibitors have become an emerging technique. A recent review has provided a comprehensive review of peptide inhibitors and their application and draw backs (Wójcik & Berlicki, 2016). Given the ACE2 surface characteristics, developing a peptide inhibitor to mimic the RBD binding surface on ACE2 could be equally valuable as developing small molecule inhibitors that bind to the S1-RBD. Furthermore, a similar result could be obtained by using a peptide that binds to the RBD and interfere with the ACE2 binding. One of the disadvantages of using peptide-based inhibitors is their susceptibility to host proteases.

4.1. Targeting host-cell membrane fusion

As described above, Ca^{2+} has been shown to play an important role in the process of fusing SARS-CoV-2 with the host membrane. Viral membrane fusion is the process by which the virus envelop merge with the host cell membrane to deliver the viral genetic materials. SARS-CoV-2 virus membrane fusion occurs after ACE2 binding and once both viral membrane and the host membrane are proximal to each other. During the process of membrane fusion Ca^{2+} ions are believed to be used by the fusion peptides for orienting themselves on the host cell membrane. This provides a unique opportunity for inhibiting the process of virus genetic material delivery to the host cell by inhibiting the peptide orienting process. If a small molecule can be used to compete with the residues that binds Ca^{2+}, it would be possible to inhibit the peptide orientation. However, given the small size of the binding site it would be unwise to take such approach. Therefore, as an alternative if the amount of available Ca^{2+} for the virus can be depleted one should be able to achieve a similar effect.

Calcium transporters located on the cell surface act as regulators of the amount of Ca^{2+} available in the extracellular space. Therefore, if an inhibitor could be used to inhibit Ca^{2+} channels then the amount of Ca^{2+} available can be effectively regulated. Consequently, this would provide a control over the membrane fusion step. Currently there are number of Ca^{2+} channel blockers available that are used to treat patients with hypertension and heart arrhythmia. Thus, it would probably be the right time to revisit those drugs and repurpose them as a treatment for SARS-CoV-2 (Figure 2, Figure 3).

Whilst repurposing the approved drugs such as ion channel inhibitors provides fairly rapid solutions as in the identification of drug candidates to inhibit receptor binding, insilico drug screening can be effectively employed to identify such drugs that have the potential to inhibit host cell membrane fusion of the virus by depleting extracellular Ca^{2+} concentration. A number of open source and proprietary molecular docking software packages are available to be used in the process but Autodock (Morris et al., 2008) and Autodock Vina (Trott & Olson, 2010) has shown to be the most popular with most of the drug screening campaigns. This software is relying on the availability of docking ready compound databases. One of the most commonly used such database is the ZINC database (Irwin & Shoichet, 2005) that contains over 230 million purchasable small molecule compounds in ready-to-dock, 3D formats. Docking algorithms can provide an estimation of the binding affinity and based on the calculated value, top hits can be selected, and further validation could be performed with molecular dynamics simulations. Finally, those promising compounds can be tested in *in vitro* and *in vivo* studies.

5. CONCUSIONS

Since its discovery two decades ago, ACE2 has been the central focus of a large number of studies that investigated the protective role of this protein in many pathological conditions including cardiovascular, renal, lung and liver disease. Intriguingly, two of the coronavirus pandemics of this century, caused by SARS-CoV and SARS-CoV-2, has hijacked ACE2 to

gain entry into alveolar epithelial cells of the lungs, causing a devastating respiratory illness in humans. However, together with findings from early studies conducted since SARS-CoV pandemic in 2003, massive amount of data that generated in response to SARS-CoV-2 in 2020 made it possible to develop vaccines targeting the infection of SARS-CoV-2. Importantly, this knowledge can now be used to develop novel therapeutics that prevent either virus entry or its cellular replication machinery. This effort of developing drugs to target virus entry and/or replication is important for treating COVID-19 patients until such time a universal vaccine that is safe and effective becomes available for this disease and similar coronavirus pandemics in the future. However, it is likely that because of the technical challenges for developing a universal vaccine, the likelihood of ongoing SARS-CoV-2 pandemic with seasonal variants of the virus may require annual vaccination for COVID-19 and thus, there is a need for novel therapeutics to treat COVID-19 patients.

REFERENCES

Afsar, B., Afsar, R. E., Ertuglu, L. A., Kuwabara, M., Ortiz, A., Covic, A., & Kanbay, M. (2020). Renin-angiotensin system and cancer: Epidemiology, cell signaling, genetics and epigenetics. *Clin Transl Oncol*. doi:10.1007/s12094-020-02488-3.

Andersen, K. G., Rambaut, A., Lipkin, W. I., Holmes, E. C., & Garry, R. F. (2020). The proximal origin of sars-cov-2. *Nat Med, 26*(4), 450-452. doi:10.1038/s41591-020-0820-9.

Benítez-Cardoza, C. G., & Vique-Sánchez, J. L. (2020). Potential inhibitors of the interaction between ace2 and sars-cov-2 (rbd), to develop a drug. *Life Sci, 256*, 117970. doi:10.1016/j.lfs.2020.117970.

Bourgonje, A. R., Abdulle, A. E., Timens, W., Hillebrands, J. L., Navis, G. J., Gordijn, S. J., . . . van Goor, H. (2020). Angiotensin-converting enzyme 2 (ace2), sars-cov-2 and the pathophysiology of coronavirus disease 2019 (covid-19). *J Pathol, 251*(3), 228-248. doi:10.1002/path.5471.

Caccuri, F., Zani, A., Messali, S., Giovanetti, M., Bugatti, A., Campisi, G., . . . Caruso, A. (2020). A persistently replicating sars-cov-2 variant derived from an asymptomatic individual. *J Transl Med, 18*(1), 362. doi:10.1186/s12967-020-02535-1.

Cannalire, R., Stefanelli, I., Cerchia, C., Beccari, A. R., Pelliccia, S., & Summa, V. (2020). Sars-cov-2 entry inhibitors: Small molecules and peptides targeting virus or host cells. *Int J Mol Sci, 21*(16). doi:10.3390/ijms21165707.

Covian, C., Retamal-Diaz, A., Bueno, S. M., & Kalergis, A. M. (2020). Could bcg vaccination induce protective trained immunity for sars-cov-2? *Front Immunol, 11*, 970. doi:10.3389/fimmu.2020.00970.

Crackower, M. A., Sarao, R., Oudit, G. Y., Yagil, C., Kozieradzki, I., Scanga, S. E., . . . Penninger, J. M. (2002). Angiotensin-converting enzyme 2 is an essential regulator of heart function. *Nature, 417*(6891), 822-828.

Daly, J. L., Simonetti, B., Klein, K., Chen, K. E., Williamson, M. K., Anton-Plagaro, C., . . . Yamauchi, Y. (2020). Neuropilin-1 is a host factor for sars-cov-2 infection. *Science, 370*(6518), 861-865. doi:10.1126/science.abd3072.

Donoghue, M., Hsieh, F., Baronas, E., Godbout, K., Gosselin, M., Stagliano, N., . . . Acton, S. (2000). A novel angiotensin-converting enzyme-related carboxypeptidase (ace2) converts angiotensin i to angiotensin 1-9. *Circ Res, 87*(5), E1-9.

Dube, M., Etienne, L., Fels, M., & Kielian, M. (2016). Calcium-dependent rubella virus fusion occurs in early endosomes. *J Virol, 90*(14), 6303-6313. doi:10.1128/JVI.00634-16.

Dube, M., Rey, F. A., & Kielian, M. (2014). Rubella virus: First calcium-requiring viral fusion protein. *PLoS Pathog, 10*(12), e1004530. doi:10.1371/journal.ppat.1004530.

Faghihi, H. (2020). Cd147 as an alternative binding site for the spike protein on the surface of sars-cov-2. *Eur Rev Med Pharmacol Sci, 24*(23), 11992-11994. doi:10.26355/eurrev_202012_23985.

Falade-Nwulia, O., Suarez-Cuervo, C., Nelson, D. R., Fried, M. W., Segal, J. B., & Sulkowski, M. S. (2017). Oral direct-acting agent therapy for hepatitis c virus infection: A systematic review. *Ann Intern Med, 166*(9), 637-648. doi:10.7326/M16-2575.

Farcas, G. A., Poutanen, S. M., Mazzulli, T., Willey, B. M., Butany, J., Asa, S. L., . . . Kain, K. C. (2005). Fatal severe acute respiratory syndrome is associated with multiorgan involvement by coronavirus. *J Infect Dis, 191*(2), 193-197. doi:10.1086/426870.

Farkash, E. A., Wilson, A. M., & Jentzen, J. M. (2020). Ultrastructural evidence for direct renal infection with sars-cov-2. *J Am Soc Nephrol, 31*(8), 1683-1687. doi:10.1681/ASN.2020040432.

Ferrario, C. M., Trask, A. J., & Jessup, J. A. (2005). Advances in biochemical and functional roles of angiotensin-converting enzyme 2 and angiotensin-(1-7) in regulation of cardiovascular function. *Am J Physiol Heart Circ Physiol, 289*(6), H2281-2290.

Ferreira, A. J., & Raizada, M. K. (2008). Are we poised to target ace2 for the next generation of antihypertensives? *J Mol Med (Berl), 86*(6), 685-690. doi:10.1007/s00109-008-0339-x.

Gembardt, F., Sterner-Kock, A., Imboden, H., Spalteholz, M., Reibitz, F., Schultheiss, H. P., . . . Walther, T. (2005). Organ-specific distribution of ace2 mrna and correlating peptidase activity in rodents. *Peptides, 26*(7), 1270-1277.

Gheblawi, M., Wang, K., Viveiros, A., Nguyen, Q., Zhong, J. C., Turner, A. J., . . . Oudit, G. Y. (2020). Angiotensin-converting enzyme 2: Sars-cov-2 receptor and regulator of the renin-angiotensin system: Celebrating the 20th anniversary of the discovery of ace2. *Circ Res, 126*(10), 1456-1474. doi:10.1161/CIRCRESAHA.120.317015.

Gierer, S., Bertram, S., Kaup, F., Wrensch, F., Heurich, A., Kramer-Kuhl, A., . . . Pohlmann, S. (2013). The spike protein of the emerging betacoronavirus emc uses a novel coronavirus receptor for entry, can be activated by tmprss2, and is targeted by neutralizing antibodies. *J Virol, 87*(10), 5502-5511. doi:10.1128/JVI.00128-13.

Grace, J. A., Herath, C. B., Mak, K. Y., Burrell, L. M., & Angus, P. W. (2012). Update on new aspects of the renin-angiotensin system in liver disease: Clinical implications and new therapeutic options. *Clin Sci (Lond), 123*(4), 225-239. doi:10.1042/CS20120030.

Gunarathne, L. S., Angus, P. W., & Herath, C. B. (2019). Blockade of mas receptor or mas-related g-protein coupled receptor type d reduces portal pressure in cirrhotic but not in non-cirrhotic portal hypertensive rats. *Front Physiol, 10*, 1169. doi:10.3389/fphys.2019.01169.

Guy, J. L., Jackson, R. M., Acharya, K. R., Sturrock, E. D., Hooper, N. M., & Turner, A. J. (2003). Angiotensin-converting enzyme-2 (ace2): Comparative modeling of the active site, specificity requirements, and chloride dependence. *Biochemistry, 42*(45), 13185-13192. doi:10.1021/bi035268s.

Guy, J. L., Jackson, R. M., Jensen, H. A., Hooper, N. M., & Turner, A. J. (2005). Identification of critical active-site residues in angiotensin-converting enzyme-2 (ace2) by site-directed mutagenesis. *Febs j, 272*(14), 3512-3520. doi:10.1111/j.1742-4658.2005.04756.x.

Hamming, I., Timens, W., Bulthuis, M. L., Lely, A. T., Navis, G., & van Goor, H. (2004). Tissue distribution of ace2 protein, the functional receptor for sars coronavirus. A first step in understanding sars pathogenesis. *J Pathol, 203*(2), 631-637. doi:10.1002/path.1570.

Hanson, Q. M., Wilson, K. M., Shen, M., Itkin, Z., Eastman, R. T., Shinn, P., & Hall, M. D. (2020). Targeting ace2-rbd interaction as a platform for covid19 therapeutics: Development and drug repurposing screen of an alphalisa proximity assay. *bioRxiv*. doi:10.1101/2020.06.16.154708.

Haschke, M., Schuster, M., Poglitsch, M., Loibner, H., Salzberg, M., Bruggisser, M., . . . Krahenbuhl, S. (2013). Pharmacokinetics and pharmacodynamics of recombinant human angiotensin-converting enzyme 2 in healthy human subjects. *Clin Pharmacokinet, 52*(9), 783-792. doi:10.1007/s40262-013-0072-7.

Hashimoto, T., Perlot, T., Rehman, A., Trichereau, J., Ishiguro, H., Paolino, M., . . . Penninger, J. M. (2012). Ace2 links amino acid malnutrition to microbial ecology and intestinal inflammation. *Nature, 487*(7408), 477-481. doi:10.1038/nature11228.

Helal, M. A., Shouman, S., Abdelwaly, A., Elmehrath, A. O., Essawy, M., Sayed, S. M., . . . El-Badri, N. (2020). Molecular basis of the potential interaction of sars-cov-2 spike protein to cd147 in covid-19 associated-lymphopenia. *J Biomol Struct Dyn*, 1-11. doi:10.1080/07391102.2020.1822208.

Herath, C. B., Warner, F. J., Lubel, J. S., Dean, R. G., Jia, Z., Lew, R. A., . . . Angus, P. W. (2007). Upregulation of hepatic angiotensin-converting enzyme 2 (ace2) and angiotensin-(1-7) levels in experimental biliary fibrosis. *J Hepatol, 47*(3), 387-395. doi:10.1016/j.jhep.2007.03.008.

Hoffmann, M., Kleine-Weber, H., Schroeder, S., Kruger, N., Herrler, T., Erichsen, S., . . . Pohlmann, S. (2020). Sars-cov-2 cell entry depends on ace2 and tmprss2 and is blocked by a clinically proven protease inhibitor. *Cell, 181*(2), 271-280 e278. doi:10.1016/j.cell.2020.02.052.

Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., . . . Cao, B. (2020). Clinical features of patients infected with 2019 novel coronavirus in wuhan, china. *Lancet, 395*(10223), 497-506. doi:10.1016/S0140-6736(20)30183-5.

Huang, Y., Yang, C., Xu, X. F., Xu, W., & Liu, S. W. (2020). Structural and functional properties of sars-cov-2 spike protein: Potential antivirus drug development for covid-19. *Acta Pharmacol Sin, 41*(9), 1141-1149. doi:10.1038/s41401-020-0485-4.

Iadecola, C., Anrather, J., & Kamel, H. (2020). Effects of covid-19 on the nervous system. *Cell*. doi:10.1016/j.cell.2020.08.028.

Imai, Y., Kuba, K., Rao, S., Huan, Y., Guo, F., Guan, B., . . . Penninger, J. M. (2005). Angiotensin-converting enzyme 2 protects from severe acute lung failure. *Nature, 436*(7047), 112-116. doi:10.1038/nature03712.

Irwin, J. J., & Shoichet, B. K. (2005). Zinc--a free database of commercially available compounds for virtual screening. *J Chem Inf Model, 45*(1), 177-182. doi:10.1021/ci049714+.

Jaimes, J. A., Andre, N. M., Chappie, J. S., Millet, J. K., & Whittaker, G. R. (2020). Phylogenetic analysis and structural modeling of sars-cov-2 spike protein reveals an evolutionary distinct and proteolytically sensitive activation loop. *J Mol Biol, 432*(10), 3309-3325. doi:10.1016/j.jmb.2020.04.009.

Johns Hopkins Coronavirus Resource Centre COVID-19 Dashboard (2020)

Kirby, T. (2021). New variant of sars-cov-2 in uk causes surge of covid-19. *Lancet Respir Med*. doi:10.1016/S2213-2600(21)00005-9.

Kleinnijenhuis, J., van Crevel, R., & Netea, M. G. (2015). Trained immunity: Consequences for the heterologous effects of bcg vaccination. *Trans R Soc Trop Med Hyg, 109*(1), 29-35. doi:10.1093/trstmh/tru168.

Klok, F. A., Kruip, M., van der Meer, N. J. M., Arbous, M. S., Gommers, D., Kant, K. M., . . . Endeman, H. (2020). Confirmation of the high cumulative incidence of thrombotic complications in critically ill icu patients with covid-19: An updated analysis. *Thromb Res, 191*, 148-150. doi:10.1016/j.thromres.2020.04.041.

Kuba, K., Imai, Y., Rao, S., Gao, H., Guo, F., Guan, B., . . . Penninger, J. M. (2005). A crucial role of angiotensin converting enzyme 2 (ace2) in sars coronavirus-induced lung injury. *Nat Med, 11*(8), 875-879. doi:10.1038/nm1267.

Lai, A. L., Millet, J. K., Daniel, S., Freed, J. H., & Whittaker, G. R. (2017). The sars-cov fusion peptide forms an extended bipartite fusion platform that perturbs membrane order in a calcium-dependent manner. *J Mol Biol, 429*(24), 3875-3892. doi:10.1016/j.jmb.2017.10.017.

Lamers, M. M., Beumer, J., van der Vaart, J., Knoops, K., Puschhof, J., Breugem, T. I., . . . Clevers, H. (2020). Sars-cov-2 productively infects human gut enterocytes. *Science, 369*(6499), 50-54. doi:10.1126/science.abc1669.

Lan, J. H., Ge, J., Yu, J., Shan, S., Zhou, H., Fan, S., . . . Wang, X. (2020). Structure of the sars-cov-2 spike receptor-binding domain bound to the ace2 receptor. *Nature, 581*, 215-220.

Lechien, J. R., Hopkins, C., & Saussez, S. (2020). Sniffing out the evidence; it's now time for public health bodies recognize the link between covid-19 and smell and taste disturbance. *Rhinology, 58*(4), 402-403. doi:10.4193/Rhin20.159.

Li, F. (2008). Structural analysis of major species barriers between humans and palm civets for severe acute respiratory syndrome coronavirus infections. *J Virol, 82*(14), 6984-6991. doi:10.1128/JVI.00442-08.

Li, F., Li, W., Farzan, M., & Harrison, S. C. (2005). Structure of sars coronavirus spike receptor-binding domain complexed with receptor. *Science, 309*(5742), 1864-1868. doi:10.1126/science.1116480.

Li, W., Moore, M. J., Vasilieva, N., Sui, J., Wong, S. K., Berne, M. A., . . . Farzan, M. (2003). Angiotensin-converting enzyme 2 is a functional receptor for the sars coronavirus. *Nature, 426*(6965), 450-454. doi:10.1038/nature02145.

Liu, C., von Brunn, A., & Zhu, D. (2020). Cyclophilin a and cd147: Novel therapeutic targets for the treatment of covid-19. *Med Drug Discov, 7*, 100056. doi:10.1016/j.medidd.2020.100056.

Liu, F., Long, X., Zhang, B., Zhang, W., Chen, X., & Zhang, Z. (2020). Ace2 expression in pancreas may cause pancreatic damage after sars-cov-2 infection. *Clin Gastroenterol Hepatol, 18*(9), 2128-2130 e2122. doi:10.1016/j.cgh.2020.04.040.

Mak, K. Y., Chin, R., Cunningham, S. C., Habib, M. R., Torresi, J., Sharland, A. F., . . . Herath, C. B. (2015). Ace2 therapy using adeno-associated viral vector inhibits liver fibrosis in mice. *Mol Ther, 23*(9), 1434-1443. doi:10.1038/mt.2015.92.

Mesel-Lemoine, M., Millet, J., Vidalain, P. O., Law, H., Vabret, A., Lorin, V., . . . Tangy, F. (2012). A human coronavirus responsible for the common cold massively kills dendritic cells but not monocytes. *J Virol, 86*(14), 7577-7587. doi:10.1128/JVI.00269-12.

Millet, J. K., & Whittaker, G. R. (2018). Physiological and molecular triggers for sars-cov membrane fusion and entry into host cells. *Virology, 517*, 3-8. doi:10.1016/j.virol.2017.12.015.

Monteil, V., Kwon, H., Prado, P., Hagelkruys, A., Wimmer, R. A., Stahl, M., . . . Penninger, J. M. (2020). Inhibition of sars-cov-2 infections in engineered human tissues using clinical-grade soluble human ace2. *Cell, 181*(4), 905-913 e907. doi:10.1016/j.cell.2020.04.004.

Moore, J. B., & June, C. H. (2020). Cytokine release syndrome in severe covid-19. *Science,*

368(6490), 473-474. doi:10.1126/science.abb8925.

Morris, G. M., Huey, R., & Olson, A. J. (2008). Using autodock for ligand-receptor docking. *Curr Protoc Bioinformatics, Chapter 8*, Unit 8.14. doi:10.1002/0471250953.bi0814s24.

Nathan, L., Lai, A. L., Millet, J. K., Straus, M. R., Freed, J. H., Whittaker, G. R., & Daniel, S. (2020). Calcium ions directly interact with the ebola virus fusion peptide to promote structure-function changes that enhance infection. *ACS Infect Dis, 6*(2), 250-260. doi:10.1021/acsinfecdis.9b00296.

Netea, M. G., Quintin, J., & van der Meer, J. W. (2011). Trained immunity: A memory for innate host defense. *Cell Host Microbe, 9*(5), 355-361. doi:10.1016/j.chom.2011.04.006.

Paiva, M. H. S., Guedes, D. R. D., Docena, C., Bezerra, M. F., Dezordi, F. Z., Machado, L. C., . . . Wallau, G. L. (2020). Multiple introductions followed by ongoing community spread of sars-cov-2 at one of the largest metropolitan areas of northeast brazil. *Viruses, 12*(12). doi:10.3390/v12121414.

Paz Ocaranza, M., Riquelme, J. A., Garcia, L., Jalil, J. E., Chiong, M., Santos, R. A. S., & Lavandero, S. (2020). Counter-regulatory renin-angiotensin system in cardiovascular disease. *Nat Rev Cardiol, 17*(2), 116-129. doi:10.1038/s41569-019-0244-8.

Pitlik, S. D. (2020). Covid-19 compared to other pandemic diseases. *Rambam Maimonides Med J, 11*(3). doi:10.5041/RMMJ.10418.

Puelles, V. G., Lutgehetmann, M., Lindenmeyer, M. T., Sperhake, J. P., Wong, M. N., Allweiss, L., . . . Huber, T. B. (2020). Multiorgan and renal tropism of sars-cov-2. *N Engl J Med, 383*(6), 590-592. doi:10.1056/NEJMc2011400.

Putnam, K., Shoemaker, R., Yiannikouris, F., & Cassis, L. A. (2012). The renin-angiotensin system: A target of and contributor to dyslipidemias, altered glucose homeostasis, and hypertension of the metabolic syndrome. *Am J Physiol Heart Circ Physiol, 302*(6), H1219-1230. doi:10.1152/ajpheart.00796.2011.

Rajapaksha, I. G., Gunarathne, L. S., Asadi, K., Cunningham, S. C., Sharland, A., Alexander, I. E., . . . Herath, C. B. (2019). Liver-targeted angiotensin converting enzyme 2 therapy inhibits chronic biliary fibrosis in multiple drug-resistant gene 2-knockout mice. *Hepatol Commun, 3*(12), 1656-1673. doi:10.1002/hep4.1434.

Rouchka, E. C., Chariker, J. H., & Chung, D. (2020). Variant analysis of 1,040 sars-cov-2 genomes. *PLoS One, 15*(11), e0241535. doi:10.1371/journal.pone.0241535.

Samavati, L., & Uhal, B. D. (2020). Ace2, much more than just a receptor for sars-cov-2. *Front Cell Infect Microbiol, 10*, 317. doi:10.3389/fcimb.2020.00317.

Santos, R. A., Simoes e Silva, A. C., Maric, C., Silva, D. M., Machado, R. P., de Buhr, I., . . . Walther, T. (2003). Angiotensin-(1-7) is an endogenous ligand for the g protein-coupled receptor mas. *Proc Natl Acad Sci U S A, 100*(14), 8258-8263.

Santos, R. A. S., Sampaio, W. O., Alzamora, A. C., Motta-Santos, D., Alenina, N., Bader, M., & Campagnole-Santos, M. J. (2018). The ace2/angiotensin-(1-7)/mas axis of the renin-angiotensin system: Focus on angiotensin-(1-7). *Physiol Rev, 98*(1), 505-553. doi:10.1152/physrev.00023.2016.

Shang, J., Ye, G., Shi, K., Wan, Y., Luo, C., Aihara, H., . . . Li, F. (2020). Structural basis of receptor recognition by sars-cov-2. *Nature, 581*(7807), 221-224. doi:10.1038/s41586-020-2179-y.

Shi, S., Qin, M., Shen, B., Cai, Y., Liu, T., Yang, F., . . . Huang, C. (2020). Association of cardiac injury with mortality in hospitalized patients with covid-19 in wuhan, china. *JAMA Cardiol, 5*(7), 802-810. doi:10.1001/jamacardio.2020.0950.

Shirato, K., Kawase, M., & Matsuyama, S. (2013). Middle east respiratory syndrome coronavirus infection mediated by the transmembrane serine protease tmprss2. *J Virol, 87*(23), 12552-12561. doi:10.1128/JVI.01890-13.

Straus, M. R., Tang, T., Lai, A. L., Flegel, A., Bidon, M., Freed, J. H., . . . Whittaker, G. R. (2020). Ca(2+) ions promote fusion of middle east respiratory syndrome coronavirus with host cells and increase infectivity. *J Virol, 94*(13). doi:10.1128/JVI.00426-20.

Sun, W. (2020). The discovery of gene mutations making sars-cov-2 well adapted for humans: Host-genome similarity analysis of 2594 genomes from china, the USA and europe. *bioRxiv*, doi: https://doi.org/10.1101/2020.1109.1103.280727.

Tang, J. W., Tambyah, P. A., & Hui, D. S. (2020). Emergence of a new sars-cov-2 variant in the uk. *J Infect*. doi:10.1016/j.jinf.2020.12.024.

Tetzner, A., Gebolys, K., Meinert, C., Klein, S., Uhlich, A., Trebicka, J., . . . Walther, T. (2016). G-protein-coupled receptor mrgd is a receptor for angiotensin-(1-7) involving adenylyl cyclase, camp, and phosphokinase a. *Hypertension, 68*(1), 185-194. doi:10.1161/HYPERTENSIONAHA.116.07572.

Tipnis, S. R., Hooper, N. M., Hyde, R., Karran, E., Christie, G., & Turner, A. J. (2000). A human

homolog of angiotensin-converting enzyme. Cloning and functional expression as a captopril-insensitive carboxypeptidase. *J Biol Chem, 275*(43), 33238-33243.

Trott, O., & Olson, A. J. (2010). Autodock vina: Improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading. *J Comput Chem, 31*(2), 455-461. doi:10.1002/jcc.21334.

Turner, A. J., Hiscox, J. A., & Hooper, N. M. (2004). Ace2: From vasopeptidase to sars virus receptor. *Trends Pharmacol Sci, 25*(6), 291-294. doi:10.1016/j.tips.2004.04.001.

Turner, A. J., Tipnis, S. R., Guy, J. L., Rice, G., & Hooper, N. M. (2002). Aceh/ace2 is a novel mammalian metallocarboxypeptidase and a homologue of angiotensin-converting enzyme insensitive to ace inhibitors. *Can J Physiol Pharmacol, 80*(4), 346-353. doi:10.1139/y02-021.

updates, W. o. Coronavirus disease 2019 - who.Int.

Varga, Z., Flammer, A. J., Steiger, P., Haberecker, M., Andermatt, R., Zinkernagel, A. S., . . . Moch, H. (2020). Endothelial cell infection and endotheliitis in covid-19. *Lancet, 395*(10234), 1417-1418. doi:10.1016/S0140-6736(20)30937-5.

Walls, A. C., Tortorici, M. A., Snijder, J., Xiong, X., Bosch, B. J., Rey, F. A., & Veesler, D. (2017). Tectonic conformational changes of a coronavirus spike glycoprotein promote membrane fusion. *Proc Natl Acad Sci U S A, 114*(42), 11157-11162. doi:10.1073/pnas.1708727114.

Wang, K., Gheblawi, M., & Oudit, G. Y. (2020). Angiotensin converting enzyme 2: A double-edged sword. *Circulation*. doi:10.1161/CIRCULATIONAHA.120.047049.

Warner, F. J., Lubel, J. S., McCaughan, G. W., & Angus, P. W. (2007). Liver fibrosis: A balance of aces? *Clin Sci (Lond), 113*(3), 109-118.

Wójcik, P., & Berlicki, Ł. (2016). Peptide-based inhibitors of protein-protein interactions. *Bioorg Med Chem Lett, 26*(3), 707-713. doi:10.1016/j.bmcl.2015.12.084.

World Health Organization (2004). Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003.

World Health Organization. (2019). Middle east respiratory syndrome coronavirus (Mers-Cov).

Wrapp, D., Wang, N., Corbett, K. S., Goldsmith, J. A., Hsieh, C. L., Abiona, O., . . . McLellan, J. S. (2020). Cryo-em structure of the 2019-ncov spike in the prefusion conformation. *Science, 367*(6483), 1260-1263. doi:10.1126/science.abb2507.

Wu, C. H., Mohammadmoradi, S., Chen, J. Z., Sawada, H., Daugherty, A., & Lu, H. S. (2018). Renin-angiotensin system and cardiovascular functions. *Arterioscler Thromb Vasc Biol, 38*(7), e108-e116. doi:10.1161/ATVBAHA.118.311282.

Wu, F., Zhao, S., Yu, B., Chen, Y. M., Wang, W., Song, Z. G., . . . Zhang, Y. Z. (2020). A new coronavirus associated with human respiratory disease in china. *Nature, 579*(7798), 265-269. doi:10.1038/s41586-020-2008-3.

Wu, K., Peng, G., Wilken, M., Geraghty, R. J., & Li, F. (2012). Mechanisms of host receptor adaptation by severe acute respiratory syndrome coronavirus. *J Biol Chem, 287*(12), 8904-8911. doi:10.1074/jbc.M111.325803.

Xu, R., Shi, M., Li, J., Song, P., & Li, N. (2020). Construction of sars-cov-2 virus-like particles by mammalian expression system. *Front Bioeng Biotechnol, 8*, 862. doi:10.3389/fbioe.2020.00862.

Yan, R., Zhang, Y., Li, Y., Xia, L., Guo, Y., & Zhou, Q. (2020). Structural basis for the recognition of sars-cov-2 by full-length human ace2. *Science, 367*(6485), 1444-1448. doi:10.1126/science.abb2762.

Yang, T., & Xu, C. (2017). Physiology and pathophysiology of the intrarenal renin-angiotensin system: An update. *J Am Soc Nephrol, 28*(4), 1040-1049. doi:10.1681/ASN.2016070734.

Yang, X., Yu, Y., Xu, J., Shu, H., Xia, J., Liu, H., . . . Shang, Y. (2020). Clinical course and outcomes of critically ill patients with sars-cov-2 pneumonia in wuhan, china: A single-centered, retrospective, observational study. *Lancet Respir Med, 8*(5), 475-481. doi:10.1016/S2213-2600(20)30079-5.

Zhu, Z., Lian, X., Su, X., Wu, W., Marraro, G. A., & Zeng, Y. (2020). From sars and mers to covid-19: A brief summary and comparison of severe acute respiratory infections caused by three highly pathogenic human coronaviruses. *Respir Res, 21*(1), 224. doi:10.1186/s12931-020-01479-w.

Zou, X., Chen, K., Zou, J., Han, P., Hao, J., & Han, Z. (2020). Single-cell rna-seq data analysis on the receptor ace2 expression reveals the potential risk of different human organs vulnerable to 2019-ncov infection. *Front Med, 14*(2), 185-192. doi:10.1007/s11684-020-0754-0.

WGS Metagenomics vs Targeted sequencing: Which is better for pathogen identification and characterization

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ABSTRACT

Next Generation Sequencing is a powerful technique which facilitates the identification and characterization of SARS-CoV2 virus in clinical samples. Here we outline two different WGS approaches occupied for genomic sequencing and characterization during this novel coronavirus outbreak. 17 respiratory samples of SARS-CoV2 patients were sequenced using a shotgun metagenomics (SM) approach while 16 patient samples were sequenced using targeted amplicons (TS) of the SARS-CoV-2 genome. Raw data were quality checked and analyzed using different bioinformatics pipelines in order to map against SARS-CoV-2 genome. Coverage plots and mapping statistics of two methods were generated and compared. Longer reads were generated in TS approach which makes the genome assembly much faster and confident. SM samples generated an average of 41 ± 10 sd. million reads per sample, whereas TS samples generated 7 ± 3 sd. million reads per sample. Turnaround time of the TS is half of what metagenomics sequencing require while, with TS it is possible to run eight times more samples in a single run. SM samples had mean depth of 482 whereas TS samples had 88. A coverage depth of more than 20 is enough to successfully call genomic variants so TS with a low output is fast and cost effective. Resulting excess metagenomics reads can be used for further microbiome analysis and de-novo assembly to map novel organisms. Hence, shotgun sequencing is very useful for sequencing novel pathogens. However, if available, amplicon-based sequencing is the most cost effective and straightforward technique for genomic surveillance and characterization of SARS-CoV-2.

Key words: Amplicon sequencing, Genomic sequencing, Next generation sequencing, SARS-CoV-2, Shotgun metagenomics

1. INTRODUCTION

Next generation sequencing (NGS) is a collection of genome sequencing technologies that are able to sequence millions of small DNA fragments in a parallel fashion. These technologies have revolutionized genomic research by avoiding number of pitfalls related to first generation sequencing technologies, allowing researchers to sequence entire genomes or exomes at once. Using NGS technology, an entire human genome, which has more than 3000 mega base pairs can be sequenced

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within a single day (Behjati & Tarpey, 2013). Whole genome sequencing (WGS), one of the techniques enabled by NGS, is the process of determining the complete or nearly complete DNA sequence of an organism's genome in a single sequencing run. Although this approach is mostly used in personalized medicine and evolutionary biology, its ability to pinpoint single nucleotide polymorphisms at a higher resolution has aided in many research aspects such as disease prediction and drug response (Ng & Kirkness, 2010).

Since the first emergence of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) case in Hubei province, China in December 2019, whole genomic sequencing played an essential role in genomic surveillance for new variants of the virus. Thanks to the collective effort of the scientific community from all over the world, there are more than 1,300,000 sequences publicly available for research by May 2021 ("GISAID", 2021). Other than identification of new variants, those data are being used to investigate outbreak dynamics including changes in the size of the epidemic over time, spatiotemporal spread and transmission routes. Also, genomic data can help create and design novel drugs, vaccines and diagnostic assays. In other words, for the first time in the world, genomic sequencing is directly guiding the public health response in real time to fight against this coronavirus pandemic (WHO, 2021).

Advanced nomenclature systems based on phylogenetics such as GISAID clade and Pango lineage have been developed and maintained online to analyse the ever-growing global sequencing data. According to CDC, multiple variants of concern are currently circulating globally; B.1.1.7, B.1.351 and P.1. These variants appear to spread rapidly and easily than other variants, which causes increased number of cases leading to put more pressure on health care systems. Also, scientific research on those publicly available data had already predicted the vaccine response to different variants, which helped countries to take precautions before certain strains get into their communities ("COVID-19 and Variants, 2021).

We have conducted this pilot study to determine which whole genome sequencing technique is the most feasible, cost effective and reliable in mapping SARS-CoV-2 genomes at our laboratory in Allergy Immunology and Cell Biology Unit (AICBU), University of Sri Jayewardenepura. We conducted Shotgun Metagenomics and Amplicon-based targeted sequencing techniques for 33 samples using two different Illumina™ sequencing platforms and outlined and compared the sequencing statistics between two techniques.

2. METHODS

2.1. Real-time PCR & library preparation

Sputum or nasopharyngeal swabs of 29 patients who were diagnosed with COVID-19, ct values of the qPCR for SARS-CoV2 less than 30, were subjected to whole genomic sequencing. Genome sequencing was carried out on samples sent to the laboratory for routine diagnostic assays. Nasopharyngeal swabs or sputum samples were lysed and RNA was extracted using QIAmp Viral RNA Mini Kit (Qiagen, USA, Cat: 52906). Presence of N and ORF1ab gene of SARS-CoV2 was detected by real time RT PCR according to manufacturer's instructions in ABI 7500 real time PCR system (Applied Biosystems, USA).

2.2. TruSeq Stranded Total RNA Library Preparation for shotgun metagenomics

The RNA concentrations of the extracted RNA samples were quantified with a NanoDrop™ 2000c Spectrophotometers (Thermo Fisher Scientific, USA). Biotinylated, target-specific oligos combined with Ribo-Zero rRNA was used to remove Ribosomal RNA from the supernatant. Following the purification, the RNA was fragmented into small pieces using divalent cations under elevated temperature. All the thermal cycling steps were carried out in a CFX96 Deep Well, Real time System (Bio-Rad, USA). After the cDNA synthesis of first and second strand, 3 prime ends of the blunt fragments were adenylated and indexed adaptors were ligated (TruSeq RNA ud Indexes). Then the ligated

fragments were cleaned up using Agencourt AMPure XP beads (Beckman Coulter Genomics, USA) followed by an enrichment PCR step. Finally, the libraries were quantified by Qubit dsDNA assay kit on a Qubit 4.0 instrument (Life Technologies), and a 1% agarose gel electrophoresis was run to confirm the 260bp fragment size. Sample libraries were normalized to 10 nM concentration before pooling sequencing on the Illumina NextSeq 550 platform.

2.3. The AmpliSeq for Illumina SARS-CoV-2 Community Panel

Starting concentrations of RNA were quantified using the Qubit 4.0 instrument (Life Technologies) and the RNA was reverse transcribed to cDNA using the AMpliSeq cDNA synthesis for Illumina Kit. Thermal cycling steps were carried out on CFX96 Deep Well, Real time System (Bio-Rad, USA). Targeted amplification of the SARS-CoV-2 cDNA was carried out with 247 amplicons/primer pairs, 237 viral specific SARS-CoV-2 targets and 5 human gene expression controls ranging from 125-275 bps in length which covers >99% of the Coronavirus genome (~30kb) and all potential serotypes of the virus. Ampliseq CD Indexes were ligated to the cDNA, followed by a cleanup step using Agencourt AMPure XP beads. The prepared libraries were enriched by PCR and cleaned up before quantifying on the Qubit 4.0 instrument. Finally, the fragment size of 350bp was confirmed by gel electrophoresis using 1% gel. Each sample library was normalized to 2nM concentration, pooled and sequenced on Illumina iSeq 100 platform.

2.4. Sequence data analysis

A 76bp paired end shotgun library of 17 samples was sequenced on Illumina Nextseq 550 platform. Resultant base call files were demultiplexed and converted to FASTQ files using BaseSpace Sequence Hub ("BSSH", 2021) Fastq generator. Read quality was checked and confirmed using fastqc tool (Andrews, 2010). To assess the quantity of host genomic DNA and other contaminants, Kraken 2 (version 2.0.1) Metagenomics pipeline (Wood & Salzberg, 2014) was used on the BaseSpace Sequence Hub and the abundance data were visualized using Krona (Ondov et al., 2011) charts. After confirming the quantities of host DNA and viral DNA, FASTQ files were again piped through Dragen ("Dragen Pipeline", 2019) RNA Pathogen Detection (version 3.5.14) pipeline to map reads against SARS-CoV-2 Wuhan-Hu-1 isolate (Genbank accession number: MN908947.3). The Dragen pipeline generated coverage plots, Binary Alignment files (BAM) (Li et al., 2009) and Variant Call files (VCF) (Danecek et al., 2011) were generated against the accession MN908947.3. Since almost all metagenomic sequences had very high depth over the reference genome, consensus sequences were directly generated from the hard-filtered VCF files using bcftools version 1.10.2 (Li et al., 2009) consensus algorithm.

A 150 bp amplicon library of 16 samples was sequenced on Illumina iSeq 100 platform. Raw base calls were converted to FASTQ files using BaseSpace Sequencing Hub Fastq generator and inspected with fastqc tool for low quality reads. FASTQ files were aligned against SARS-CoV-2 Wuhan-Hu-1 isolate (Genbank accession number: MN908947.3) and BAM and VCF files were generated via DRAGEN RNA Pathogen Detection (version 3.5.14) pipeline. Resulting BAM files were checked using samtools (Li et al., 2009) version 1.10 flagstat algorithm for alignment quality and samples with more than 75% genome coverage and moderate to low coverage depth were further analysed to obtain consensus sequences. Variants filtered by the somatic variant caller of the Dragen pipeline were used to generate consensus sequences using bcftools commands and percentage of ambiguous variant calls (Ns) were calculated for each sequence.

3. RESULTS AND DISCUSSION

See Figure 1. Shotgun metagenomics samples had very high total read counts per sample (41,489,077 ± 10,435,532 sd) compared to targeted sequencing (7,435,532 ± 3,300,165 sd). This can be explained by the shotgun metagenomics approach capturing the genetic material of not only the organism of interest but the environmental organisms and the

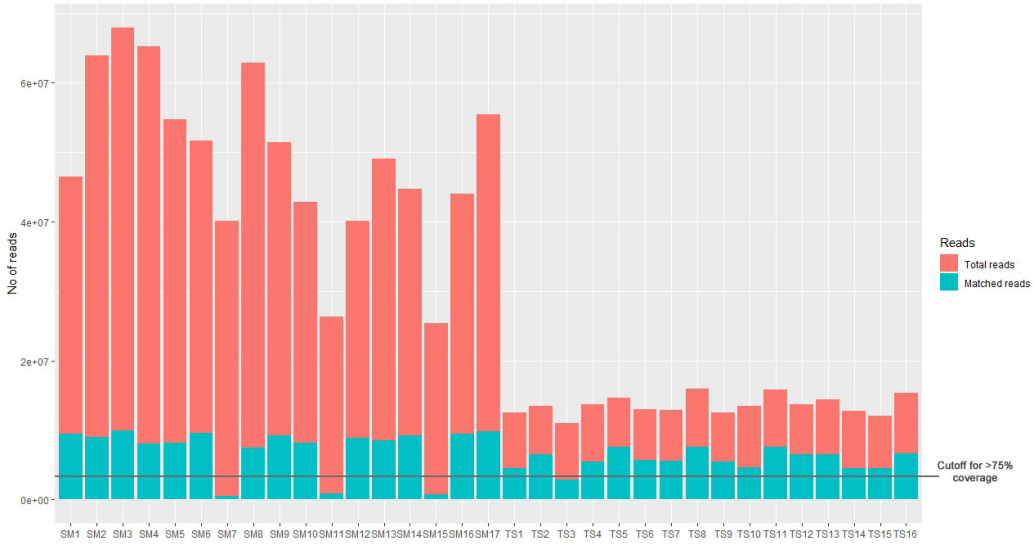

Figure 1. Total reads and reference matched reads for each sample.

Total reads and SARS-CoV-2 reference matched reads shown for Shotgun Metagenomics (SM) samples and Targeted sequencing (TS) samples. Reads cut-off required for more than 75% of the coverage across the SARS-CoV-2 genome is shown. More samples were retained with the targeted sequencing approach.

host genome. Targeted sequencing samples had generated significantly less reads due to the amplicons produced during the library preparation step which were specifically arisen from the SARS-CoV-2 genome. However, average amount of reads aligned to the SARS-CoV-2 reference sequence (MN908947.3) per sample varied between 7.8 million to 5.6million reads in both approaches (shotgun metagenomics: 7,828,127 ± 610,261 sd, targeted sequencing 5,758,850 ± 1,318,212 sd).

Even though all the shotgun metagenomics samples generated high total reads, 3 samples (SM7, SM11 and SM15) had failed to capture adequate amount of reads to cover more than 75% of the SARS-CoV-2 genome (Figure 1). However, except for one (TS3), all the other targeted sequencing samples were able to retain reads above the cut-off value to cover more than 75% of the genome. Failed metagenomics samples were further analysed to find out that most of the reads came from rRNA. This is frequently occurred with shotgun metagenomics sequencing due to not discarding majority of non-specific genetic material such as rRNA during the library preparation step which isn't a concern in amplicon-based sequencing approach.

Although there was a clear difference in total read count distribution for two sample groups (Figure 2A), reference mapped read counts were distributed closely (Figure 2B). Importantly, both sequencing approaches had adequate mapped read counts for successful mapping across the SARS-CoV2 genome. Targeted sequencing samples had comparatively lower sequencing depth distribution while metagenomics samples had uneven distribution of very high to very low sequencing depth. However, the very high sequencing depth of metagenomics samples do not always improve the output but sometimes elongates the downstream analysis with requirement of subsampling.

Metagenomics samples had overall high sequencing depth compared to targeted sequencing samples (482 ± 348 sd vs 88 ± 47 sd). Since the reads are divided between more samples in amplicon-based technique it has less sequencing depth per sample. However, in theory the sequencing depth should be higher in amplicon-based techniques because a vast

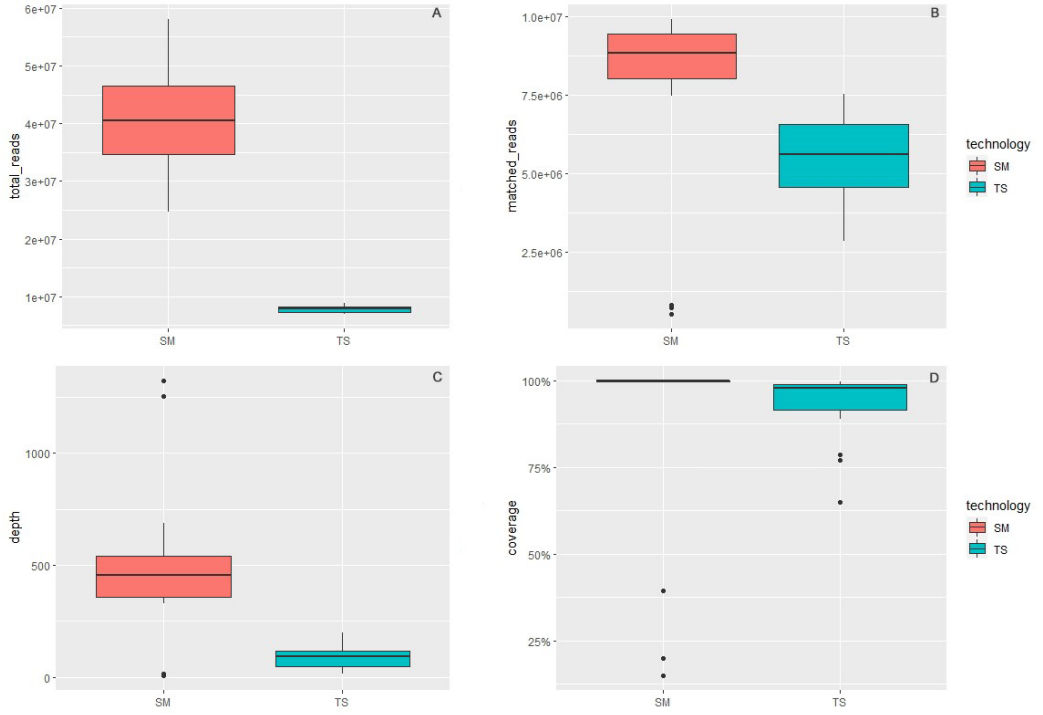

Figure 2. Boxplots showing A) Total number of reads B) Reference matched reads C) Sequencing depth and D) Coverage across SARS-CoV-2 genome between Shotgun Metagenomics (SM) vs Targeted Sequencing (TS) groups.

number of DNA strands in the pool comes from selectively amplified amplicons but practically researchers either use large number of samples or a platform with lesser specs to properly utilize the reads and cost. In this case, amplicon sequencing was carried out using an illumine iseq 100 platform which has significantly low output compared to high end Nextseq 550 platform. However, a sequencing depth of more than 20 is sufficient to successfully call genomic variants therefore targeted sequencing on a low output platform such as illumine iseq 100 is not only cost effective but also reduces the turnaround time without compromising the output (Jiang et al., 2019).

Coverage over the SARS-CoV-2 genome of metagenomics samples were near 100% except for 3 samples that had rRNA overexpression issue. Amplicon-based samples had coverage between 75% to 99% except for the one failed sample due to low read count. Technically, achieving full genome coverage is nearly impossible with most NGS technologies due to 5' and 3' ends of the genome having the least sequencing depth. Also, the genome coverage of more than 80% is accepted in most post analysis tools and pipelines. Hence, amplicon sequencing showed more acceptable uniformity in coverage across samples compared to metagenomics. See Figure 3.

Shotgun metagenomics data analysis requires an extended bioinformatics workflow compared to the targeted sequencing approach due to the de-novo genome assembly, and other intermediate steps required to discard environmental and host reads. Also, computational and storage resources required for shotgun metagenomics analysis is considerably higher compared to the targeted sequencing due to the massive output generated by the shotgun library. In contrast, bioinformatics workflow for amplicon-based sequencing is relatively straightforward and lightweight. Due to its targeted nature there are less reads to sort and discard. Also, the reference based read alignment increases turnaround time and accuracy of the assembly to a greater extent. Thus, the bioinformatics

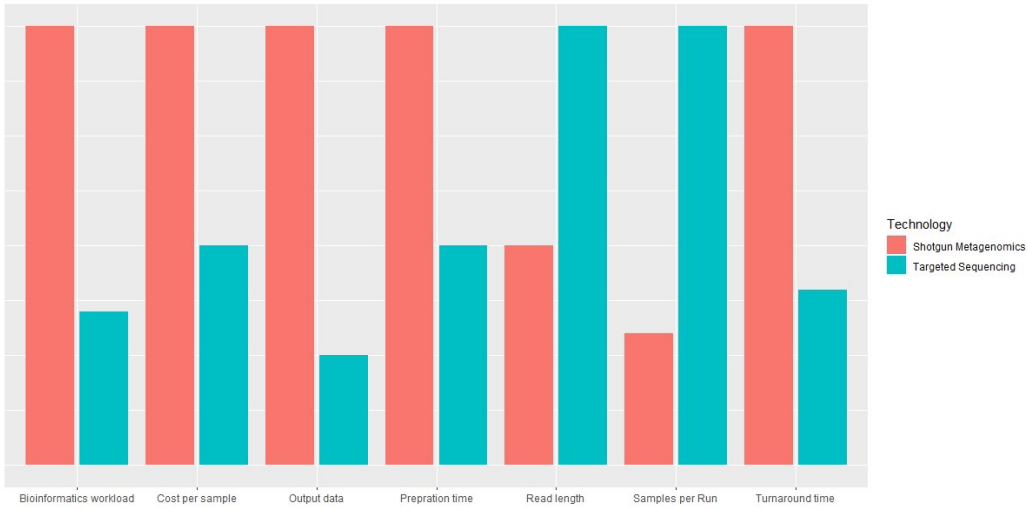

Figure 3. Comparison between Shotgun Metagenomics vs Targeted Sequencing.

workflow used in targeted sequencing reduces the turnaround time in half when compared with metagenomics workflow. Also, the wet lab workflow of the targeted sequencing is relatively fast reducing the turnaround time altogether.

Amplicon based technique used 150bp as the standard read length while metagenomics workflow used 75bp reads. Having longer read lengths is considered as an advantage in downstream analysis because process of read mapping against the reference genome is much faster and confident with longer reads. Also, having large number of short reads makes the genome assembly highly fragmented hence there is more room for errors (Chhangawala et al., 2015).

Shotgun metagenomics require at least 20 million reads per sample due to its library containing genetic material of large number of other organisms. Hence, a reagent kit with 250 million output reads could be used for no more than 15 samples, whereas the same reagent kit can easily be used for 96 or even 384 samples for amplicon-based sequencing. This cuts the cost and workload of targeted amplicon sequencing in half over metagenomics sequencing.

Excess reads generated in metagenomics samples are mostly derived from the host (human) and other respiratory microbiota. This always makes the downstream analysis a much tedious process compared to the amplicon-based data analysis, which does not involve in complex process of removing host sequences and other artifacts. However, resulting microbiome data can be used for further metagenomics analysis. Also, this approach can be used to map novel organisms by occupying a complex de-novo assembly whereas amplicon-based sequencing is limited to reference guided assembly which is only for a known pathogens or organisms (Sharpton, 2014).

In summary, shotgun metagenomics sequencing is a very useful technique when it comes to sequencing of novel organisms. Lack of evidence of a stable reference genome can delay the development and validation of an amplicon based targeted sequencing approach. Thus, shotgun metagenomics technique would have been the most popular choice of sequencing during the beginning of the Covid19 pandemic. However, with availability of stable reference genome and other genomic resources, amplicon based targeted sequencing is the most cost effective and straightforward WGS approach for genomic surveillance and

characterization of a well-known pathogen like SARS-CoV-2.

REFERENCES

Andrews, S. (2010). FastQC: A Quality Control Tool for High Throughput Sequence Data (Version 0.11.9) [Linux]. http://www.bioinformatics.babraham.ac.uk/projects/fastqc/.

BaseSpace Sequence Hub. (2021). Retrieved 1 May 2021, from https://basespace.illumina.com.

Behjati, S., & Tarpey, P. (2013). What is next generation sequencing?. Archives Of Disease In Childhood - Education & Practice Edition, 98(6), 236-238. doi: 10.1136/archdischild-2013-304340.

Chhangawala, S., Rudy, G., Mason, C., & Rosenfeld, J. (2015). The impact of read length on quantification of differentially expressed genes and splice junction detection. Genome Biology, 16(1). doi: 10.1186/s13059-015-0697-y.

COVID-19 and Variants. (2021). Retrieved on 1 May 2021, from https://www.cdc.gov/coronavirus/2019-ncov/transmission/variant.html.

Danecek, P., Auton, A., Abecasis, G., Albers, C., Banks, E., & DePristo, M. et al. (2011). The variant call format and VCFtools. *Bioinformatics,* 27(15), 2156-2158. doi: 10.1093/bioinformatics/btr330.

Dragen Pipeline. (2019). Retrieved 1 May 2021, from https://basespace.illumina.com/apps/9930921/DRAGEN-RNA-Pathogen-Detection.

GISAID. (2021). Retrieved 1 May 2021, from https://www.gisaid.org/.

Jiang, Y., Jiang, Y., Wang, S., Zhang, Q., & Ding, X. (2019). Optimal sequencing depth design for whole genome re-sequencing in pigs. *BMC Bioinformatics,* 20(1). doi: 10.1186/s12859-019-3164-z.

Li, H., Handsaker, B., Wysoker, A., Fennell, T., Ruan, J., & Homer, N. et al. (2009). The Sequence Alignment/Map format and SAMtools. *Bioinformatics*, 25(16), 2078-2079. doi: 10.1093/bioinformatics/btp352.

Ng, P., & Kirkness, E. (2010). Whole Genome Sequencing. *Methods In Molecular Biology*, 215-226. doi: 10.1007/978-1-60327-367-1_12.

Ondov, B., Bergman, N., & Phillippy, A. (2011). Interactive metagenomic visualization in a Web browser. *BMC Bioinformatics*, 12(1). doi: 10.1186/1471-2105-12-385.

Sharpton, T. (2014). An introduction to the analysis of shotgun metagenomic data. *Frontiers In Plant Science*, 5. doi: 10.3389/fpls.2014.00209.

WHO (2021). Genomic sequencing of SARS-CoV-2: a guide to implementation for maximum impact on public health. Retrieved from https://www.who.int/publications/i/item/9789240018440.

Wood, D., & Salzberg, S. (2014). Kraken: ultrafast metagenomic sequence classification using exact alignments. *Genome Biology*, 15(3), R46. doi: 10.1186/gb-2014-15-3-r46.

Horizontal/vertical collapsible low-cost face shield‡

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ABSTRACT

Due to the pandemic situation around the world there is a huge demand for personal protective equipment especially for medical staff and other officers who are directly engaging with infected people. So face shield is one of practical and popular solution used to prevent covid-19 transmission and infection among people. But most of the existing products in the market have some issues regarding to safety and usage. By considering practical issues of existing developments in locally and internationally, a novel face shield is developed by using locally available materials. In this study, main drawbacks of existing products in the market are analysed based on safety, usage and material selection. By following this study a novel face shield is designed with collapsible features for both horizontal and vertical directions on the same design. Also in this study material selection criteria are explained in detail based on availability, cost and safety. By following that, design study is explained by considering safety, comfortability, part separation and head movement of user. With compare to other products this design has size adjustability thus it provides more convenient product to wear for a long time. Also through ear guard protection user can use mobile phone without contacting face by hand. But in existing products such arrangements are not available. Furthermore due to parts separation capability of the design it provides more convenient approach to sanitize all the parts properly. Due to material selection and design approach, this design has the lightest weight with compare to existing solutions.

Key words: Covid-19, PPE, Face shield, Horizontal/vertical collapsible, Helmet

1. INTRODUCTION

According to WHO, the covid-19 virus was initially identified in Wuhan, China in December 2019. On 30 January 2020, Director-General of WHO declared the outbreak of COVID-19 a Public Health Emergency of International Concern (PHEIC), and on 11 March 2020, COVID-19 was characterized as a pandemic (WHO, 2020a). According to the statics of WHO, around 80 million of people in globally affected and around 1.7 million of people were dead (WHO, 2020b). In order to prevent the transmission of covid-19 virus among people, WHO has introduced new rules and regulations. According to the given instructions washing hands, avoid touching face, wearing a mask and physical distance among people are mandatory facts to avoid virus infection and transmission (WHO, 2021). Because the covid-19 virus is infected to a human body mainly through nose, mouth and eyes. As a result of that there exist a huge demand for personal protective equipment (PPE) among medical staff and other workers all around the world.

‡ **Short Communication**

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Face mask is one of the most popular PPE used by many people to avoid virus infection and transmission through breathing. But it only provides protection around nose and mouth. It does not cover full face in order to avoid direct contact with virus. Also on the other hand face mask is not recommended for children and old people because of lack of availability of oxygen for breathing. In some cases children may not be able to wear a mask due to disabilities or specific situations such as speech classes where teacher needs to see their mouths. In such cases it is recommend to use a face shield as an alternative to mask (WHO, 2020c). Moreover even though people are well aware about the phenomenon of virus infection sometime they are unable to avoid contact their faces by hands because of their day to day habits. So there should be a method to avoid contact with face by hands because only with face mask it is not practical to provide fully safe arrangement. Furthermore even a person wears a mask sometimes droplets generated when an infected person coughs, sneezes or exhales can drop on face because of lack of protection available in a face mask.

As an alternative to masks, WHO recommends to use face shield which should cover the entire face, wrap around the sides of the face and extend to below the chin (WHO, 2020c). By using this type of face shield it can provide full protection to entire face with compare to face mask. Initially face shields were used for medical staff that was directly engaging with covid-19 patients. But due to full face protection and other reasons, currently face shields are also more popular among other users as well. In order to full fill this requirement several manufacturers have introduced different types of face shields all around the world. But based on the practical usages there exist many drawbacks in existing developments. One of the most highlighted problem is non-collapsible feature (Amazon, 2020b, 2020c). In some cases if a person feels uncomfortable due to heat around face area, sometimes user prefers to remove the shield for a while. In this case the design should have collapsible feature to support the requirement. Otherwise the user needs to remove the face shield completely. Also due to this non-collapsible feature in existing products, it can cause to create mist on the shield when those are worn for a long time. Thus it causes to create issues for clear vision through the shield. In order to solve this matter some manufacturers have introduced new face shield designs with collapsible feature (Amazon, 2020d). But almost all the products available in the market support vertical collapsible feature only. So there exist an issue when these types of designs are used for some users who are wearing helmet such as police officers, military officers…etc. So it is better to have both horizontal and vertical collapsible features on a same design. Furthermore in those designs, there is no protection in between the forehead and shield to prevent droplets from top (Amazon, 2020d). On the other hand in non-collapsible face shields a sponge is used in between the forehead and the shield in order to properly fix the face shield to the head (Amazon, 2020b). But due to this material selection the temperature around the forehead would increase. Thus it causes to create uncomfortable if it is used for longer period. On the other hand due to surface of sponge sometimes droplets of virus may penetrate through sponge. In such a situation there could exist some issues when it is cleaned before it reuses. If a solid material is used with some flexibility then such issues can be avoided. The other main drawback of sponge is that if there is dust on the sponge then it is very hard to remove even with cleaning.

In existing products in the market use elastic strips to fix the shield to the head (Amazon, 2020b). As a result of that most of the designs do not have the feature of size adjustability. So it can cause to create more tension around the head. Thus it causes to create headache for some users. Also in existing developments there is no any protection for ears (Amazon, 2020b, 2020c, 2020d). So if someone tries to have a phone call then both mobile phone and hand can be directly contacted with face. If that so the face shield will not provide safety anymore. On the other hand when using the same face shield frequently it should be able to clean all the parts easily and properly. So it is better to have parts separation capability for

face shields. But most of the existing products in the market do not have this feature when its need to be cleaned (Amazon, 2020b). Thus it does not guarantee a proper cleaning before it is reused. According to the current situation all around the world, a face shield should have an affordable price to fulfil the requirements for all the users. But based on the used materials and technologies some face shields are sold for much higher prices (Amazon, 2020a).

2. METHODOLOGY

As discussed in above section there are different types of face shields available in the market. But most of the products have many practical drawbacks when those are used. These drawbacks were clearly discussed in the previous section by referring available products in the market. So in this paper a low cost face shield is introduced with collapsible features for both horizontal and vertical directions. Also in this design, part separation capability is considered as a mandatory requirement when cleaning the face shield. Furthermore when considering the mobile phone usage, a design of separate ear guard which can be attached or detached based on user requirement is also considered in order to ensure full safety. On the other hand when designing a face shield attachment to the head, size adjustability is mainly considered to avoid any pain around the head. Thus it can ensure a comfortable arrangement for the user for long usage. Finally light weight is considered as the other main feature when designing the final product.

2.1. Material Selection

One of the main point that is considered when selecting materials is the cost. Because the cost for final product should be minimized as much as possible in order to fulfil the requirement of most users with an affordable price. So in this design crystal clear 0.3 mm Polyvinyl Chloride (PVC) transparent sheet is used as a low cost material for the shield development. The main reasons for selecting this material are cost and availability at local market. In order to fix the face shield properly to the head, webbing is used for the headband instead of elastic strip. With the attachment of elastic strip to webbing, the size of the headband can be adjusted according to the user's requirement. Thus it ensures a comfortable arrangement for the head without creating any pain around head. Also in this design there is a separate arrangement to properly fix the face shield to the forehead in order to prevent droplets coming from top of the head. For this forehead guard Ethylene Vinyl Acetate (EVA) sheet is used because of low cost and availability at local market. Due to softness and flexibility of EVA sheet, the face shield can be properly fixed to the forehead with more comfortable arrangement. For ear guard development the same PVC sheet is used with velco strip to attach with face shield. In this design both ear guards can be easily attached or detached to the headband based on user's preferences.

2.2. Design Study

As explained in earlier the basic design approach of this face shield is to provide both horizontal and vertical collapsible features on a same design. Also the design should be able to cover the face completely without creating any issue for the head movements. So parameter selection for the front shield is very important aspect in this design. By considering the availability of materials and head movement of user, dimension of 210x290 mm is used for the front shield. With this parameter selection this face shield design can support head movement with acceptable range without creating any issue regarding to safety aspects. Also when selecting the parameters for forehead guard the width is considered as 25.4 mm in order to minimize the pressure around the forehead and also to minimize cost as well. Meanwhile the length is selected as same as front shield. In order to fix the front shield to the headband, separate forehead guard band is used with velco strip attachment. In order to fix the front shield, forehead guard and forehead guard band together, cable tie arrangement is used. When attaching the front shield to the headband, user can adjust the length of forehead guard band. So based on user's preferences front shield placement can be adjusted in order to maintain a comfortable arrangement with head. Thus it helps to wear the face shield for a long time

without creating any pain around the head. For ear guard construction two 50x75 mm PVC sheets are used with velco strip. So according to the user's requirement the ear guards can be easily attached to headband. Also due to the design approach the placement of ear guards can be adjusted. Details description of parts of face shield is shown in Figure 1.

2.3. Design Operation

As discussed in the design study, this novel face shield composed of different features in order to provide more convenient product. When the face shield is used for the first time there are some basic stages to follow. Otherwise the device will not function properly and for a long usage it could create some pain for the user. Here are the basic stages to be followed when using this design for the first time.

- First the headband should be tied to the head with minimum tension by using elastic strip.
- Then adjust the headband until it is align with the head. In this case the red vertical line printed on the headband should be placed at the center of the forehead.
- Place the two ear guards on the headband. In this stage ear guard placement can be adjusted according to the user's preferences. On the other hand with this separate attachment it provides feature to remove the ear guards according to user's preferences.
- After the placement of headband, the forehead guard band can be attached onto the head. In this stage the forehead guard band should be attached to the headband with minimum tension to support collapsible feature.
- If the user follows the above steps properly then the device will be able to function properly. When the user needs to collapse the face shield in vertical direction, user needs to move the front shield upwards by using only one hand. According to the user's preferences the vertical position of front shield can be adjusted as shown in Figure 2 and Figure 4.
- Also when collapsing the face shield in horizontal direction the user needs to detach the one side of forehead guard band based on the side of operation as shown in Figure 3.

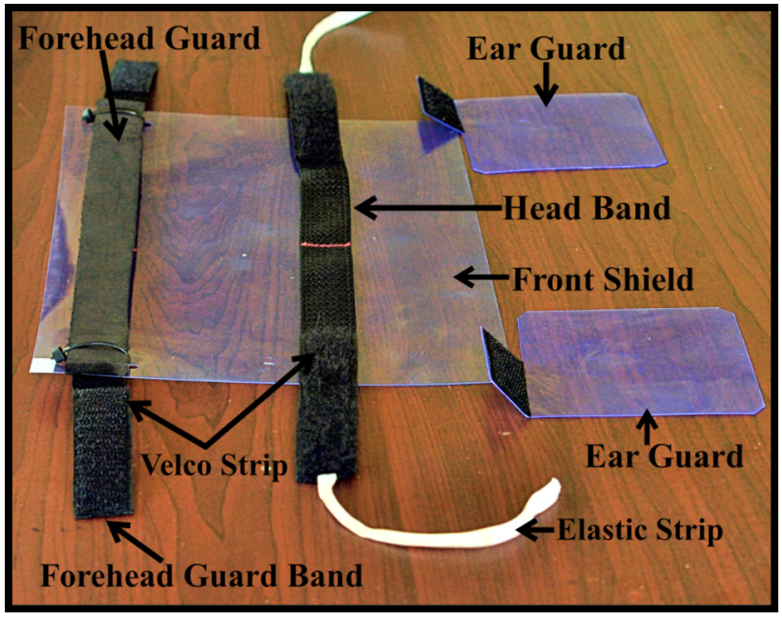

Figure 1. Description of parts of face shield

Figure 2. Stages of vertical postures of face shield

Figure 3. Stages of horizontal postures of face shield

Figure 4. Customized design for school children

- Above steps should be followed when the face shield is used for the first time only. After initial adjustment, the face shield can be easily attached or detached through top of the head.

2.4. Parts Separation

According to WHO cleaning and disinfecting surfaces frequently, is one of mandatory aspect to prevent virus infection and transmission. When using the PPE it is very important to clean all the parts properly if those are reused. Otherwise usage of same PPE can cause to infect the virus to the user. As a protective shield for the face, sometimes droplets of covid-19 infected person may be fallen onto the face shield. In such a situation if the user is unable to clean all the parts of face shield properly when reusing, it can cause to infect the virus to the user. So as safety measures, it is better to have part separation capability in order to properly sanitize the face shield before it reuses. But most of the products in the market have some issues regarding to part separation when cleaning. As explained earlier sponge based forehead guards design could have some issues to properly clean dust or droplets which are already penetrated through sponge. On the other hand in these types of designs the sponge is stuck to the front shield. Thus it could cause some difficulties when cleaning the sponge properly.

In this novel face shield design, parts separation capability is considered as one of the main requirement with regard to safety measures. By following this requirement material selection and design construction have been explained in design study. In this novel design all the parts can be separated as shown in Figure 5. As it is demonstrated all the parts can be sanitized completely without any issue.

3. RESULTS AND DISCUSSION

Regarding to PPE development several solutions have been introduced around the world. Among those developments, face shield is one of the most popular PPE used by medical staff and other front line health workers. Even there are several developments on PPE, most of the solutions are suffered with some practical issues when those are using for long time periods. In face shield development also solution must be more practical while maintaining safety measures. As discussed earlier this paper presents a practical solution

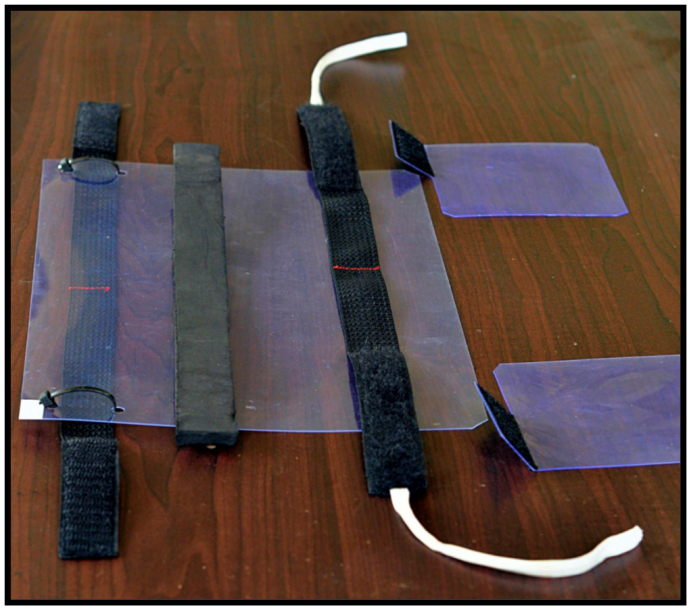

Figure 5. Disassembled face shield

for a face shield development with affordable price.

Due to material selection for headband it provides more comfortable arrangement for the user's head. Also size adjustability of headband helps to avoid any pain around the head when compared to existing products. In this face shield design forehead guard band is used to fix the front shield to headband and the band length can be adjusted according to user's preferences. So this helps to properly fix the front shield to the head when compared with existing products. Because in some face shield developments, the front shield is fixed to head via predefined tension. Also due to the forehead guard, the forehead and front shield are properly sealed. So fluids that may contain the corona virus cannot be contacted with face from the top of the head. But in some designs there exist a gap in between front shield and forehead. On the other hand based on the material selection for the forehead guards it ensures more safety. In existing products in the market there is no protection for ears when using the mobile phone. But in this design separate ear guards are attached with the face shield to avoid contact with face while using a mobile phone. Based on the design approach the front shield can be collapsed in both horizontal and vertical direction. When compare to the existing products in the market, this is the one and only face shield design which can support both horizontal and vertical collapsibility on a same design. Moreover the face shield has parts separation capability. Thus it helps to sanitize all the parts properly when compared to existing products. All the materials used for face shield development are locally available. Thus it helps to minimize manufacturing cost. The weight of the face shield is about 50g so it provides more convenient product to use.

Through guidance of Sri Lanka Inventors Commission, around 50 pieces of face shields were distributed among the medical staff of five government hospitals in Sri Lanka. Here are the given comments by the medical staff of Kalutara government hospitals. Also through online business more than 500 pieces of face shields were sold for retail price (for 1 pieces of purchase) of Rs.250.00 all around the Sri Lanka.

- Very convenient product to wear
- All the elements of face are fully covered
- Feel more comfortable when using for longer periods
- No mist on the shield
- Face shield is properly fixed to head
- It is very easy to clean and can be reuse as a new face shield
- No pain for head

4. CONCLUSION

In this study, basic requirements of a face shield design were discussed based on safety and usage. By following these requirements a novel face shield design with improved safety aspects was explained in details. With compare to the existing products in the market this design has both horizontal and vertical collapsible features on a same design. On the other hand when compared to existing solutions this solution has ear guard protection which can be easily attached or detached based on user's preferences. Furthermore due to size adjustability of headband and forehead guard band, user feels more comfortable arrangement when compared to other products. Part separation capability is another significant different when compared to other face shields. Thus it is easier to clean all the parts properly. Due to usage of locally available material, manufacturing cost is minimized in order to maintain an affordable price for the final product.

ACKNOWLEDGEMENTS

This project was financially supported by Sri Lanka Inventors Commission.

REFERENCES

Amazon. (2020a, July 8). Medspec Protect Face Shield (Model FS-2.0) | Reusable Shields for Medical, Dental, & Essential Workers | Fogless & Adjustable Medical Face Guard with Quick-Release Lens System | Made in

The USA: Industrial & Scientific. Amazon. Com: https://www.amazon.com/Medspec-Protect-Essential-Adjustable-Quick-Release/dp/B08CRZDHPX/ref=sr_1_66?dchild=1&keywords=face+shield&qid=1610015333&sr=8-66

Amazon. (2020b, July 18). Face Shield, 10 Pack Clear Mask with Glasses for Kids and Adult, Anti-Fog Reusable Plastic Safety Face Shield No Installation Required with Comfortable Sponge and Elastic Band for Women Men. Amazon.Com. https://www.amazon.com/Protection-Reusable-Anti-Fog-Installation-Comfortable/dp/B08D8JFF5K/ref= sr_1_5?dchild=1&keywords=face+shield&qid=1610013896&sr=8-5

Amazon. (2020c, July 24). TCP Global Salon World Safety Face Shields with Glasses Frames (Pack of 10)—Ultra Clear Protective Full Face Shields to Protect Eyes, Nose, Mouth—Anti-Fog PET Plastic Sanitary Droplet Splash Guard. Amazon. Com. https://www.amazon.com/TCP-Global-Safety-Shields-Glasses/dp/B08DL29QNH/ref=sr_1_6?dchild=1&keywords=face%2Bshield&qid=1610014268&sr=8-6&th=1

Amazon. (2020d, December 6). 10 PACK Full Face Shield Protective Flip-Up Clear Anti Fog Reusable. Amazon.Com. https://www.amazon.com/Shield-Protective-Flip-Up-Clear-Reusable/dp/B08PS2BKRN/ref=sr_1_9?dchild=1&keywords=Flip-Up+face+shield&qid=1610014181&sr=8-9

WHO. (2020a). Sri Lanka | COVID-19| coronavirus| WHO. World Health Organization. https://www.who.int/srilanka/covid-19

WHO. (2020b). WHO Coronavirus (COVID-19) Dashboard | WHO Coronavirus (COVID-19) Dashboard With Vaccination Data. WHO Coronavirus (COVID-19) Dashboard. https://covid19.who.int/

WHO. (2020c, August 21). Coronavirus disease (COVID-19): Children and masks. World Health Organization. https://www.who.int/news-room/q-a-detail/q-a-children-and-masks-related-to-covid-19

WHO. (2021, January 6). Coronavirus disease (COVID-19) advice for the public. World Health Organization. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public

Low-cost negative pressure isolation chamber‡

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ABSTRACT

Covid 19 is a highly infectious disease that led to a pandemic worldwide(Cucinotta & Vanelli, 2020). One of the main challenges of the disease is its impact on the health care staff. The safety of the healthcare staff can be significantly compromised during patient transport since the team is exposed to the patient for a prolonged period. The Isolation pods are used to transport Covid 19 and other highly infectious diseases to mitigate this risk. We have developed a Low-Cost Negative Pressure Isolation Chamber, which was tested and proven effective and safe.

Key words: Isolation chamber, Low-cost, Negative pressure, Sri Lanka

1. INTRODUCTION

The negative pressure isolation pod was first described in 2002 and further developed in 2009 and 2012 by United States (Paschal Jr et al. 2002) (Kubicsko et al. 2009) (Paschal Jr et al. 2012). United States Army first used it to transport victims following biological or chemical terrorist attacks. Later this was developed further for use in both negative pressure and positive pressure isolation of patients in healthcare settings. The negative pressure mode protects the surrounding individuals from harmful organisms from an infected patient. The positive pressure operation is used to transport an immunocompromised patient to protect from harmful environmental agents. However, isolation pods are only used in developed countries due to the extremely high cost.

2. METHODOLOGY

Basic principles of the newly invented Low-cost negative pressure Isolation pod are the maintenance of the patient's physiology during the patient transport and the clearance of the infectious agents from the exhausted air. This device composed of two main components. The isolation chamber and control unit. The isolation chamber is made from collapsible, transparent polyethene. The control unit is consisting of a blower and UltraViolet C(UVC) light. The air from the chamber is exposed to a UVC light before exhausted to clear harmful pathogens. The airflow rate is maintained to be sufficient to ensure the air quality inside the chamber.

3. DISCUSSION

Covid 19 is considered a highly infectious disease that mainly transmits via droplets. But the air-born transmission occurs during aerosol-generating procedures when the exhaled air is composed of a high viral load (Kohanski et al. 2020). High flow oxygen and Non-invasive ventilation are considered aerosol-generating procedures (Kohanski et al. 2020). If the patient requires these to be

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Figure 1. Isolation chamber with a dummy inside

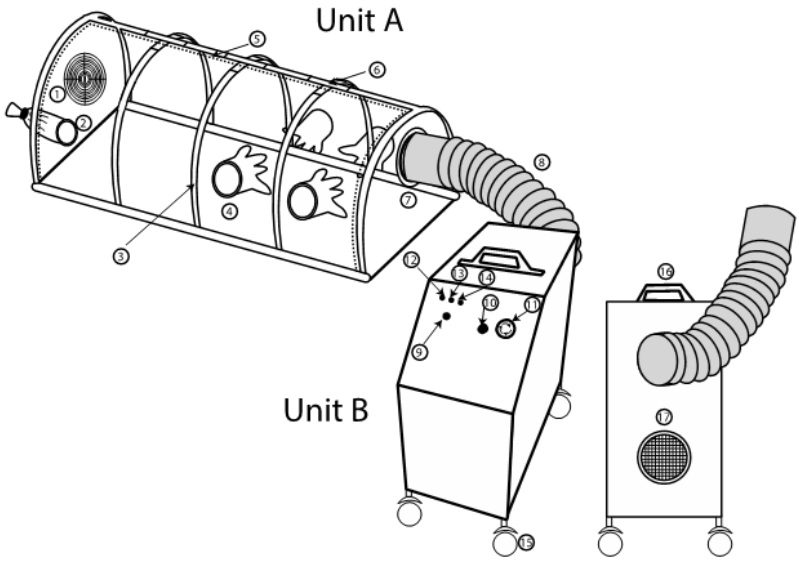

Figure 2. Low-Cost Negative Pressure Isolation Chamber technical details

Unit A- Polyethene Chamber

1. *Air inlet*
2. *Working port*
3. *Curved connectors*
4. *Gloves*
5. *Zip*
6. *Detachable connectors*
7. *Air outlet*
8. *The hose*

Unit B- Control Unit

9. *Power on button*
10. *Overload protection*
11. *Blower on and off button*
12. *Red light battery power indicator*
13. *Yellow light charging indicator*
14. *Greenlight system starting up indicator*
15. *Wheels*
16. *Handle*
17. *Air exit port*

continued during the transport, the risk to the accompanying health care staff is further increased. This risk can be minimised by the use of the Low-Cost Negative Pressure Isolation Chamber.

The safety of the product was tested in the Industrial Technology Institute. It is recommended that there should be at least 12 air cycles per min in the chamber to maintain a healthy environment inside the chamber(Luethge et al., n.d.). This was achieved in this unit by having more than 60L/min of airflow. Detailed safety checks were done with a volunteer inside the chamber. The carbon dioxide concentration inside the chamber was measured with the ultrasensitive infrared analyser. It was 448+/-7ppm, which is close to the atmospheric level. Further testing showed that the device could clear any accumulated carbon dioxide if the blower were not switched on before the patient entered the chamber. Humidity inside the chamber was 55+/-2% to 61+/-2%. The temperature inside the chamber was 33.12+/-0.12 ^{o}C to 33.61+/-0.15 ^{o}C. Oxygen concentration inside the chamber was 19.8+/-1%. Microbiological tests revealed 99% efficiency in the clearance of organisms. The healthy volunteers could stay inside the chamber for up to 4 hours continuously without significant discomfort.

4. CONCLUSION

A low-cost negative pressure isolation chamber successfully maintains adequate air quality parameters during patient transport to ensure patient safety. The device is also capable enough to clear 99% of the organisms to maintain the safety of the health care staff. A low-cost negative pressure isolation chamber will revolutionise the intra-hospital and inter-hospital transport of Covid 19 patients in Sri Lanka. This device is also helpful in other highly contagious diseases other than Covid 19. It can also be used to transport strangers with undiagnosed dangerous agents, which military personals can encounter.

SOURCE OF FUNDING

Inventors Commission

ACKNOWLEDGEMENT

Sri Lanka Inventors Commission, Industrial Technology Institute, Mr Mahesh Horawala Withana, Mr Sudarshana Kumara

REFERENCE:

Cucinotta, D., & Vanelli, M. (2020). WHO declares COVID-19 a pandemic. In Acta Biomedica (Vol. 91, Issue 1, pp. 157–160). Mattioli 1885.

Paschal Jr, C. R., Illi, O. J., Haubeil, G. W., Gauger, J. R., & Mullins Jr, R. L. (2002). Convertible Patient Isolation Pod.

Kubicsko, S., Cooper, P. J., & Buchanan, J. (2009). Collapsible Patient Isolation Pod.

Paschal Jr, C. R., Illi Jr, O. J., Haubeil, G. W., Gauger, J. R., & Mullins, R. L. (2012). Convertible Patient Isolation Pod.

Kohanski, M. A., Lo, L. J., & Waring, M. S. (2020). Review of indoor aerosol generation, transport, and control in the context of COVID-19. International Forum of Allergy & Rhinology, 10(10), 1173-1179. doi:https://doi.org/10.1002/alr.22661

Luethge, M., Frank, R. ;, John, R., & Hauser, M. (n.d.). ASSESSMENT OF OXYGEN AND CARBON DIOXIDE LEVELS IN A NEGATIVE PRESSURE INDIVIDUAL ISOLATION SYSTEM, ISO-POD ™.

Development of microorganism diverting and clearing device to mitigate the risks involved in Ambu ventilating a patient diagnosed with or suspected to have a contagious respiratory tract infection, including COVID-19‡

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ABSTRACT

Patients suspected of having severe/critical symptoms of COVID-19 need ventilator support, but the availability is a global concern. Use of primary ventilator care, such as Ambu ventilation, can be an alternative if the potential risks involved in a patient with a contagious respiratory tract infection, including COVID-19 in are mitigated.

We developed a Microorganism Diverting and Clearance Device (MDCD) which can potentially address limitations of current Ambu ventilating process with a patient diagnosed with a contagious respiratory tract infection.

Effectiveness of the Ambu ventilating process coupled with the prototype of MDCD was tested at the Industrial Technological Institute (ITI). Artificial bioaerosols were prepared with Staphylococcus aurous and passed through the MDCD under three conditions where the MDCD chamber filled with sterilized distilled water, 0.01% Hypochlorous acid (HOCl) solution and 0.01% HOCl solution coupled with a heat treatment mechanism. Microbial populations of input air and output air were measured. Tests carried out in duplicates, and percentage reductions were calculated.

The percentage reductions of the bacterial population between input and output air under three different test conditions were 41.6%, 77.7% and 86.1% respectively. The highest reduction (nearly 90%) of the bacterial population was achieved under the condition where the aerosol passed through the MDCD chamber filled with HOCl coupled with a heat treatment unit.

Complete elimination of microbial population may be achieved by adjusting HOCl concentration. This device has other potential applications such as to disinfect any airflow, clean a ventilator and can be fitted to Anaesthetic Gas Scavenging System (AGSS) terminal.

Key words: Ambu, Bioaerosol, COVID-19, Microorganism, Ventilator.

Patent number 21037

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1. INTRODUCTION

The current coronavirus disease 2019 (Covid-19) pandemic is a highly unpredictable situation characterized by therapeutic and logistic uncertainties. Patients suspected of having severe/critical symptoms of COVID-19 need ventilator support, but the availability is a global concern (Notz *et al,* 2020).

Use of primary ventilator care, such as Ambu ventilation, can be an alternative if the potential risks involved in a patient diagnosed with a contagious respiratory tract infection, including COVID-19 in Ambu are mitigated.

We developed a Microorganism Diverting and Clearance Device (MDCD) which can potentially address limitations of current Ambu ventilating process with a patient diagnosed with a contagious respiratory tract infection.

2. METHODOLOGY

Limitations of current Ambu ventilating process with a patient diagnosed with or suspected to have a contagious respiratory tract infection were identified considering three key areas of Ambu ventilation process namely,

1. Conventional Ambu bag
2. Microorganism filter
3. Active scavenging system

The prototype of the MDCD was developed, addressing the above limitations. The prototype comprises a chamber which has features to incorporate disinfecting processes through which the exhausting air passes.

Effectiveness of the Ambu ventilating process coupled with the MDCD was tested at the Industrial Technological Institute (ITI). Inoculation suspension was prepared with *Staphylococcus aurous* (ATCC 25923) with a minimum microbial population of 105 CFU/ mL. Artificial bioaerosols were generated using a nebulizer and passed through the MDCD under three conditions where the MDCD chamber filled with

1. sterilized distilled water
2. 0.01% Hypochlorous acid (HOCl) solution
3. 0.01% HOCL solution coupled with a heat treatment mechanism.

Exhausting air was collected into preprepared plate count agar in duplicates using an air sampler. Plates were incubated at 37+ 1*0* C for 48 + 2 hours, and the bacterial colonies were counted at each plate to calculate the percentage reduction in each condition.

3. RESULTS AND DISCUSSION

The percentage reductions of the bacterial population between input and output air under three conditions of MDCD chamber were given in Table 1.

Approximately, a reduction of 50% of the bacterial count between input and output air without was observed with the chamber filled with distilled water. The rate of reduction of the bacterial count between input and output air increases with the introduction of HOCl, which was further increased to 86.1% when a heat treatment unit was coupled with HOCl in the MDCD chamber.

Table 1. Percentage reduction of the bacterial population between input and output air under three different test convictions

Test condition (MDCD Chamber)	**Percentage reduction**
Bacterial population (aerosol) after passing through distilled water (condition 1)	41.6%
Bacterial population (aerosol) after passing through HOCl (condition 2)	77.7%
Bacterial population (aerosol) after passing through HOCl with the combined effect of heat treatment (condition 3)	86.1%

Thus this prototype can potentially

- Eliminate the risk factor to healthcare workers involved in Ambu ventilating a patient diagnosed with or suspected to have a contagious respiratory tract infection.
- Prevent the spreading of the microorganism to others through efficient isolation and destruction.
- Relieve the backpressure associated with filtration in a closed system

4. CONCLUSION

Complete elimination of microbial population may be achieved by adjusting HOCl concentration. This device has other potential applications such as to disinfect any airflow, clean a ventilator and can be fitted to Anaesthetic Gas Scavenging System (AGSS) terminal.

ACKNOWLEDGEMENT

Sri Lanka inventors commission (SLIC) for generous funding.

REFERENCES

Notz, Q., Herrmann, J., Stumpner, J. et al. Anästhesie- und Intensivbeatmungsgeräte: Unterschiede und Nutzbarkeit bei COVID-19-Patienten. Anaesthesist 69, 316–322 (2020). https://doi.org/10.1007/s00101-020-00781-y

QR Code based application approach for issuing smart curfew passes‡

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ABSTRACT

Due to the number of curfew violations increasing almost up to 62,000 within the first two months (Hapuarachchi, 2020), it is observed that an effective and robust method is required to prevent people from misusing the issued curfew passes as well as to avoid the use of forged curfew passes.

It is found that most of the curfew pass violations are possible because of the way the officers must interact and validate the information. Another most common way is the use of forged curfew passes (DailyFT, 2020), which are very difficult to identify since the existing version of curfew pass is printed on regular paper, which could be easily faked using a household printer.

Key words: QR code, Curfew pass, Curfew violations, Identification system, Smart pass, Management system

1. INTRODUCTION

Since it is an essential and crucial task to prevent the general public from gathering and practice social distancing in order to curb the spread of COVID-19 (Hapuarachchi, 2020) while maintaining the critical services of the country, it has been quite a challenge for the police to distinguish essential service personnel from the general public on the roads. Due to the number of curfew violations increasing almost up to 62,000 within the first two months (Hapuarachchi, 2020), it is observed that an effective and robust method is required to prevent people from misusing the issued curfew passes as well as to avoid the use of forged curfew passes. In this case, identifying these violations is a challenging task and ineffective use of police officers' precious time in these harsh times.

The solution is to store the data in a centralised database, which can be accessed by the officers in the field very quickly without having to use any special equipment or expertise.

We propose to build a low-cost yet reliable system to store the information of issued curfew passes in a centralised database and to print a QR code (DailyFT, 2020) along with the pass, which will allow the officers on the road to quickly scan with their smartphone and extract the information from the database and validate. This will allow some corollary advantages as well, which will be discussed later in the paper.

2. RELATED WORKS

This section will investigate the technology related to the QR code and introduce the curfew pass issuing system's technology.

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2.1. QR Code

The QR code is a two-dimensional bar code matrix type that displays the black and white plaid pattern information. In China, Japan, Korea, the United Kingdom, and the United States, the QR code is mainly used, and the name is derived from the 'Quick Response' trademark of Denso Wave. By overcoming the capacity shortcomings of conventional bar codes, extended-form two-dimensional bar codes, and contents with length and width information, character data can be stored in addition to numbers. Typically, it is used by reading it with a dedicated digital camera or scanner (Denso Wave Inc., 2019).

Conventional bar codes can store one-dimensional numbers or text information. In contrast, QR codes can store even more information by providing two-dimensional horizontal and vertical directions in which character details such as alphabets and Chinese characters can be stored in addition to numbers. For the size of the QR code, the program's version is determined by the volume of text, the type of character, and the mark for error recovery, and the cell is fixed by the resolution of the printer or scanner. The version consists of 1-40 and has a predetermined number of cells for each version. A quadrangle point that forms the QR code is a cell. There are 21 cells horizontally and 21 cells vertically in the cell starting with version 1, and 4 cells are expanded with each version increase, and in version 40, 177 cells per 177 cells are set to be contained. Figure 1 shows the structure of the QR-code.

QR-code is divided into different zones, including quiet region, locating pattern, timing pattern, orientation pattern, format information, version information, data, error correction keys, etc., in order to scan data. All info, including numbers, English characters, Chinese characters, Korean characters, symbols, binary and control code, etc., can be processed by QR-code. Up to 7,089 characters (numbers) with one code will convey the quantity of information.

Recently, the improved QR-code iQR-code was developed. More data volumes than the current QR code can be saved by iQR-code. Besides, the iQR-code will produce smaller codes than the current QR-code. It can save up to 80 per cent higher information quantities if it has the same size as QR-code. If it has the same information quantity, it can generate 30 per cent smaller information size quantities (Yu et al., 2013).

The error correction level for the QR-code is up to 30 per cent of the whole code, which means that the code can be restored with this percentage of the smeared or corrupted area. This is boosted to 50 per cent with the iQR-code, on the other side.

2.2. Existing curfew pass issuing and identification system

It is found that most of the curfew pass violations are possible because of the way the officers must interact and validate the information. Most of the violations are happened by carrying unauthorised personnel other than the allowed people in the curfew

Figure 1. *Structure of the QR Code*

pass. To validate, a police officer must manually go through each person's identification documents and compare them with the issued curfew pass, which requires interacting closely with the people. This method is prone to result in errors while sparing valuable time. Another most common way is the use of forged curfew passes (DailyFT, 2020), which are very difficult to identify since the existing version of curfew pass is printed on regular paper, which can be easily faked using a household printer. To verify a pass, a police officer must contact the police station and confirm there manually.

An integrated curfew pass management system (Park & Moon, 2007) that automatically handles the issuing and authentication processes using such technologies has been widely researched and developed due to auto-recognition technology such as RFID sticker, card biometric technology such as fingerprint recognition, facial recognition, etc.

The automated curfew pass management framework (Josphineleela & Ramakrishnan, 2012) based on RFID is a system that automatically aggregates the specifics of the given curfew pass when the smart card attached to the RFID tag is recognised by the reader mounted at the security checkpoint and provides efficient confirmation of a curfew pass compared to the previous manual process. The scheme, though, is costly to install and requires challenges such as the opportunity to loan the smart card, fraud, and the downside of not recognising the pass when the smart card is missing or not in possession.

An automatic fingerprint-based curfew pass tracking device is a system that aggregates the specifics of the given curfew pass by identifying the fingerprint of individuals using a fingerprint reader is a trustworthy technique that can recognise the User without the issue of being misplaced, loaned, or stolen. However, it has the drawbacks of being costly to construct like the RFID-based system and a significant disadvantage of being unhygienic.

A client-server framework was built along with facial recognition methods to boost the authentication of the individual cardholder in a previous electronic validation system (Lee, 2010) based on the smart card, which automatically handles the validation of the corresponding pass by recognising the facial information of the User with the support of a neural network. It has demonstrated more than 92 per cent reliability due to evaluating the CS context system to validate the developed system.

Due to unmanned service, such an automated device reduces the time to verify the curfew pass. It has the benefit of checking the authenticity of the pass by itself over the Internet. However, there is an expensive issue with the implementation expense of installing the device to structure the integrated system since it needs different devices such as RFID readers, fingerprint readers, clickers, etc. Besides, complications such as not being remembered when the smart card is missing or not in possession, loaning of cards or using counterfeit cards, and a complicated validity check situation due to the devices' malfunction, such as reader error faulty cards, may be present. See Table 1.

An electronic curfew pass validation scheme that strengthens and supplements existing systems' drawbacks is suggested in this article.

3. DESIGN OF SMART CURFEW PASS SYSTEM

The smart curfew system's main challenge is to reduce the system installation effort, implementing tamper prevention techniques, and avoiding machinery breakdown.

The features suggested in this paper are recognising the curfew pass by using the QR code where the pass is automatically processed by recognising the police station's QR code. This does not require extra reader transactions for the authentication scan to be completed and has no installation fee. Since the pass is accepted using the police officer's smartphone, the curfew pass's probability of breach is very little.

Table 1. Comparison results between RFID, Barcode and QR

Characteristic	RFID	Barcode	QR
Reads per Second	200	2	8
Read Range	25 feet	2 inches	>14 inches
Read/ Write	Yes	No	No
Anti-collision capabilities (simultaneously read capabilities)	Yes	No	Yes
Cost	> 40 LKR	0.5 LKR	< 0.1 LKR
Reusability	More	Less	Less
Human Intervention	Less	More	Less
Line of sight required	No	Yes	Yes
Read Speed	200 milliseconds	< 1 second	< 500 milliseconds
Dirt Influence	No effect	Very High	Less
Security	More	Less	More

Figure 2 shows the flowchart of the proposed smart curfew pass system in this paper.

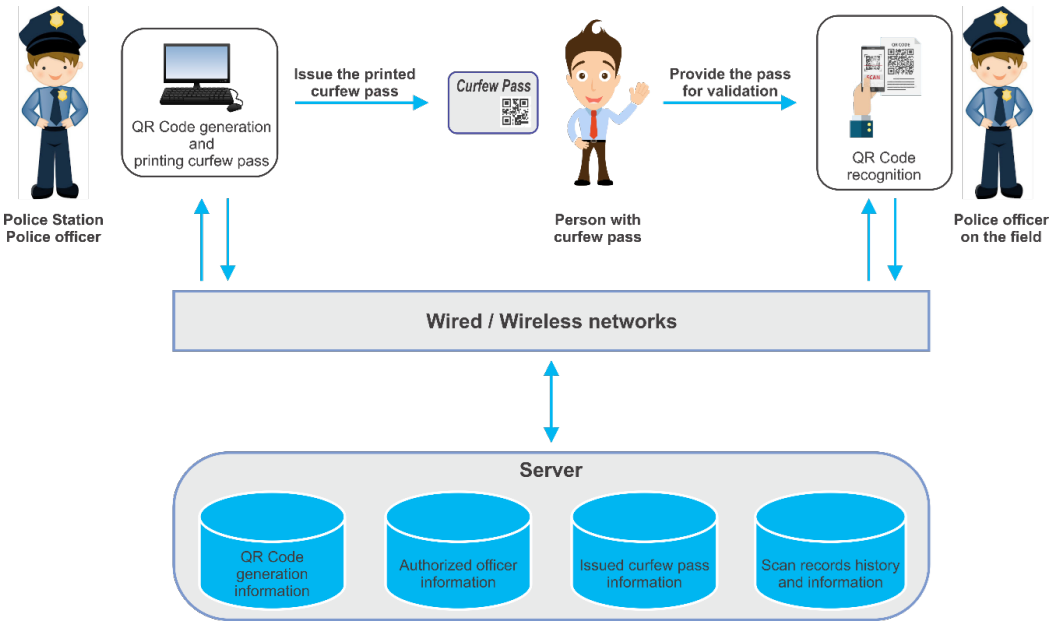

Figure 2. *Flow of the Smart Curfew System*

3.1. Design of QR Code Generator and Reader

The QR code generator and readers are widely used and developed. However, the QR code generator and readers previously created do not encrypt the QR code contents, so it is at risk of leakage.

In the proposed centralised server, the QR code generator produces the QR code. It stores information about personal identity information for validation control within the QR code created at that time (ID number, Face photo, validity period, etc.). It produces a unique QR code any time a pass is given to avoid QR code misuse. The information inserted into the QR code will also be used for encryption by the seed encrypted algorithm. The contents of the QR code could not be identified unless a dedicated reader is used. The QR code is generated on the server by the issuing police station, and the police officer may choose the media to display the generated QR code, such as on a printed curfew pass.

By obtaining the information embedded in the QR code after the QR code is accepted, the QR code reader sends the obtained information and the officer's identity to the server. After processing the transmitted data and after updating the data, the server renews the database to fulfil the User's condition.

3.1.1. Design of Database for Attendance Management System

The database structure for configuring the system consists of *Police_user, User, Curfew_Pass*, and *Vehicle*. First, *Police_user* is a table to check whether the User is valid or whether the person accessing is a station officer or a field officer. When the software is executed to use the suggested method, it cannot log every time the authentication is first accessed.

Curfew_Pass is a table containing the pass information, the given station, the number of the Vehicle, and in the case of the *User*, it is a table containing the information of individuals requesting the smart pass, identity information and the purpose of the curfew pass, and the *Vehicle* is a table containing vehicle information and used as the primary data in the *Curfew_Pass* table to list the vehicle data.

The server generates the QR code based on the *Curfew_Pass* table, and the QR code generates a link to accessing the data of this table.

Figure 3shows the database structure of the proposed smart curfew pass system in this paper.

4. DEVELOPMENT OF SMART CURFEW SYSTEM USING QR CODE

The framework introduced in this paper is enforced with a server-related program, the application program of station officers, and the field officers' application program. For the server-related program, the Linux-based apache server was used, MySql for the database and PHP was used to build the web interface.

On request from the station officer, the QR code is created on the server, and for protection, seed algorithm is used for encryption and inserted into the QR code. The android-based field officers' software was separately built using the eclipse for the application program.

It can be tested for generation and status. In the field officers' mode, QR code recognition and validity stats can be checked.

4.1. Application Program for Police Officer on the field

The configuration of the main menu screen of the field officer's application is shown in Figure 4, displaying the curfew pass information.

4.1.1. Application Program for Generating Curfew Pass

The configuration of the main menu screen of the field officer's application is shown in Figure 5, Figure 6, Figure 7, which consists of user authentication, generation of QR

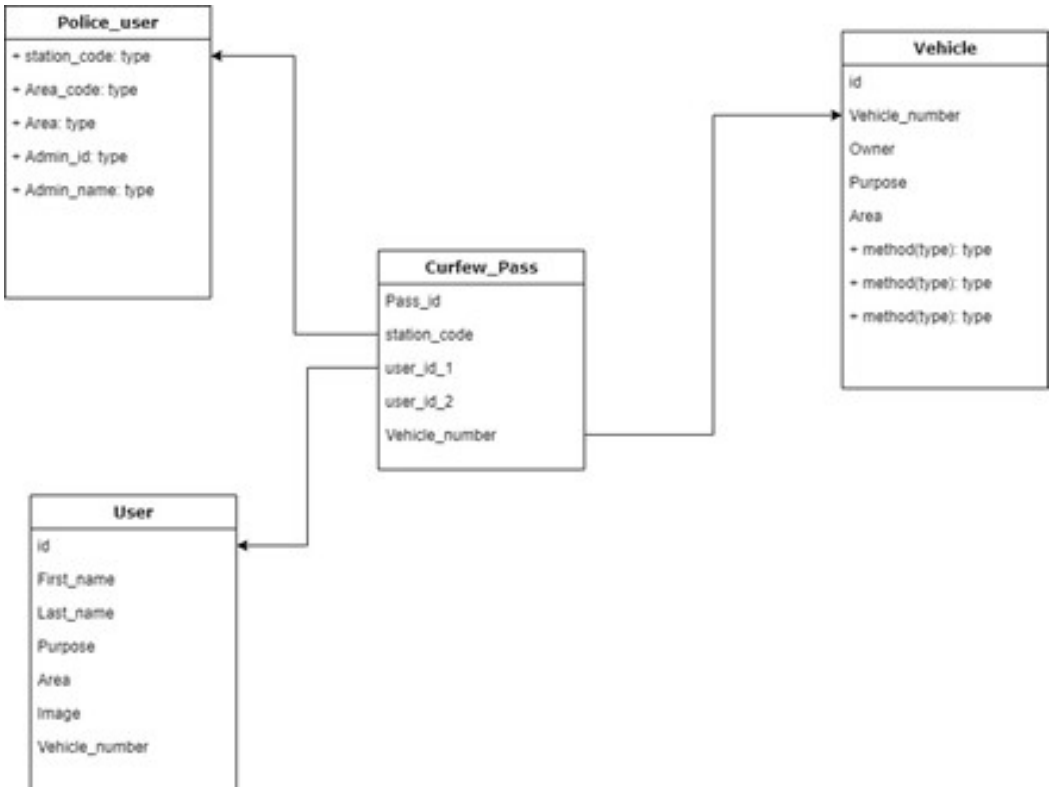

Figure 3. *Database Structure*

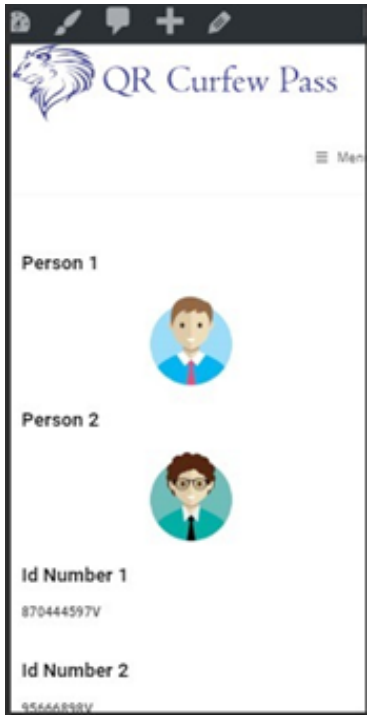

Figure 4. *Mobile Application*

code, displaying curfew pass information and termination of the program.

5. CONCLUSION

There are problems with the previous curfew pass issuing and identification system, such as fake pass generation, pass misuse by loaning the pass to their mates, system recognition rate, and failure to recognise fakes due to weak verification methods.

In this paper, a smart curfew pass method using the QR code was suggested to improve such issues. For the validity check, the proposed system does not require a separate purchase of the QR code generator. Besides, to recognise the created QR code, it does not require a separate purchase of the QR code reader. Since the application developed in the proposed system can be accessed by police officers on the ground using their smartphones to be used as a reader, there are no costs incurred for buying the equipment to be used for generating or reading, so it is economical as

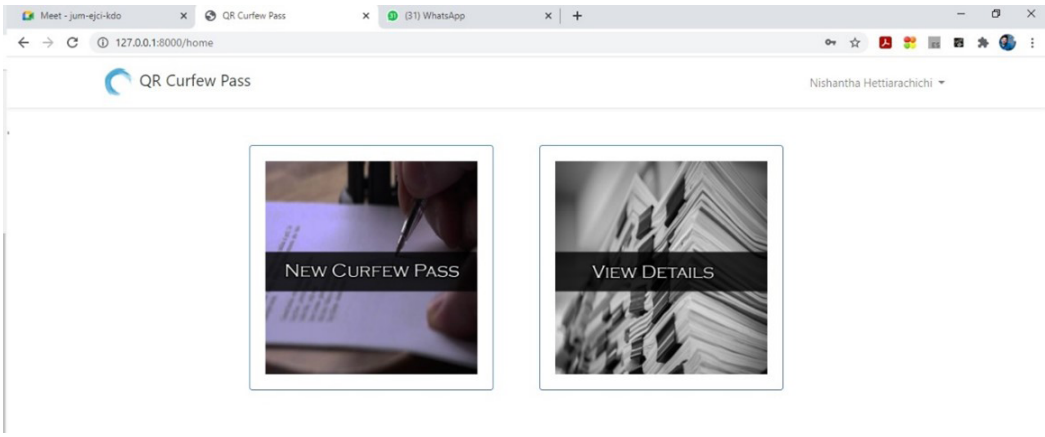

Figure 5. *Main screen of desktop application*

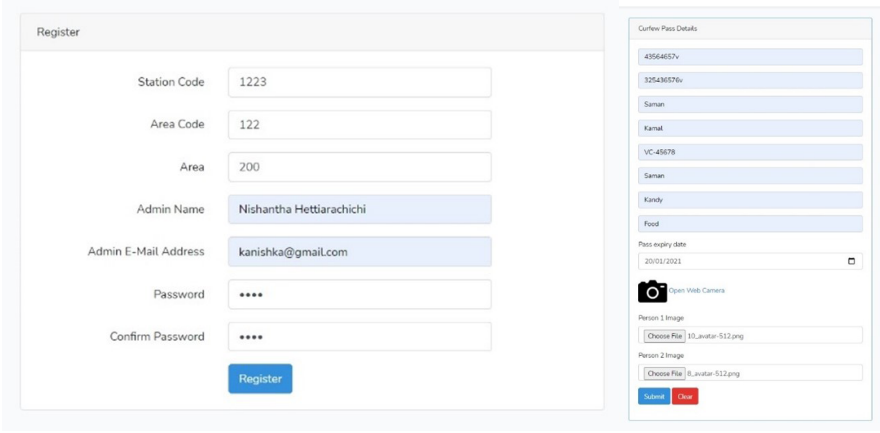

Figure 6. *Data collection screens*

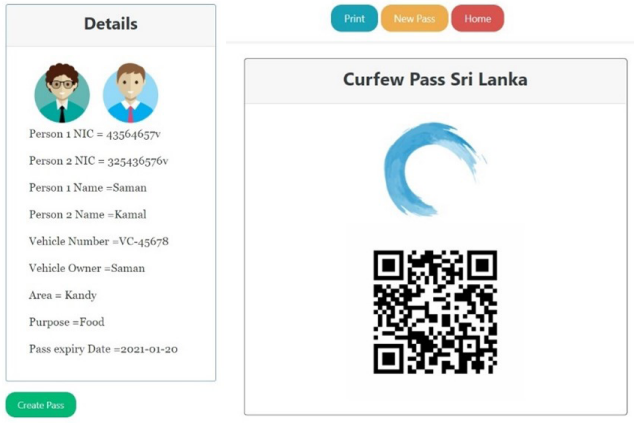

Figure 7. *Generated Curfew pass*

it does not raise the construction costs when installing the system. To solve the issue of "fake pass generation," the QR code is encrypted in the proposed framework, and the server is implemented with different security features.

Even if parts of the code are contaminated or impaired, the QR code has a higher recognition rate than the bar code where it can still be recognised, decreasing the case of not being able to recognise due to code damage.

The future study aims to strengthen the framework proposed to be extended to any situation connected to several access control and management systems.

REFERENCES

DailyFT. (2020, April 3). *COVID-19 death toll climbs to 4; cases top 150 mark | Daily FT*. DailyFT. https://www.ft.lk/front-page/COVID-19-death-toll-climbs-to-4--cases-top-150-mark/44-698469

Denso Wave Inc. (2019). *QRcode.com/DENSO WAVE*. QR Code.Com. https://www.qrcode.com/en/index.html

Hapuarachchi, P. (2020, May 22). *Nearly 7,000 people penalized for curfew violations: SL Police*. News 1st. https://www.newsfirst.lk/2020/05/22/nearly-7000-people-penalized-for-curfew-violations-sl-police/

Josphineleela, R., & Ramakrishnan, M. (2012). An Efficient Automatic Attendance System Using Fingerprint Reconstruction Technique. *International Journal of Computer Science and Information Security*, *10*(3), 77–82.

Lee, W. B. (2010). A Attendance-Absence Checking System using the Self-organizing Face Recognition. *The Journal of the Korea Contents Association*, *10*(3), 72–79. https://doi.org/10.5392/JKCA.2010.10.3.072

Park, S.-H., & Moon, B.-C. (2007). The Development of Attendance Management System Using the RFID. *Journal of The Korean Association of Information Education*, *11*(2), 139–146.

Yu, X., Song, Y., Yu, Y., Yu, S., Cheng, H., & Guan, Y. (2013). An Encryption Method for QR Code Image Based on ECA. *International Journal of Security and Its Applications*, *7*(5), 397–406. https://doi.org/10.14257/ijsia.2013.7.5.36

Development of a pneumatically driven, time-cycled ventilator with user-determined volume and pressure control capability‡

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ABSTRACT

The outcome of this research is a ventilator, with pneumatic and electronic sensing & control system, which monitors, assists, or control pulmonary ventilation and respiration in intermittent or continuous modes. Our ventilator provides the most essential functions in three modes of operation, namely, continuous, synchronous, and spontaneous. The user is facilitated with the touch-sensitive screen to enter required and appropriate parameters within each mode of operation such as tidal volume, frequency, Oxygen percentage, inspiration to expiration ratio and trigger sensitivity.

Key words: ***Time-cycled ventilator, Control pulmonary ventilation, Respiration, Intermittent mode, Continuous mode, Volume control, Pressure control***

1. INTRODUCTION

As the Covid-19 virus spreads across the world, the intensive care unit (ICU) faced the numerous challenges. Management of acute respiratory failure and hemodynamics instability were the key components in severe form of disease. Hospital administrators at the preliminary level and policymakers at the strategic level were expected to be prepared for a substantial increment in critical care infrastructure and supplies. Critical care management may include the rationing of scarce ICU resources such as ventilators.

Hence there is a dire need for a ventilator design that can be mass manufacturable especially at a low cost and with minimal manufacturing facilities. Any proposed design demands the possession of the essential facilities which should be achieved with off-the-shelf components. The pathology of the lungs is dynamically changing; therefore, the ventilator design should possess the facilities to adapt to the change in a user-friendly manner. Collaboration at the local, & international level or industry & academics would facilitate the best chance of survival for the population already in danger.

For the management of acute respiratory failure, access to a ventilator is one of the essential equipment. The ventilator is a pneumatic and electronic sensing & control system, which monitors, assists, or control pulmonary ventilation and respiration in intermittent or continuous modes, to control the human body's oxygen /carbon dioxide levels. The main outcome of this research is a ventilator, which has a pneumatic and electronic sensing & control system, which monitors, assists, or control pulmonary

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ventilation and respiration in intermittent or continuous modes.

2. PREVIOUS WORK

The number of products are currently available in the market and also many research work are in progress to develop a novel ventilator models. The development efforts are directed in multi-faceted directions. One of the key directions is the improvement of the functions of the equipment such that the quality of the patient experience would be enhanced. The second direction is incorporating intelligence to facilitate the assistive decision-making process by the medical practitioner. Thirdly more use-friendly interfaces and ergonomics are being developed.

In (Putensen et al.,2001; Varpula et al.,2004; Maxwell et al.,2010; González et al.,2010; Keilty et al.,2010), authors have explained methodologies like positive pressure ventilation and airway pressure release ventilation. One of the modes in application commercially is called, bilevel or biphasic positive airway pressure ventilation, where the equipment maintains two pressure levels as high and low to support the inspiratory and expiratory efforts of the patient respectively. Pressure-targeted synchronized intermittent mandatory ventilation, which allows the patient to breathe spontaneously, during both the inspiration and expiration processes. Another recent introduction is high-frequency ventilation (Froese,1998; Chang, 1984; Fessler et al., 1984; Bollen et al., 1984; Courtney et al., 1984; Sud et al., 1984; Young et al., 1984; Ferguson et al., 1984), where high frequencies within the range from 120 – 900 breaths/ minute with small tidal volumes provide the gas exchange with the lungs. As per (Chang, 1984) augmented diffusion coaxial flows and Taylor dispersion techniques are being practiced in the aforesaid gas exchange process.

Another innovation is the automation of the weaning process (Branson et al., 1984), with the underlying concept is saving of time factors based on several ventilator measurements. The aforesaid concept has been commercialized as automatic pressure ventilation or simply volume support (Branson et al., 1984), as a novel alternative to conventional pressure-based ventilation. However, the volume support ventilation can be considered as a pressure support methodology that utilizes tidal volume as a feedback control parameter of the pressure control process. However, (Branson et al., 1984; Jaber et al., 1984) points out that volume support could prone to failures at the number of occurrences, such as both high and low volume settings. For example, if the volume setting is more excess than demanded by the patient, then recovering patients may not endeavor to revert to the natural breathing process and patient fatigue may result due to insufficient volume settings due to extra effort demanded to maintain a certain tidal volume. As highlighted in (Petter et al., 1984), the adaptive support ventilation scheme adopts the rhythm of ventilation during the machine trigged efforts, also states that the scheme could adoptively wean ventilatory support safely. The work (Lellouche et al., 1984), presents a scheme based on the feedbacks of tidal volume, respiratory frequency, and end-tidal carbon dioxide volume to control the ventilation.

Considerable research efforts have also been launched to improve the synchronization of the ventilation process of the patient. The works (Fabry et al., 1984; Guttmann et al., 1984), explains a scheme, called endotracheal tube resistance compensation, which has been commercialized as automatic airway or tube compensation. The aforesaid scheme is based on the concept, due to the resistive effect of the endotracheal tube, the built-up pressure in the airway circuit lags the same as the ventilator circuit, hence resulting in a lesser gradient and intern could lead to lack of synchronization. The solution proposed is to compensate the flow delivery as per a mathematically calculate the endotracheal resistance. The initial inspiratory pressure starts from a higher value and in turn reach the inspiratory pressure setting and vice versa for expiratory pressure

Pressure gradient adjustment to improve the flow synchronization is proposed in (Ho & MacIntyre 1984), which will be adjusted as per

the state of the patient, by generating a smooth square wave pressure profile. However optimal gradient for an appropriate tidal volume for a given pressure is patient dependent. An effort to improve breath cycle synchronization with pressure support has been addressed in (Tokioka et al., 1984). The research was to find a solution for the too early or too late flow ceasing phenomena. The solution is to adjust the flow criteria of the pressure support cycle to keep the synchronization of the cycle with the end of patient effort taking the patient comfort as a guide for adjustments.

A scheme called, proportional assist ventilation is proposed in (Lellouche & Brochard, 1984; Younes, 1984). The scheme can be explained as a processed analog to an amplification of the patient's effort to assist himself. The scheme takes controlled breaths with fixed flow and volume as inputs and algorithms calculate the resistive and elastic ventilatory muscle loads, which will be repeated periodically for continuous updating of the process. The initiation may be based on either flow or pressure and flow delivery & pressure varies with the patient's effort.

A neurally adjusted ventilatory assistance scheme is addressed in (Sinderby & Beck , 1984; Grasso et al. , 1984; Bosma et al., 1984; Ranieri et al. , 1984; Sinderby , 1984), which makes diaphragmatic electromyographic pulse for triggering, by utilizing an esophageal catheter with an array of diaphragm EMG sensors, which sense the initiation, intensity, and ceasing of the patient effort. Depending on the aforesaid pulse input the pressure and flow delivery will be calculated.

3. METHODOLOGY

The product presents a complex and urgent application of knowledge, which demands accurate measurement, correct instrumentation, power management, and signal integrity on which human life may be dependent. In this research study, we have carried out the design of a ventilator with the most essential functions that can be switched to three modes of operation, namely, continuous, synchronous and spontaneous. The user is facilitated with the touch-sensitive screen to enter required and appropriate parameters within each mode of operation such as tidal volume, frequency, Oxygen percentage, inspiration to expiration ratio, system sensitivity.

The proposed ventilator is a matched integration of a compressed air tank, air and oxygen inputs, a set of valves and tubes, and a patient circuit of tubing. The compressed air tank is pneumatically compressed to supply an air/oxygen mixture. The lung's elasticity is utilized to release the overpressure, also called passive exhalation, and expiration is released usually through a one-way valve within the patient circuit tubing. The oxygen percentage of the inspiration supply can be adjusted from 21% (ambient air) to 100% (only oxygen). The prototype design simulates basic human lung function and is meant to be utilized in pulmonary therapies where lung is compromised. The goal of the first phase of this project is to prove that our concept is working and examine its technical feasibility.

4. THE VENTILATOR SUBSYSTEMS

The two main sub-systems of the ventilator are the valve system and the mixing chamber as depicted in Figure 1 below.

The internal view with control valves on the right side of Figure 2 can be seen below. Furthermore, the connections to the patient and from the patient can be seen on

Figure 1. The main two subsystems of the ventilator

Figure 2. The controller and control valves

the left middle of Figure 2. The white box on the bottom of Figure 2 contains the main controller and on the right side of that, the vertically mounted box contains the 24V DC power supply. We utilized a microcontroller as the main controller of our ventilator.

5. THE VENTILATOR MENU SYSTEM

We endeavored to make the menu system as simple as possible. The initial window indicates the three ventilation modes namely, Continuous Mandatory (CMV), Synchronized Intermittent Mandatory (SIMV), and Continuous spontaneous (SPON) on the touch-sensitive screen, as depicted in Figure 3.

Once the user selects any of the modes, depending on the mode the appropriate parameters will be appeared on the second screen for the user to enter the values as presented in Figure 4.

Once all the parameters are set user has either the option of in the same window or shift to the next window by pressing the 'Graphic' button indicated in blue color on the bottom

Figure 3. Basic Modes of Ventilation

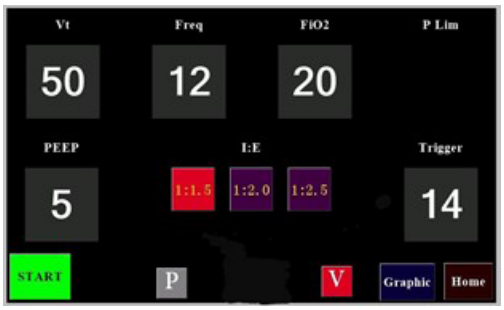

Figure 4. Entering the parameters for the selected mode

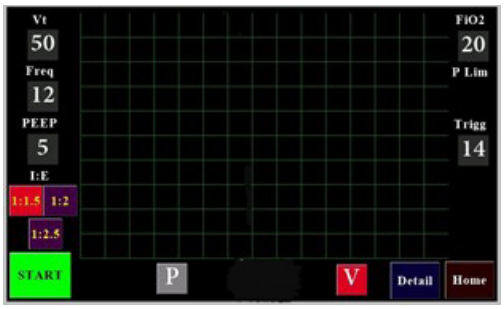

Figure 5. The window for a detailed profile view of the operation

right corner of the screen and will be shifted to the window depicted in Figure 5.

In either window 2 or 3 to start the operation of the ventilator within any of the selected modes, the user has to just press the 'START' button of green color that can be seen on the bottom left corner of both Figure 4 and Figure 5.

6. TEST TRIALS

We conducted several trials as indicated in Figure 6, Figure 7, Figure 8 and Figure 9. However, the system was not tested on human patients yet. During the test trials, we found that the micro-controller we used was not reliable for long-term usage, and decided to

Figure 6. The System Connections in Theatre setup

Figure 7. The System Connections from the Ventilator

Figure 8. Workshop Testing of Valves and performance of the Controller

utilize an industrial-grade programmable logic controller for the next phase of our project.

7. CONCLUSION

The proposed ventilator, which has pneumatic and electronic sensing & control system, which monitors, assists, or control pulmonary ventilation and respiration in intermittent or continuous modes, was achieved with successful performance. The goal of the first phase was to prove our concept and examine its technical feasibility, which was also achieved. The lessons learned will be utilized for the improvements of the methodology

Figure 9. The system connected for testing with an artificial lung

and system features of the second phase of the project.

8. FUTURE WORK

At present we are in the process of completing the second phase of the project utilizing an industrial-grade programmable logic controller as the main controller unit. Clinical trials after ethical clearance and National Medicines Regulatory Authority approval is required prior to utilization at clinical environments. The proposed system under the second phase is comprised of several novel facilities, which could not be found in contemporary ventilators.

REFERENCES

Bollen, C.W., Uiterwal, S.P.M., vanVught, A.J. (2005). Cumulative meta analysis of high frequency vs conventional ventilation in premature neonates. *Am J Respir Crit Care Med*, 168, 1150–1155.

Bosma, K., Ferreyra, G., Ambrogio, C., et al (2007). Patient-ventilator interaction and sleep in mechanically ventilated patients; pressure support versus proportional assist ventilation. *Crit Care Med,* 35(4), 1048–1054.

Branson, R.D. & MacIntyre, N.R. (1996). Dual control modes of mechanical ventilation. *Respir Care*, 41, 294–305.

Chang, H.K. (1984). Mechanisms of gas transport during high frequency ventilation. *J Appl Physiol*, 56, 553–563.

Courtney, S.E., Durand, D.J., Asselin, J.M., et al (2002). High frequency oscillatory ventilation vs conventional mechanical ventilation for very low birth weight infants. N Engl J Med, 347, 643–652.

Fabry, B., Zappe, D. & Guttman, J. (1997). Breathing pattern and additional work of breathing in spontaneously breathing patients with different ventilatory demand during inspiratory pressure support and automatic tube compensation. *Intensive Care Med,* 23, 545–552.

Ferguson, N.D., Cook, D.J., Guyatt, G.H., et al (2013). High-frequency oscillation in early acute respiratory distress syndrome. *N Engl J Med*, 368(9), 795–805.

Fessler, H.E., Hager, D.N., Brower, R.G. (2008). Feasibility of very high-frequency ventilation in adults with acute respiratory distress syndrome. *CritCare Med*, 36(4), 1043–1048.

Froese, A.B. (1998). High frequency oscillatory ventilation for ARDS: let's get it right this time. *Crit Care Med*, 25, 906–908.

González, M., Arroliga AC, Frutos-Vivar F, et al (2010). Airway pressure release ventilation versus assist-control ventilation: a comparative propensity score and international cohort study. *Intensive Care Med*, 36(5), 817–827.

Grasso, S., Puntillo, F., Mascia, L., et al (2000). Compensation for increase in respiratory workload during mechanical ventilation. Pressuresupport versus proportional-assist ventilation. *Am J Respir Crit Care Med*, 161(3 Pt 1), 819–826.

Guttmann, J., Haberthür, C., Mols, G., Lichtwarck-Aschoff, M. (2002). Automatic tube compensation (ATC). *Minerva Anestesiol*, 68(5), 369–377.

Ho, L. & MacIntyre, N.R. (1991). Effects of initial flow rate and breath termination criteria on pressure support ventilation. *Chest*, 99, 134–138.

Jaber, S., Delay, J.M., Matecki, S., et al (2005). Volume-guaranteed pressure support ventilation facing acute changes in ventilatory demand. *Intensive Care Med*, 31, 1181–1188.

Keilty, K., MacLusky, I. B., & Padman, R. (2007). Noninvasive Positive-Pressure Ventilation. *Comprehensive Pediatric Hospital Medicine*, 1268–1272. doi:10.1016/b978-032303004-5.50213-1.

Lellouche, F. & Brochard, L. (2009). Advanced closed loops during mechanical ventilation (PAV, NAVA, ASV, SmartCare). *Clin Anaesthesiol*, 23, 81–93.

Lellouche, F., Mancebo, J., Jolliet, P., et al (2006). A multicenter randomized trial of computer-driven protocolized weaning from mechanical ventilation. *Am J Respir Crit Care Med*, 174, 894–900.

Maxwell, R.A., Green, J.M., Waldrop, J., et al (2010). A randomized prospective trial of airway pressure release ventilation and low tidal volume ventilation in adult trauma patients with acute respiratory failure. *J Trauma*, 69(3), 501–510.

Petter, A.H., Chiolero, R.L., Cassina, T., et al (2003). Automatic "respirator/ weaning" with adaptive support ventilation: the effect on duration of endotracheal intubation and patient management. *Anesth Analg*, 97, 1743–1750.

Putensen, C., Zech, S., Wrigge, H., et al (2001). Long term effects of spontaneous breathing during ventilatory support in patients with ALI. *Am J Respir Crit Care Med*, 164, 43–49.

Ranieri, V.M., Giuliani, R., Mascia, L., et al (1996). Patient ventilator interaction during acute hypercapnia; pressure-support vs. proportional-assist ventilation. *J Appl Physiol*, 81, 426–436.

Sinderby, C. (2002). Neurally adjusted ventilatory assist (NAVA). *Minerva Anestesiol*, 68, 378–380.

Sinderby, C. & Beck, J. (2008). Proportional assist ventilation and neurally adjusted ventilatory assist–better approaches to patient ventilatory synchrony? *Clin Chest Med*, 29(2), 329–342.

Sud, S., Sud, M., Friedrich, J.O., et al (2010). High frequency oscillation in patients with acute lung injury and acute respiratory distress syndrome (ARDS): systematic review and meta-analysis. *BMJ*, 18(340), c2327.

Tokioka, H., Tanaka, T., Ishizu, T., et al (2001). The effect of breath termination criterion on breathing patterns and the work of breathing during pressure support ventilation. *Anesth Analg*, 92(1), 161–165.

Varpula, T., Valta, P., Niemi, R., et al (2004). Airway pressure release ventilation as a primary ventilatory mode in acute respiratory distress syndrome. *Acta Anaesth Scand*, 48, 722–731.

Younes, M. (1992). Proportional assist ventilation, a new approach to ventilatory support. *Am Rev Respir Dis*, 145, 114–120.

Young, D., Lamb, S.E., Shah, S., et al (2013). High-frequency oscillation for acute respiratory distress syndrome. *N Engl J Med*, 368(9), 806–813.

Drone network to combat impending Covid19 pandemic conditions‡

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ABSTRACT

An outline of an initial drone ecosystem for Sri Lanka and its system in place for handling Covid 19 has been discussed, taking into consideration various accredited sources from recent literature on best practices implemented globally and some adjustments where the authors feel could be done differently. The phase-wise implementation of the network could help Sri Lanka and other developing nations leverage emerging technologies to improve their overall infrastructure. Initially, tasks focused on would be visually orientated tasks using advanced algorithms to gather useful metrics and simple logistics. The network is designed to streamline data gathering and processing ability for field teams to make calculated and coordinated responses to emerging issues.

The pandemic has exposed us to various challenges, from a medical and social standpoint the risk of infection at close contact requires the general public to adhere to guidelines set out by the health authorities. The risk posed to social workers during an outbreak such as disinfecting locations and ensuring social distancing and adherence to wearing a face mask during a pandemic is real world challenge. Further, complexities of logistics especially in critical medical supply chains such as blood bank requirements, transportation of PCR samples, antigen test kits, and vaccine distribution to and from rural areas have impacted the overall quality of healthcare services.

This paper identifies limitations in human capital in terms of drone operators and policy limitations such as an absence of defined airspace for civilian drone operations and lack of operator certifications for safer flights which requires further debate. The paper however limits its focus to optimizing the gathering and evaluating process for information usability from various sources such as drones and other ministries on a centrally operated algorithm to allow for better-informed decision making in real-time. This factor has been identified as an important gap that if addressed correctly could improve the overall infrastructure of Sri Lanka during and after the crisis.

Key words: COVID-19, Drone transport

1. INTRODUCTION

Since the COVID-19 pandemic had a severe impact in countries across the globe, innovations in technology have been initiated in many sectors to counter the crisis as well as in a post-COVID-19 period. Sri Lanka has seen a diverse range of innovations from Robots to Medical equipment and Drone technology. As the popularity of Drones has continued to rise over the past few years, the need for better equipped, more functional,

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and versatile drones have become a subject of debate during the COVID-19 period. The Civil Aviation Authority appealed to the public to register their drones, to create a pool of drone operators. In this backdrop, there are enormous possibilities for the drone to serve in order to minimize the risk of contamination by serving in transportation to surveillance and disinfection of a selected area.

The case of surveillance and disinfection which are typically closed range tasks, require the drones to be more capable of sensors for detection and actuators for physically intensive tasks such as spraying a disinfectant in an already contaminated built-up area. Generally, aforesaid tasks are to assist the law enforcement authorities; hence drones have to be rugged in nature and may require better flight duration. The sizing of drones also may require consideration in view of high altitude obstacles such as telecommunication and power wires in rural areas and close proximity to buildings in urban areas. The maneuverability and remote controllability may require careful consideration, in view of high interference levels and high level of radiofrequency signal levels typically found on top of buildings.

In the case of transportation, it may be in the range of consumer goods to emergency medical supplies inclusive of blood and organs at the extreme end. In between, we have medicine transposition in an area for patients, who are registered to a certain clinic, who are surely at risk from attending hospitals under prevailing conditions and in the commercial sense, it may be pharmacies that maintain drug delivery to their customers, who are having difficulties to physically be present at the pharmacy. For advanced utilization, we can use the system for blood and organ transportation, which may demand to maintain a certain set of climatic and physical conditions using specially designed containers depending on the distance of transportation. Monitoring of the temperature, barometric pressure, altitude, vibration, and location via global positioning system (GPS) during transportation is mandatory for blood, blood product, and organ transportation.

Generally, aforesaid tasks are to assist the medical authorities and maintain the commercial activities of a country, hence drones have to be autonomous in nature and should have more endurance. The maneuverability requirements in this application are the fire

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and forget scheme, where the drones are given the waypoints to comply as per the pre-defined set of orders until completion of the task and return back.

2. PREVIOUS WORK

A number of research works have been published on the subject area of medical transportation. For medical transportation, the work of Pahoni R. et al (2015) [1] proposes a drone with flexible wings in order to address the demands of medicine, drug and blood transportation. The authors claim that the simulation outcome proves that the proposed design fulfills the challenges posed by heavy winds and then minimizes the effect on the cargo concerned. The work of Budiharto et al (2018), covers on similar lines to Pahoni (2015) based on a fixed wind autonomous drones project implemented in east African countries, mainly to transport blood from a central location in view of enhancement of rural health care facilities. The utilization of medical transportation by quadcopter drones was enhanced by incorporating deep learning into the detection process using the video of a target of cargo delivery also with the aid of a GPS is explained by Ayyappaa et al (2019). The work of Scalea et al. (2018), is on blood transportation by an autonomous unmanned aerial vehicle. A six-rotor Unmanned Aircraft System for organ transportation is explained by Ashok et al (2019), which has been tested for ideal conditions for organ transport requirements such as temperature, pressure change, vibrations due to changes of height, at a peak velocity of over 67 kmph during 14 missions. Prior and post biopsies have also been carried out on the transported organs and found no damages within the maximum range of 4.2 km. A prototype of an aero ambulance quadcopter for blood transportation is presented in Krishna et al (2018), which can be tracked on a mobile phone utilizing a GPS onboard. A scheme using aerial vehicles to measure and the patient parameters such as temperature and pulse rate are wirelessly reported in the work of Sabra et al. (2018). The prime objective was to reach faster than conventional ambulances and obtain the services of a medical specialist, however, the range is limited to 500 m. The security aspect of the applications of aerial vehicles within the aspects of safety, privacy, and security are reviewed in Sabra et al. (2018).

With the development of drones to address the various medical and social challenges within this pandemic, various frameworks for the implementation at scale have been developed such as the work of Gharibi et al (2016) which shows a multi-layered autonomous operation for the Internet of Drones (IOD. The work of Mozaffari et al (2016) shows a framework for optimal uplink and downlink communications within the IoD using ground antennas and the circle packing theory. With minimal interruptions in the network, large volumes of IoT data can be collected and processed within milliseconds.

Capraz et al (2020) discusses the use of GPU accelerated parallel programming for multi UAV systems as an alternative to serial and parallel CPU solutions. This is because the architecture of a GPU is designed for parallel computing facilitating the processing requirements of IoD. To reinforce this approach Mizell and Biery (2017) discuss how GPU accelerated computing is the way forward for IoT and Real-time data analytics which is also applicable to the IoD ecosystem. Sanjab et al (2017) in his work propose a novel framework to address cyber-physical security of drone systems using the prospects theory in their game formulation theoretically showing that subjective decision making of the vendor and attacker led to delays in delivery time.

3. METHODOLOGY

Although many schemes are being used as per the author's knowledge, very limited utilization is for Covid-19 operations globally using drones. Hence we intend to focus our efforts mainly on the transportation of urgent medical cargo, aerial disinfection, and public space surveillance. Drones that are prevailing in the global markets are predominantly geared to carry lightweight items or parcels. In this instance, we identify documents or packages that are usually distributed through the post, to

be transported through drones. This will be an important step in locations that are demarcated as vulnerable or hotspots for the general post service to operate. Based on the results of this phase, the drone service could be optimized and scaled to handle deliveries of medical supplies in accordance with health guidelines and standards.

- In the case of public space surveillance, drones could be utilized to monitor crowds of people, and whether they adhere to social distancing at a given place and time. At the same time, thermal imaging capability could be used to monitor temperatures, thereby communicating such observations and results to relevant health authorities. This will be an important step in the big data collection process and will provide crucial information for Artificial Intelligence and Machine Learning processes to be implemented (Ramakrishnan and Srinivasan, 2009). Such data would enable authorities to make timely decisions to counter the spread of the virus in a given town, city, district, or province.

Some of the safety features that should be adopted by drones include

1. Automation

The drawn system should be highly automated and can conduct its own flight planning and delivery planning.

2. Redundancy

Drones should be equipped with many duplicate systems to ensure safety.

3. Design

Lightweight is a feature to improve safety on the ground.

4. DRONE OPERATIONS FRAMEWORK FOR MEDICAL MONITORING AND LOGISTICS

The proposed Drone Operations Framework will consist of the following:

- Drone Operations Centre
- Base Stations
- Secure Communication Channels
- Ecosystem Security

4.1. Drone Operations Centre (DOC)

We envision a Drone Operations Centre to be formed under the Ministry of Defense with the Tri Forces, Police, and Civil Aviation Authority. It would be similar to the model of a Control Tower in aviation where the relevant tiers in authority will have access to a User Interface customized for the drone network. The DOC will have SOPs outlining procedures for each stakeholder. Each stakeholder within the establishment will have an important role to play in the successful operations.

The DOC is designed with 5 benchmarks in consideration.

4.1.1. Ease of deployment and flight planning

The proposed operation will run on a fluid operating system that is designed to optimize IoT networks. Deployment of the operation will be a user-centric plug and operate model working on a hybrid on-site and cloud infrastructure.

Taking into consideration the challenges in mobility and social distancing measures with the current pandemic few architectural changes have enabled us to provide a remote work environment with the capability of full-scale operations. The model requires system users to work with an encrypted bootable USB as their identity within the network. The bootable device will also work as a temporary remote data storage where relevant operational data will automatically be collected. Later at a user-specified time, it can be scheduled to

upload this data to the relevant servers within the network.

Using this approach means that the backbone for the operations will be running on a local cloud-based server but the data would be stored with individual users which they will have the responsibility to update onto the main server when connected to the network. An internal blockchain database management will allow privacy of sensitive data with access to blocks granted on user access levels thereby ensuring accountability for access, viewing, and editing the chain. The clearance level of the network users will determine what they see.

Flight planning is done based on existing drone mission planners frameworks however the environment is designed with future applications in mind to cater to Industry 4.0 IoT network operations within a virtual setting. The constantly learning work environment strives to automate the identified process, personalized according to user requirements, reduce the dependency on mouse and keyboard functions where scripting has been simplified, revives the use of desktop assistants using bots trained with advanced algorithms designed to assist users across a wide range of tasks (Figure 1).

4.1.2. The energy efficiency of network

The cost of energy consumption is a crucial part of the overall ecosystem as current drones offer limited battery capacity thus requiring multiple backups and any additional functionality of the drone directly impacts the flight duration. Using drones within the system is done on a plug and play model where drones can be connected to the network as required for missions interacting with the system through a user handshake on a blockchain thread to enter and exit the network. The energy efficiency of the network will be calculated based on the data gathered from all individual missions for further process optimizations.

Figure 1. Ruby OS IoT programming interface

Although GPU computing is highly productive it requires a lot of energy to run multiple cores at the same instance. Therefore two operating models can be considered where the network is used at certain times of the day to run multiple missions within a timeframe or to exploit the full potential of drones and apply impactful direct or indirect use cases at scale to address the challenges that COVID 19 has caused many sectors to face. Further optimization paths could involve multiple ministries databases interlinked within the network to facilitate the collecting and analyzing of data to give insightful outputs.

The near-real-time data of COVID 19 cases being detected by multiple sources such as hospitals and public health inspectors would allow better decision making when planning flights to monitor the adherence of COVID 19 precautions in place. Aerial footage of public places of tension would give the authorities better visibility of population density and crowd dispersal teams can be deployed efficiently. This holistic approach of the network would provide an optimal energy output in terms of efficient use of resources and saving time on the decision-making process by semi-automation for large-scale interconnected networks.

4.1.3. The efficiency of handover and moving from networks

As the most accessible form of networking the proposed framework would rely on the ground infrastructure of network service providers initially after which we vision an infrastructure upgrade having dedicated services for the drone network. Low latency and high bandwidth are crucial for many IoT operations which is a challenge using existing service provider coverage however initial

operations can be focused within the network hotspots.

Algorithms developed for semi-autonomous operations will allow automatic handover protocols between accepted networks which will be a combination of cell tower networks, satellite connections, and ground station and portable modems. This collective network source allows the drones to maintain the optimum connectivity based on the mission. Fully autonomous flights that require video downlink would be highly dependent on the connectivity of the network while logistic drops would only require waypoints to complete the task (Figure 2).

A redundancy prevention model for this network is the constantly learning AI module which uses the drone's visual and other sensors and an updated virtual map of the area of the mission which is scalable. This can be done using 3D modeling software linked to visual and other sensor feeds of the drones in operation. Routine flights will capture changes in terrain and other obstacles which over time will provide further redundancy measures that can be pushed as updates to the drones. In case of a total network failure for example the drone will be able to navigate through the learning environment to its designated emergency landing location or complete a fully autonomous flight with only the visually modeled map. For initial deployment and process optimizations, a standard blockchain encrypted tracking device can be provided for drone users to attach and activate when operating their drones, if the drone doesn't initiate a handshake with the network and the drone is powered and reaches an altitude over 25ft an SOS automatic response will be initiated.

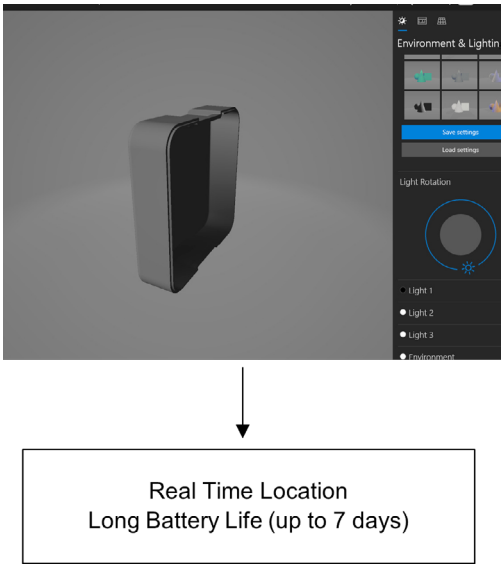

Figure 2. Tracking device prototype

4.1.4. Security and safety

The sensitivity of this ecosystem requires the highest level of security. Being a cornerstone of our work multiple measures are in place to provide the highest level of network and physical level security. The encrypted bootable pen drive would serve as tier 1 level security which ensures that users' data is with them and user-approved data only will be available on the main cloud server. Source code protection is also given the highest priority because of centralized work environments working on a decentralized network serving as tier 2 security. This allows for multiple entities to collaborate within the same environment.

The physical location of operations and server sites is the tier 3 security where base stations and server sites would be within the secure locations. External logistics to civilian locations can be designed at latter phases with public-private partnerships.

4.1.5. Resource management efficiency

Designed to be a lean operation, this operation will utilize an advanced analytical framework along with complex algorithms to make resource efficiency calculations a semi-autonomous process (Figure 3). Cost efficiency of a mission, landing bay management, database management is some of the areas that could benefit from the proposed framework. The use of management bots to perform higher-level automated management functions will ensure optimum human and capital resource management.

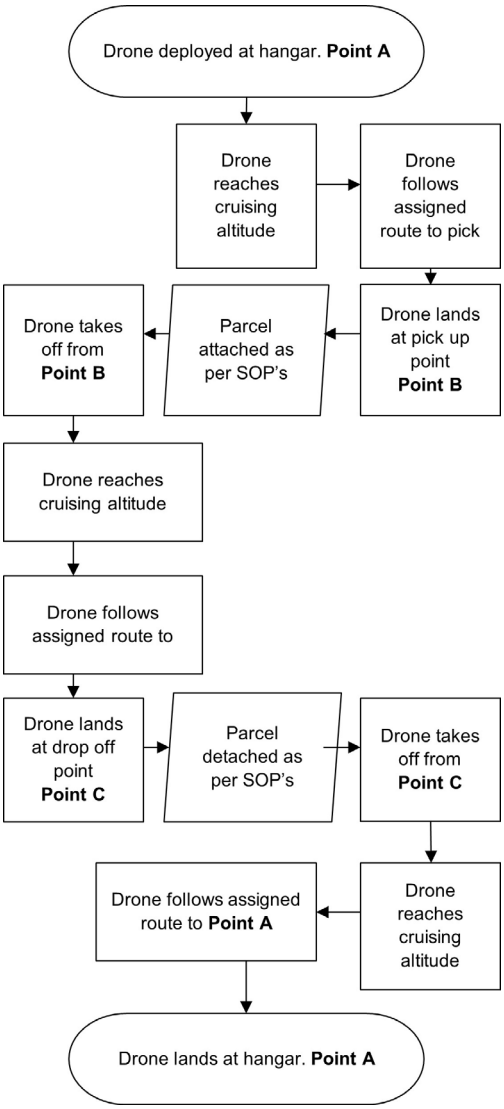

Figure 3. Process of delivery and return

Using algorithms to automate established management and theory practices the network will provide calculated suggestions for users in critical decision making within a very short time. Leveraging GPU processing multiple algorithms can run parallel computing tasks to achieve the set objectives. GPU accelerated cloud computing will offer easy scaling up or down of operations (Figure 4, Figure 5).

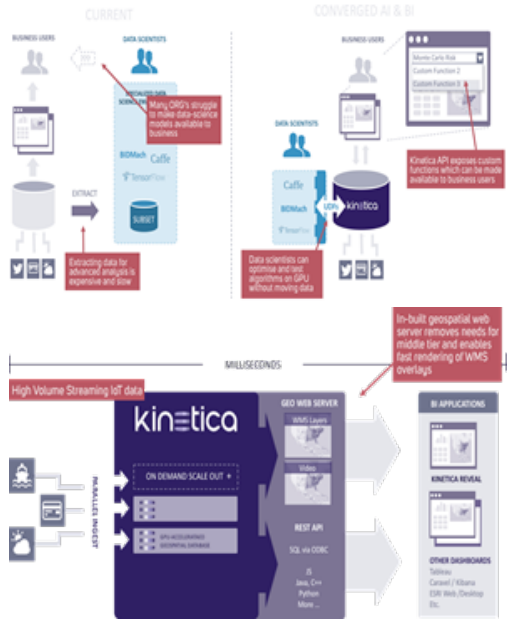

Figure 4. GPU Database Management

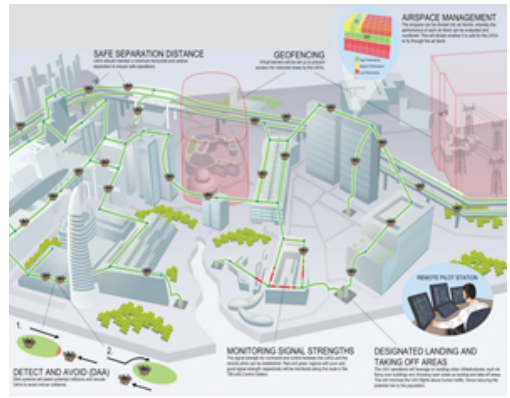

Figure 5. Landing bay operations and mission planning

4.2. Base stations

Base stations will be identified in select locations of the country (districts). These could be Police stations and locations that come under the purview of the Ministry of Defense. This ensures a safe and secure operational environment for the drones. These stations will operate as drone base stations and landing sites. Logistics could be arranged to and from these stations according to the requirement. The base stations will also serve as charging docs for the drones and allow for drone inspections

to ensure the standard of the hardware and operation.

Base stations should have a dedicated drone pad and strong network connectivity to ensure proper handoff. The implementation of new technologies will provide much-needed networking and computing upgrades to the locations as well to reinforce their local database and operations as well. In many envisioned drone-based applications, drones will communicate with many different smart objects, such as sensors and embedded devices. Securing such communications requires an effective and efficient encryption key establishment protocol.

4.3. Relay stations

Relay stations will be located around or as midway points between base stations for serving long-haul carrier drones, to switch payload, recharge and find refuge in unfavorable weather conditions. Requirement and cost of setting up relay stations could be made of a fraction of that of a Base station by adapting to ergonomic design of standalone towers with capability to land and host a dozen inactive drones. Additionally, each relay station can be equipped with RTK base stations providing millimeter accuracy to drone navigation and act as true north for ad hoc call home procedures.

4.4. Network Security

Any formation of network infrastructure will have to be fortified to outdate existing tools used for expected cyber-attacks where one configuration(p2p, cloud, on-premise) of a network is fortified against certain attacks the other might be vulnerable, a cluster of networks can be implemented as sub-system layers working independent of others. A navigation layer would work separately from the administrative layer providing de-coupling of layers at network architecture level. Each layer's hardware requirements could also be easily identified by this approach and optimized for speed at the hardware layer. For example, the Vision/Sensor layer and Hardware Accelerated authentication layer (Key-Hashing using GPU Compute) once abstracted will be reliant on GPUs while the rest of the layers would be reliant on speed and the redundancy of the layer.

Data Security would be a layer with multiple redundancies, on-premise cold storage, coherent backups, fast recovery and resumption of standard and fallback operations. All crucial data shall be written to a write-read-only database or over to a self-healing peer-to-peer network storage (blockchain) (Figure 6).

4.5. Secure communication channels

All communication from Drone to base or relay stations will have to be written from scratch with dynamically configurable module to outdate existing network snooping tools used by bad-actors(hackers). Logging all unusual behaviors on each network and collating the results would show up targeted and non-targeted attacks before even an actual attack could take place. However human eye is required to monitor and fine-tune the train the networks' ability to identify suspected activities.

Any sophisticated early warning system will have to be built on this foundation. The protocols can be designed and implemented by the relevant authorities to achieve benchmarked optimizations (Figure 7, Figure 8).

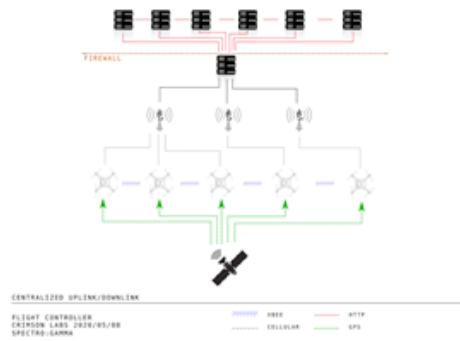

Figure 6. Network Security

Figure 7. Secure communication channels

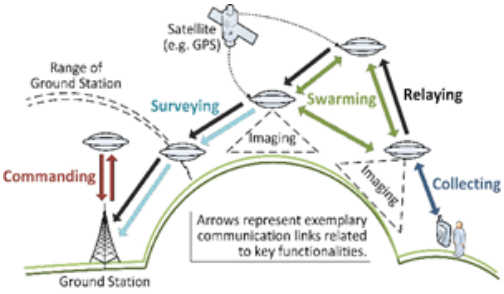

Figure 8. Drone Network Communications

5. DISCUSSION AND CONCLUSION

The debate still remains on Srilanka's readiness to collectively strive to compete on a global level in this era where technological disruption is giving some countries a competitive edge over others. There are real-world challenges where the majority of the general public is facing hardships at a ground level due to inefficiencies of resource planning such as food and medicine shortages, delays in blood and organ transport, inaccessibility to remote locations without proper roads caused by construction delays, power shortages and unidentified COVID 19 clusters. Some developed and well-funded nations are able to push forward and evolve into newer concepts and realize a better quality of life which we are striving to realize.

Competing on a global level is crucial in order to sustain the developmental and economic goals of the country. However, it can only be achieved by operating at a higher level of creativity and innovativeness. The generations ahead will benefit immensely if the necessary infrastructures are in place to assist their developments. Policymakers will have to weigh the benefits to the macroeconomics of the country which would influence the scope of operations however the implementation of long-term infrastructures should be encouraged and considered as a key driver for future economic sustainability.

The implementation of pilot projects at various levels of complexity and sensitivity would be the next step in implementing successful missions using IoT networks and as the efforts are primarily applied to mitigating issues arising from COVID 19 directly or indirectly, we propose a collaborative work environment to take Sri Lanka forward in the new era.

REFERENCES

Anon, Full Page Reload. *IEEE Spectrum: Technology, Engineering, and Science News*. Available at: https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/crowdsourced-protein-modeling-efforts-focus-on-covid19 [Accessed February 15, 2021].

Anon, GPU Database - A Complete Introduction. *OmniSci*. Available at: https://www.omnisci.com/learn/gpu-database [Accessed February 15, 2021].

Anon, GPU Database Market Research Report - Forecast to 2023: MRFR. *GPU Database Market Research Report - Forecast to 2023 | MRFR*. Available at: https://www.marketresearchfuture.com/reports/gpu-database-market-7344 [Accessed February 15, 2021].

Anon, NVIDIA and Kinetica for Accelerated Analytics. Available at: https://www.nvidia.com/content/dam/en-zz/Solutions/data-analytics/documents/analytics-kinetica-solution-overview-737502-us-lr.pdf [Accessed February 15, 2021].

Anon, NVIDIA GPUs Power Kinetica Active Analytics Platform. *Kinetica*. Available at: https://www.kinetica.com/partner/nvidia/ [Accessed February 15, 2021].

Ashok, K.R. et al. (2019). Aero Ambulance Quad copter Based Technology for An Emergency Healthcare. *2019 5th International Conference on Advanced Computing & Communication Systems (ICACCS)*.

Ayyappaa, N. et al. (2019). Autonomous Drone for Efficacious Blood Conveyance. *2019 4th*

International Conference on Robotics and Automation Engineering (ICRAE).

Budiharto, W. et al. (2018). Fast Object Detection for Quadcopter Drone Using Deep Learning. *2018 3rd International Conference on Computer and Communication Systems (ICCCS)*.

Capraz, S., Azyikmis, H. & Ozsoy, A. (2020). An Optimized GPU-Accelerated Route Planning of Multi-UAV Systems Using Simulated Annealing. *International Journal of Machine Learning and Computing*, 10(3), pp.471–476.

Gharibi, M., Boutaba, R. & Waslander, S.L. (2016). Internet of Drones. *IEEE Access*, 4, pp.1148–1162.

Krishna, V.V., Shastri, S. & Kulshrestha, S. (2018). Design of RPV for Medical Assistance. *2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*.

Mizell, E. & Biery, R. (2017). Introduction to GPUs for Data Analytics, O'Reilly Media Inc., First Edition, Chapter 5 pp 17-20.

Mozaffari, M. et al. (2016). Unmanned Aerial Vehicle With Underlaid Device-to-Device Communications: Performance and Tradeoffs. *IEEE Transactions on Wireless Communications*, 15(6), pp.3949–3963.

Ramakrishnan, S. & Srinivasan, S. (2009). Intelligent agent based artificial immune system for computer security—a review. *Artificial Intelligence Review*, 32(1-4), pp.13–43.

Sabra, A. et al. (2018). Description of Security Impact of Drones Challenges and Opportunities. *2018 21st Saudi Computer Society National Computer Conference (NCC)*.

Sanjab, A., Saad, W. & Basar, T. (2017). Prospect theory for enhanced cyber-physical security of drone delivery systems: A network interdiction game. *2017 IEEE International Conference on Communications (ICC)*.

Scalea, J.R. et al. (2018). An Initial Investigation of Unmanned Aircraft Systems (UAS) and Real-Time Organ Status Measurement for Transporting Human Organs. *IEEE Journal of Translational Engineering in Health and Medicine*, 6, pp.1–7.

BIBLIOGRAPHY

Golden, R. (2020). Kinetica + NVIDIA RAPIDS Speed Up Predictive Data Analytics with the Power of GPUs. *Kinetica*. Available at: https://www.kinetica.com/blog/kinetica-nvidia-rapids-speed-up-predictive-data-analytics-with-the-power-of-gpus [Accessed February 15, 2021].

Laksham, K.B. (2019). Unmanned aerial vehicle (drones) in public health: A SWOT analysis. *Journal of Family Medicine and Primary Care*, 8(2), p.342.

Newell, A. 1980. Physical Symbol Systems*. Cognitive Science, 4(2), pp.135-183.

Pahonie, R.-C., Mihai, R.-V. & Barbu, C. (2015). Biomechanics of flexible wing drones usable for emergency medical transport operations. *2015 E-Health and Bioengineering Conference (EHB)*.

Poljak, M. & Šterbenc, A. (2020). Use of drones in clinical microbiology and infectious diseases: current status, challenges and barriers. *Clinical Microbiology and Infection*, 26(4), pp.425–430.

Popović, M. (2020). Counting penguins with drones. *Science Robotics*, 5(47).

Staff, J.E.M.S. (2021). New Partnership in Drone Delivery System for Human Organs. *JEMS*. Available at: https://www.jems.com/operations/new-partnership-in-drone-delivery-system-for-human-organs/ [Accessed February 15, 2021].

Trevett, N. et al. (2019). Vulkan SC -. *The Khronos Group*. Available at: https://www.khronos.org/vulkansc [Accessed February 15, 2021].

Turing, A. (2004). Computing Machinery and Intelligence (1950). *The Essential Turing*.

Won, J., Seo, S.-H. & Bertino, E. (2015). A Secure Communication Protocol for Drones and Smart Objects. *Proceedings of the 10th ACM Symposium on Information, Computer and Communications Security*.

Index

NATIONAL SCIENCE FOUNDATION

COVID 19: Impact, Mitigation, Opportunities and Building Resilience

From Adversity to Serendipity

Perspectives of global relevance based on research, experience and successes in combating COVID-19 in Sri Lanka

Volume 01

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ISBN: 978-624-5896-00-4