KDUIRC
INTERNATIONAL RESEARCH CONFERENCE

15TH INTERNATIONAL RESEARCH CONFERENCE

Economic Revival, National Security, and Sustainability through Advancement of Science, Technology, and Innovation

29TH - 30TH SEPTEMBER 2022

BUILT ENVIRONMENT AND SPATIAL SCIENCES

PROCEEDINGS

GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

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ECONOMIC REVIVAL, NATIONAL SECURITY, AND SUSTAINABILITY THROUGH ADVANCEMENT OF SCIENCE, TECHNOLOGY, AND INNOVATION

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General Sir John Kotelawala Defence University
Ratmalana, Sri Lanka

Published by

General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka

Tel: +94-771002822

e-Mail: irc2022@kdu.ac.lk

Website: https://www.kdu.ac.lk/irc2022

ISBN 978-624-5574-72-8

Other Proceedings of the Conference:

Defence and Strategic Studies: ISBN 978-624-5574-65-0
Medicine: ISBN 978-624-5574-66-7
Engineering: ISBN 978-624-5574-67-4
Law: ISBN 978-624-5574-68-1
Management, Social Sciences and Humanities: ISBN 978-624-5574-69-8
Allied Health Sciences: ISBN 978-624-5574-71-1
Computing: ISBN 978-624-5574-70-4
Built Environment and Spatial Sciences: 978-624-5574-72-8
Technology: ISBN 978-624-5574-74-2
Criminal Justice: ISBN 978-624-5574-75-9
Basic and Applied Sciences: ISBN 978-624-5574-73-5

Published on

29th September 2022

e-Book Version

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Welcome Address

Major General Milinda Peiris RWP RSP VSV USP ndc psc MPhil (Ind) PGDM
Vice Chancellor, General Sir John Kotelawala Defence University

Chief Guest, Secretary - Ministry of Defence, General Kamal Gunaratne (Retd), Keynote Speaker, Hon. Prof. Subramanian Swamy, Your Excellencies in the Diplomatic Corps, Chief of Defence Staff, Gen Shavendra Silva, Commander of the Army, Lt Gen Vikum Liyanage, Commander of the Navy, Vice Admiral Nishantha Ulugetenne, Eminent plenary speakers representing our friendly nations, Vice Chancellors of Other Universities, Former Commandants of KDA, Former Chancellors and Vice Chancellors of KDU, Rectors of KDU Campuses and Deputy Vice Chancellors, Deans of Faculties and Centre Directors, Senior Military Officers and Police officers, Academics, Administrative Staff, Students, All distinguished guests including those who connected with us in the cyberspace, Ladies and gentlemen, Good Morning to you all! I am deeply honoured to make the welcome address at this inauguration of the 15th International Research Conference (IRC) of General Sir John Kotelawala Defence University. To begin with, I warmly welcome our chief guest this morning, Gen Kamal Gunaratne (Retd), Secretary to the Ministry of Defence for gracing this important occasion. We owe you a great deal of respect for the whole-hearted support extended for the progression of this university at all times. Also, may I have the distinct honour of welcoming our keynote speaker, the esteemed and renowned personality, Hon Prof Subramanian Swamy from neighbouring India.

Hon Sir, we are extremely grateful to you for accepting our invitation and honouring us with your gracious presence to deliver the keynote address of this two-day international research conference. I am sure that your eminent presence adds great value to the event, and we are looking forward to listening to your words of wisdom, which will surely set the most appropriate tone for this scholarly event.

I also welcome the Chief of Defence Staff, Gen Shavendra Silva, Commander of the Army, Commander of the Navy and all other members of our Board of Management. Let me also warmly welcome the members of the Diplomatic Corps representing our friendly nations, Vice Chancellors and Senior Academics from other universities, Former Commandants of KDA, Former Chancellors & Vice Chancellors of KDU, Other officials of Ministry of Defence, Academics, Senior Military Officers, Plenary speakers, Scholars presenting papers in this two-day conference, and all other distinguished invitees and students joining this event physically as well as on cyberspace. As the Vice Chancellor of KDU, I admire your valuable presence at this occasion.

Reflecting on KDU IRCs held last year and the year before, we held them under the most trying circumstances of the grave pandemic. They really tested our resilience and

defiance against challenges to the very core. Along with the IRCs, we determinedly continued with all academic and other activities of the university with much vigor, and the results are evident in our achievements.

Ladies and gentlemen, today, we are glad that KDU has firmly established its foot print as a unique higher educational model in the world, which even its critics would not be able to disagree with. The best evidence is its steady growth in its popularity as an Higher Education Institute in Asia, as well as the quality of its output, which are evident in the Times Higher Education Impact Ranking, 2022 table, where KDU is ranked 2nd in Sri Lanka for Quality of Education and 4th in the overall ranking in the country and in the 801-1000 range globally. A more recent indicator of our growth is evident in the world ranking of Law Schools, where the KDU faculty of law took a leap in the world ranking from the 498th place in 2021 to the 83rd place in 2022, from the 189th place to the 25th place in Asia, and from the 5th place to the 2nd place in Sri Lanka.

Ladies and gentlemen, today, we hold the 15th consecutive IRC at a time when we, Sri Lankans are in a grave need to pull up our socks as a nation to face the seemingly unsurmountable economic crisis we are in. And we as a university are determined to give our utmost best for the nation at this crucial juncture.We believe that the role of the universities and the intellectual community of the nation is of paramount importance for the resurrection of our economy, and that of the nation's defence university is even more significant as it deals with the national security perspective which is inseparably linked with the economic crisis and with a possible recovery from the same.

Serious research in defence and security studies needs to go hand in hand with rigorous research in all other fields. This, we believe, is an essential prerequisite for a quick and sustainable recovery from the crisis. So, we carefully selected the overarching theme, *"Economic Revival, National Security, and Sustainability through Advancement of Science, Technology, and Innovation"* for this year's conference, and its scope encompasses a wide range of significant research possibilities to engage in.

Our aim in selecting this theme entails a holistic vision of the complexities of economic and national security perspectives which demand comprehensive inter- and multidisciplinary approaches to resolve contemporary issues. The expectation is to carry forward the research outcomes to the attention of those in authority to consider implementation to resolve related issues. I do not intend to talk any further on this aspect as I am sure our keynote speaker would elaborate on the conference theme and its significance. Ladies and gentlemen, having commenced in the year 2008 in a humble way, the KDU IRC gained gradual momentum as a trustworthy forum for the country's scholarly community to showcase their multi-disciplinary research outcomes. And what is noteworthy is the ever growing increase in the number of research papers submitted for the conference, and more so is

the increasingly higher quality of the papers presented at the conference.

Therefore, KDU enjoys the humble pride of its leading role in strengthening the research culture in the country that is more and more inclined towards product based or problemsol ving outcomes in relevant fields, which I believe is the need of the hour. Also the involvement of internationally collaborative research is on the increase. Anyone who visits the KDU IRC Proceedings would note the evolutionary path of the progression in research in the country spearheaded by KDU – You could see the increasingly high numbers of researchers representing almost all the universities, other Higher Education Institutes and research institutes of the country as well as those from renowned universities, Higher Education Institutes and research institutes in the world. So, we are proud of our role in establishing local and international research and scholarly networks that would further enhance creation of new knowledge in diverse disciplines and dissemination of the same.

Ladies and gentlemen, the organizers of this year's research conference too have been doing their utmost best to maintain and upgrade the quality of the annual research conference despite challenges, especially in the face of financial constraints which compelled them to significantly cut down on peripheral expenses.

The circumstances have compelled them to rely on our own resources as much as possible, which I believe is a blessing in disguise in the crisis situation to convert challenges into opportunities. I appreciate their effort and the support extended from all quarters to make the KDU International Research Conference a resounding success in terms of achieving its objectives. So, let me conclude by once again welcoming our chief guest, the erudite keynote speaker, and all the other distinguished invitees. I convey my congratulations to all researchers who will be presenting their research during the couple of days.

I also request those whose papers were not selected through the double blind reviewing process not to get disheartened because you had competed with many for a placement in the conference. Finally, let me express my heartfelt thanks to the Chairman of the Conference Organizing Team, Dr. Kalpa Samarakoon, Secretary, Dr. Pandula Athawuda Arachchi and the other members of the team for the tireless hours, days and weeks you spent to see the success of this important event.

May the KDU IRC be a haven for establishing scholarly links at national and international levels, which would pave the way for fruitful research, academic and even industrial collaborations for the betterment of our nation, its security and its social, economic and political stability that would in turn pave the way for the creation of a self-sufficient nation in the not so long future. Let us optimistically believe in ourselves and in our potentials to reach that target sooner than later.

Thank you.

Chief Guest Speech

General Kamal Gunaratne (Retd) WWV RWP RSP USP ndc psc MPhil
Secretary - Ministry of Defence, Sri Lanka

Hon. Prof. Subramanian Swamy, Keynote speaker of the 15th International Research Conference 2022 of General Sir John Kotelawala Defence University, Your Excellencies in the Diplomatic Corps, Chief of Defence Staff, Commander of the Army, Commander of the Navy, Chief of the Staff of Sri Lanka Air force, Vice Chancellors of Other Universities, Vice Chancellor of KDU, Eminent speakers from friendly foreign nations, former commandants of KDA, former Chancellors and Vice Chancellors of KDU, Rector of KDU Metropolitan Campus, Rector of KDU Southern Campus and Deputy Vice Chancellors, Deans of Faculties and Directors, Senior Military Officers and Police officers, Distinguished guests, Ladies, and Gentlemen's. Good morning to all of you.

I consider it as a great pleasure and privilege to be present here today as the chief guest of the inauguration ceremony of General Sir John Kotelawala Defence University's International Research Conference, which is taking place for its 15th consecutive time.

Without a doubt it provides as opportunity for academics, professionals, researchers and practitioners from all around the world to share their research findings and expertise addressing mutual challenges in their fields. Further it provides an opportunity for a wide interaction and networking with national and international scholars in respective fields which in turn proved beneficial for the participants to broaden their horizons of knowledge through intellectual discussions most importantly despite the global pandemic situation and the reason economic, social and political setbacks in effect it is truly inspiring to see that the KDU is continuation the conduct of this conference with renewed spirit and commitment

Therefore, ladies and gentlemen at this moment I would like to encompass
My sincere appreciation to the Vice Chancellor and the conference organizers for the invitation extended for me to be the chief guest to the most significant academic events of this University. In this context of promoting an excellent academic culture generation of knowledge and subsequent applications of it led to innovations and novel technologies that are crucial for the advancement of humanity, well-being, and sustainability. The knowledge is generated by scientific research and at this backdrop, it is delightful to see that the theme of this year's conference reads economic revival, National Security, and Sustainability through the advancement of Science, Technology, and Innovations, which is a well-timed theme reflecting directions that we should pursue as a country irrespective of the boundaries of time and era.
Further, at this moment, ladies and gentlemen, I will be failing in my duty if I do not acknowledge the distinction of a brilliant keynote address conducted by the former Minister of Commerce Law and the Justice

Republic of India, Honorable Professor Subramanian Swamy. Sir, we as Sri Lankans truly appreciate the accept acceptance of our invitation extended to attend and maintain throughout the past in continuation of the display of your friendliness towards Sri Lanka. The ideas that would be shared by you in this eminent forum today will indeed bring a sparkling light to the discussions to be conducted during this conference that will become highly fruitful with your intellectual input.

All the foreign and the local participants including the senior officers od tri-forces and police would be immensely benefited by the inputs that would be given by you to broaden the Horizon of their knowledge.

Moving on the the focus of the conference I must emphasized that with the effects of globalization in effect the growing international independencies affecting the Sri Lankan National security as well as reasons concerns raised by economic and political implications. There is a recognized need for assessment of the potential to national security, that may emerge during the thrive towards revival of national economy and sustainability.

As per my belief given the importance of certain sectors to the effective functioning of the Sri Lankan society the said need for a deeper conceptual understanding of the threats that may impact the implied economic revival and sustainability in all aspects focusing on technological scientific and innovative faces would be comprehensively discussed with in the earnest gathering of intellectuals during these two days.

A strategic standpoint keeping the past and also most recent lessons learned

In mind a newfound leadership of the present government, Sri Lanka should call for national determination where all sectors of Sri Lankan society including civil organizations, security institutions, political entities and business associations come together to discuss fundamental issues such as national identity, national reconciliation, transitional justice, governance structure, economic revival and many more.

This is a fundamental step towards building consensus and religious legitimizing state institutions and private organizations in the country towards a common goal. Not only would such an effort-based process serve as the foundation for a national pact addressing the country's issues, pointing out how it would concurrently compel every group in society to work towards state building and the sustainability of a secure country due consideration to scientific and technological innovations.

Furthermore, giving high priority to providing solutions to the country's most freezing matters of concern to improve the world's image of Sri Lankans society the Sri Lankan government must take every step necessary to recover high-priority initiatives in the fields of the economy, institution-building, and political reform.

Whilst giving true meaning to the said initiatives in order to address emerging challenges promoting more research and development becomes a task of topmost priority bestowed upon all of us who are present here today.

Fortunately, as a secretary Defence and the Chairman of the KDU Board of Management, I

feel tremendously proud and content to state that KDU is at the forefront of researching the development and security related problems holistically.

In this context, one of the unique aspects of KDU IRC in comparison to s plethora of symposia that we witness in the country and beyond its borders remains to be its firm commitment to defence and strategic aspects of the contemporary world with emphasis on local and regional trends.

In that this conference continues to pioneer in upholding the notion that security is a prerequisite for the viability of achievements in all other areas in which mankind relies on in order to facilitate such outcomes it maintains a seamless association of defence and security with other core areas such as Sciences, Medicine, Engineering, Build environment and Spatial Sciences, Technology, Management, and Huminites. We are fundamental knowledge images. To be honest, I personally acknowledge this pragmatic philosophy as a remarkable achievement of KDU and thereby of the country as a whole. Resulting in interactions and dialogue across apparently distinct disciplines will certainly usher increasing exchanges and collaborations among experts in diverse areas, therefore, I am well certain that all faculties of Sir John Kotelawala Defence University with their interest and commitment to knowledge in diverse academic disciplines and outside researchers' inputs would contribute immensely to this year's research conference theme.

The knowledge that you are giving to another and sharing during this conference would be an immense benefit not only to the academic community but to the entire humankind to make their lives better.

In conclusion, ladies and gentlemen, at the current context we are on the average of striving to accomplish serenity and excellence in an economic revival, national security, and sustainability through unexploited frontiers of technological innovations as a nation. Therefore, conferences of this nature are instrumental in clearing our fond of mind for the betterment of establishing solutions, therefore, let me express my sincere appreciation to the Vice Chancellor and organizers of the 15th KDU IRC 2022 for inviting to this occasion as the chief guest and giving me an opportunity to speak to you. Let me appreciate all the efforts and congratulate all of you for working your way towards a timely and appropriate theme. Finally, I wish all the participants all the very best in their research endeavors and the KDU research conference for 2022 to be successful in every way.

Keynote Speech

Hon Prof Subramanian Swamy
Former Minister of Commerce, Law & justice, India

Hon. Professor Subramanian Swamy, former Cabinet Minister of India made insightful remarks in the keynote address and initiated his speech by extending his gratitude towards Vice chancellor Major General Milinda Peiris for the invitation bestowed on him and went on to acknowledge the presence of the chief guest, Secretary to Ministry of Defence, General Kamal Gunaratne stating, how the Indians themselves couldn't put an end to a major terrorist problem in the region. Professor Swamy recollected how Sri Lanka has never been defeated throughout history, exempting a few setbacks. Furthermore, Professor Swamy remarked how the 21st century isn't going to distinguish between large nations and small nations, as it's a new era with innovations. Speaking from his experience as a trained economist, Professor Subramanian Swamy recalled how all economic development took place when the share of innovation calculated within the GDP rounded up to at least 55%, indicating the development of the USA, Europe and China as examples. He explicating further, mentioned that the growth rate of GDP would be dependent upon the extent to which one innovates. Professor Swamy also recognized the role that could be assumed by the universities in the development of the concept of innovation.

Professor Swamy, elaborated on the inception of the definition of – National security relating to its historical context. He expressed that for most of the 20th century national security had been a matter of military power, and explicated with the dawn of the 21st century, non-state actors posed most of the challenges to national security as opposed to conventional military warfare. Moreover, professor Swamy emphasized that long-term unsustainable practices make the state more vulnerable to internal and more resilient to external threats. Professor Swamy pointed out the "economic factor "as the primary reason behind Sri Lanka's recent upheaval. Furthermore, he scrutinized the removal of democratically elected people from office, which in turn would disallow them to complete their full term, which he recognized as a blow to the country's national security.

Professor Swamy detailed important aspects that need to be regarded in policy formulation; clearly defined structure of objectives, the order of priorities, strategy to achieve them, and resource mobilization. He also stated that no country should be too dependent on one country, and pointed out how Sri Lanka owes a single country, a staggering 52% in internal and external debt. He further resonated that the world has moved from the notion of "development" to "sustainable development", "sustainable economic development and sustainable national security" during the course of the last thirty years of the 20th century. Professor Swamy asserted that the most stable system of governance is democracy. Furthermore, he perceived economic security, political security, energy security, homeland security, and new

technology and innovations to be primary elements that constitute sustainable national security. Honourable professor Subramanian Swamy concluded his speech by stating that the sustainable national security of a country is the ability to provide comprehensive protection and holistic defence of citizenry and climate change, other issues of globalization, terrorism and many more.

Vote of Thanks

Dr Kalpa W Samarakoon

Conference Chair, 15th International Research Conference,
General Sir John Kotelawala Defence University

The Chief Guest, General Kamal Gunarathne, Secretary to the Ministry of Defence, The keynote speaker, Hon Prof Subramanian Swamy, Chief of the Defence Staff, Commander of the SL Army, Commander of the SL Navy, The Representative of the Commander of the SL Air force, The Vice Chancellor of KDU, The Rector KDU Southern Campus, The Rector KDU Metropolitan Campus, The Deputy Vice-Chancellor (Defence & Administration), The Deputy Vice-Chancellor (Academic), Deans of Faculties, Directors, Senior Professors, Senior Officers of tri-officers, and Police, Distinguished invitees, Colleagues, ladies, and gentlemen. Good morning!

Sri Lankans have been suffering an economic slowdown in the post covid era, in particular, with a social and economic crisis, food insecurity, and inequitable provision of health and education, due to its over-reliance on traditional exports, tourism, and constant geopolitical battles. In this context, KDU has been successful in organizing its 15th consecutive International Research Conference. We, strategically analyzed the role of academia of the country to collectively come together and facilitate the transfer of knowledge, skills, and solutions using science, technology, and innovation.

The IRC theme selection for 2022, aims to provide a multi-professional platform to all the scholars based in Sri Lanka and overseas to bring in their innovative research ideas to fulfil this national responsibility thrust upon us, to revive the nation's economy, to achieve sustainable economic growth coupled with an environment of justice and enhanced security for all. This year's conference attracted more than six hundred and ninety paper submissions in 11 sessions the highest-ever submissions since the inception of IRC. This indicates the amount of novel knowledge generated in our country. This year is the conference's inaugural technology and criminal justice sessions.

With deep appreciation and gratitude, I would like to express my heartiest thanks to General Kamal Gunaratne, the secretary to the Ministry of Defence who is our Chief Guest today at KDU-IRC 2022. Sir, your gracious presence in this occasion despite other commitments is truly appreciated and encouraging, and it has certainly added glamour and value to this important event on the KDU calendar. The same goes with Hon. Prof. Subramanian Swamy. He is a renowned academic and has been a distinguished politician in India and even beyond. Sir, I greatly appreciate your willingness to be our keynote speaker. It is truly an honour, privilege, and inspiration to witness your presence among the KDU community today.

I would like to take this opportunity to express my heartfelt gratitude and deep appreciation to the Vice Chancellor of General Sir John Kotelawala Defence

University, Maj. General Milinda Peiris, with your leadership, guidance, and timely decisions, prevailed throughout the event organization. The event would not be bound to be a success without your active input, particularly under the current difficult context. Thank you indeed Sir.

I will be failing in my duties if I didn't acknowledge the crucial involvement of KDU Deputy Vice-Chancellor (Defence and Administration), Brigadier W. Chandrasiri. He in fact steered KDU-IRC 2022 organization effort providing correct and pragmatic directions successfully even when the team was at difficult crossroads. I would also like to thank the Deputy Vice-Chancellor academic and all faculty Deans and Directors, who held the responsibilities for organizing and conducting forthcoming academic sessions.

Ladies and Gentlemen, as I said before, It has been a seemingly overwhelming challenge to organize, coordinate and conduct a research conference of this magnitude at this time.

I must appreciate the support of our sponsors. Platinum Sponsors, together with banking giants namely, Bank of Ceylon, People's Bank, and special sponsors, Gamma interpharm and George Stuart Health.

Let me take this opportunity to thank generously, conference secretary, Dr Pandula Athaudaarachchi, Senior lecturer and consultant interventional cardiologist, and the tremendous work done by the three co-secretaries, Dr. Gihani Jayaweera, Lt Col Lasitha Amarasekara and Ms. Sandali Goonathilaka, who stood alongside me ever since work has been commenced in mid of 2022 with exceptional commitment. I also thank all the session coordinators who supported tirelessly around the clock from the moment. I am certainly indeted to them for the success of KDU-IRC 2022.

I deeply appreciate all the presidents of the committees, and committee members, faculty committees, Office of Vice-chancellor, Office of DVC, officers of Bursar, Officers of the registrar, Adjutant, co-admin who held and executed the roles and responsibilities over the IRC. A special thank goes to the media and communication team led by the Director of IT, Publishing, printing and editorial committees.

I take this opportunity to thank all authors who shared their valuable research works at KDU-IRC. I thank both internal and external reviewers who perused and evaluated the submissions. Please be assured that your expertise shown and valuable time spent in critical reviewing is duly appreciated.

An event of this dimension cannot happen overnight. The wheels start rolling months in advance, it requires meticulous planning and execution and an eye for details. I cannot thank everyone enough for the involvement they have shown, So please bear with me if I would not have named all the supporters.

I expect that participants of the two-day conference that commenced just now will have an occasion that broadens their horizons of own know-how and improve networking in a refreshing environment which all of us at KDU has attempted to facilitate.

I wish you the very best at the conference.

Thank you very much!

BUILT ENVIRONMENT AND SPATIAL SCIENCES

PLENARY SESSION

Crisis in Sri Lanka; Revitalizing the Debt restructure Strategy using the resilience of the Built Environment: Retrospective analysis of the Construction Industry

Prof Lalith De Silva

Professor Emeritus, University of Moratuwa, Chair, RIBA Members of Sri Lanka
Head, School of Architecture, SLIIT University

The Sri Lankan crisis is something that had never been experienced by the nation before. All sectors of the economy and society including the construction industry is badly affected making thousands of businesses are being closed and causing unemployment to a few hundred of thousand of people. It is reported that many have suicide due to the inability to sustain their debts.

Sri Lanka probably is the only nation, that first experienced the fate of mankind and the fate of vehicles on the day when the world runs out of fossil Fuel.

A survey was conducted through more than one hundred thousand random cross-sections of people, to get their view of them the crisis and validate the proposed solutions.

This research will offer insight into socio-economic chaos in a volatile political instability, currently undergoing in Sri Lanka and possible short-term and long-term solutions for debt restructuring strategy.

Proposed suggestions will be of interest to academics, researchers, students and industry professionals who wish to do further research and persons connected or wish to be informed about how the monetary and fiscal policies of the future government of Sri Lanka can make an impact on micro and macro economy to ensure the social wellbeing of the people and they are happy.

Boosting National Development Through Sustainable Construction

Ch. QS. G M Upul Shantha

Chartered Quantity Surveyor
Director of Cost Management Services (Pvt.) Ltd and CCIS (PVT) Ltd

Systems theory can be used together with lateral thinking to understand the complex nature of the world we live in. There are many challenges and opportunities around us during these uncertain times. We can consider the world as one system having interconnected sub-systems of economic, technological, environmental, social and political, etc. For example; Economical sub-system shows characteristics like rising inflation, interest rates, recession fears, supply chain shifts, and de-globalization. Environmental subsystem is centered around climate change, carbon emission targets, sustainability, and natural disasters while political systems show a shifting of world powers, re-alignment of world players, the rise of liberal nationalism, and decoupling of China. Technological fronts see the digitalization, new technologies such as AI, augmented realities, embedded systems, autonomous transport, and the flux of new technologies in energy. Socially you will find an aging population, increase life expectancy, a shift in workplace dynamics, online working, effects of the pandemic, food security, poverty, and social injustice, and many more. In this complex interconnected global world, Sri Lanka is not immune to the same challenges. One challenge however stands out. All 17 sustainable development goals agreed upon under the UN in 2015 all include the following clause -" while tackling climate change and working to preserve our oceans and forest". In 2019 world agreed to carbon emission targets to tackle climate change, especially global warming. The construction sector is responsible for major CO_2 emissions as per United Nations. The world is moving towards more environmentally sustainable carbon-neutral products, people, and processes. At this critical juncture, Sri Lanka is facing a major but also necessary correction of our social, technological, environmental, political, and economic systems. One of the key areas that Sri Lanka would be focusing on for sustainable national development is achieving carbon emission targets to gain a competitive advantage in the process, people, and product markets. In the case of Construction, people should be equipped with the required skills for the sustainable construction sector and make passionate about sustainable construction culture. The construction process starts from design inception and finally disposing of the construction product. From the inception, this process should be based on sustainable principles and techniques such as circular economy, reducing embedded carbon footprint, improving efficiency to reduce energy and resources, use of concepts 3R's, reduction of waste, elimination of harmful chemicals, moving towards greener energy, improving process efficiency through digitalization and creating smart cities and

livable habitats. The construction product created by passionate people through principals suited to Sri Lanka will give Sri Lankan Construction Industry a unique characteristic among world players.

Sustainable Land Administration System for National Development

Mr. S. Sivananatharajah

Additional Surveyor General, Sri Lanka Survey Department

In any country without the basic administration of land, the tenure to land and property cannot be secured, that mortgage loans cannot be established as a basis for property improvement and the economic development of land is not controlled through overall planning policies and regulations. Land administration systems (LAS) are about addressing these problems by providing a basic infrastructure for implementing land-related policies and land management strategies to ensure social equity, economic growth, and environmental protection which leads to the sustainable development of a country. Simply, information about land and land market processes that can be derived from effective land administration systems plays a critical role in all economies and sustainable development countries.

In this context, this presentation addresses the necessity of better land administration for the sustainable development of a country, highlights challenges faced by the land administration process in the Sri Lankan context, and describes how existing challenges in land administration influence the economy of the country. Finally, it discusses a few key remedial actions that need to be taken to develop an effective land administration system for Sri Lanka to ensure sustainable development in the country.

Make STEM Graduates the Future Innovators

Prof. Saman TWS Yapa

Department of Decision Sciences, Faculty of Management Studies and Commerce
University of Sri Jayewardenepura

A nation competing with other nations may be in one of the three levels of technology; factor-driven, efficiency-driven, and technology-driven. Sri Lanka needs to jump a long leap to the third from the current level of the early second. Sri Lankan universities should play an important role in this jump by not only enrolling more students into STEM (Science, Technology, Engineering, and Mathematics) degree programmes but also preparing them to become future innovators who will move the country toward prosperity. STEM graduates have great potential, due to their technical expertise and problem-solving skills, to become innovators, especially in two types of innovations, the generation of new or improved products and the introduction of new production processes. However, to become a successful innovator one should possess several personal characteristics and interpersonal, critical and creative thinking, innovation-specific, and practical skills. Transforming a STEM graduate into a future innovator and then into an innovative manager is particularly challenging due to the contrasting characteristics of the STEM graduates and the innovators. STEM graduates have been trained to use mostly the left brain, i.e., the logical side, while innovators must use the right brain, i.e., the creative side. In this transformation, more activities can be included in the curriculum of STEM programmes to enhance undergraduates' non-technical soft skills. More interdisciplinary/multidisciplinary subjects should be introduced as real-life problems are multi-disciplinary. Some courses in Management, Marketing and Economics also can be introduced to provide students with an understanding of the business world. The academic units of the universities can work with businesses to identify opportunities and problems that prevail in the business world. Further, undergraduates and academic staff should be encouraged to work in cross-disciplinary teams. STEM programme-related faculties and the Management/Business faculties of the universities can work in collaboration to promote the innovation culture. Even though it is challenging to make future innovators, it is the utmost responsibility of the universities as there is no future for Sri Lanka without innovation.

Development of a Livable City Index (LCI) Model using Geoinformatics

Prof. Nitin Kumar Tripathi

Professor of Asian Institute of Technology, Thailand

In recent years, research and development on livable cities have gained much attention due to the complexity and diversity of livability standards. Due to the already-existing grand-scale developments commonly found in most capitals, research on livability is often conducted in smaller semi-urban cities. Using Khon Kaen District in Thailand as a case study, we have developed a Livable City Index (LCI) based on residents' opinions and experts' recommendations with the integration of Geographic Information System (GIS) techniques. The first stage of the survey (out of three), identifies marked variations in attitudes towards the livability of a city. The survey evaluates nine significant factors (Safety, Economy, Environment, Education, Health, Transportation, Recreation, Population Density, and Public Utility) through the Analytical Hierarchy Process (AHP) for LCI development. The LCI map reveals that only 3.49% of the Khon Kaen area corresponds to the highest and high livable city levels. This contradicts the earlier ranking of the city as the most livable city in 2010, which was only based on economic factors. Moreover, the proposed method was applied to another area—the Muang district of Suphanburi in western Thailand—to test its reliability, and the results were found to be similar. This supports the integration of residents' participation in assessing the livability of a city, and this proposed approach can be adopted in other areas for LCI development. LCI model may be implemented in other cities which have similar socio-economic and environmental settings. However, developing a new LCI model based on local conditions and preferences will take little effort. This approach can provide a useful planning map to enhance the livability of various zones of the city and ultimately make the whole city attain a good living condition.

TECHNICAL SESSION

Review on the Height Datum Unification in Sri Lanka

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Abstract*: Single or Multiple Tide Gauges (TGs) observations are typically used to observe the sea level changes and those observations are used to define the vertical datums/Local Vertical Datums (LVDs) in an Island-wide or continental-wide. The national geodetic datum is the most significant framework for any surveying work like construction, engineering, mapping, or hydrographic in any country. This network usually should consist of both horizontal (latitude and longitude) and vertical (height) components with a higher order of accuracy to fulfil the survey and mapping needs within the country. Vertical datums are based on the geopotential whereas horizontal datums are geometric. Vertical datums are mostly based on the equipotential surface like the geoid, an equipotential surface that coincides with the Mean Sea Level (MSL) of the oceans. Currently, there are numbers of LVDs existing in the world and usually, those are used to define using spirit levelling, gravimetric observations, and TGs observations and it was continuously described within the geodetic literature over the past decades. Sometimes within that, it can be identified Global Vertical Datums (GVDs) which were based on the low-resolution geoids. According to the International Association of Geodesy (IAG) one of its main tasks is to create unification of the existing LVDs around the world through the Global Geodetic Observing System (GGOS). The main objective of this study is to identify a suitable vertical datum unification method that can be applied for the vertical datum in Sri Lanka which was formed in early 1930 and it is highly needed to re-observe it in order to fix the potential datum bias due to various geodynamic effects. The concept of the Unification of height/vertical datum is increasingly interesting nowadays which makes the comparison of various datums in different regions possible. Our study revealed that the Geodetic Boundary Value Problem (GBVP) approach is the most appropriate process that can be used for the unification process of the vertical datum in Sri Lanka.*

Keywords: *Geodetic Boundary Value Problem, Mean Sea Level, Unification, Vertical Datum, Tide Gauge*

1. Introduction

The national geodetic control system is the most vital framework for any surveying like engineering, construction, hydrographic and mapping purposes. This framework should consist of both horizontal (latitude and longitude) and vertical components with higher-order accuracy. Horizontal datums are normally identified as geometrical and vertical datums are mostly known as equipotential. The vertical datum is a reference system used for determining the physical heights (elevations) of a point on, above, or below the surface of the earth. It may be a LVD based on MSL or a GVD built on low-resolution geoids. Single or multiple TGs observations of the MSL were used to define most of the LVDs. However, it can be clearly stated, that the local MSL does not exactly coincide with the global equipotential surface like geoids, which was used to determine the

LVDs for island-wide or continental-wide. According to Amin et al., (2019), a geoid is defined as a particular equipotential surface of the gravity field of the Earth that gives the best-fitted model for the undisturbed MSL (Amjadiparvar et al., 2015; Vu et al., 2021) with the sense of least square adjustment. Further, this undisturbed sea level is not possible to achieve because of the sea currents, external gravity forces, atmospheric pressure, etc. and for that convention, MSL should also be needed. Until recent years, these LVDs were consistent in time, and reference stations are normally considered as steady and consistent over the decades.

The height of a point or elevation is an important component for the positioning, and it should reference to some height datum. To determine the vertical component, the spirit levelling is adopted with reference to some equipotential surface (Balasubramania, 1994). An equipotential surface was defined as the geopotential value W_0 (Sánchez et al., 2016), which is taken as the base surface for the measurements of the physical heights, normally known as a vertical/height datum. To define the potential value of W_0 and the origin of the vertical levelling network, the fundamental TGs were used, and zero level height was defined (Amjadiparvar et al., 2015; Balasubramania, 1994; Dayoub et al., 2011; Hayden, 2013; Hayden et al., 2012; Sjöberg 2013).

Within the world, there are more than hundred LVDs exist and those are based on the reference surfaces and the adopted height systems, which differ between the countries and the regions. Most of them are based on the averaging sea level observations of a single or multiple primary TGs, assuming that the MSL at these TGs coincides with the geoid (Balasubramania, 1994; Dayoub et al., 2011). Balasubramania (1994), mentioned that the vertical datums adopted for the different countries or regions are based on their computed average MSL observations over 19 years of tidal observations, different methods, and different time epochs. He further mentioned that the observations of MSL of later epochs will not coincide with this reference vertical surface or datum.

Ihde et al. (2000) mentioned that the Global Positioning System (GPS) can also be used for levelling purposes if the geoid is precisely known enough to concern the relationship between the levelling reference system and the GPS reference system. But still, precise geoids yet to be achieved for the European region with a few centimetres' accuracies for practical consideration can be used for the GPS/levelling purposes for the existing vertical networks.

According to Sánchez (2007, 2009), the global potential value assigned to the zero-height level should be adopted to have a precise explanation and realization for the unified height system. In the geodetic literature, it can be identified different strategies and approaches are used to define the unified vertical datums around the world and it is one of the most significant tasks of the GGOS of the IAG. With the improvement of science and technology, it was observed and identified the changes on the surface of the earth and pointed toward having high-accurate unified vertical datums that can be used for any kind of surveying activities. The main objective of this study is to identify a suitable method that can be used for the height datum unification of the Sri Lankan level net named Ceylon Level Net established in 1930 using multiple TGs observations and two-way spirit leveling. To fulfill the above-mentioned objective, already published research papers were reviewed and various strategies that can be used to get the solution for the unification of the height datums are studied in the following paragraph.

2. Vertical/Height Datum Unification Strategies

Unification of vertical datum has been broadly discussed and examined in the geodetic literature and the physical geodesy within the last centuries and still it is investigated to develop unified vertical datums for some countries for the purpose of all kinds of survey activities. A number of geodesists examined and introduced different tactics that can be used for the unification process (Ardalan & Grafarend, 2004; Ardalan et al., 2010; Ardalan & Safari, 2005; Ebadi et al., 2019; Gerlach & Rummel, 2013; Gruber et al., 2012; Rummel & Ilk, 1995; Rummel, 2000; Sansò, 1981; Zhang et al., 2009; Zhang et al., 2020). Those are spirit levelling and gravimetric observations, the oceanographic approach, and the GBVP approach.

Strategy – Spirit Levelling with the Combination of Gravimetric Observation Approach

This strategy was used to connect two or more LVDs in some countries. As an example, the United European Levelling Network 1995/1998 (UELN95/98) was used as the vertical datum for the twenty-seven (27) countries in the European region since 1990. Later by using the spirit leveling and the geopotential numbers derived from the gravimetric observation were used to upgrade the LVD to centimeter-level accuracy and formed the European Vertical Reference Network (EUVN) (Ihde et al., 2000). Another typical case study is the height datum adjustment of North American Vertical Datum 1988 (NAVD88) in Canadian, Mexico, and the United State using the above-mentioned strategy (Amjadiparvar et al., 2015; Zilkoski et al., 1992).

Strategy ii – The Oceanographic Approach

Different LVDs even if they were not connected by the points on the ground, can be connected using the oceanographic approach (Rummel & Ilk, 1995; Thompson et al., 2009; Woodworth et al., 2012). Oceans are the fundamental obstacles to the height datum unification (Rummel & Ilk, 1995), because it is not possible to conduct direct spirit levelling on the surface of the oceans. To overcome this problem, potential differences were derived from ocean levelling using geostrophic and steric levelling methods.

Woodworth et al. (2012) show that the application of ocean levelling can be used for the vertical datum unification, and for the determination of mean dynamic topography (MDT) at the coast area such that North Atlantic coastlines, and islands, North American Pacific coast and Mediterranean and obtained sub-decimeter level accuracy. As explained by Amjadiparvar et al. (2015), MDT is used for the oceanographic approach to determine the changes in MDT at the primary TGs of the datum and shows that the differences are equivalent to the datum parameters. They further mentioned that MDT can be calculated using satellite altimetry based on mean sea surface or MSL at the TGs joint with a geoid model. Hayden et al. (2014), give a better explanation of the determination of the MDT using a geographic approach also.

The MSL records at the selected TGs are integrated into the levelling network, in combination with oceanographic models of sea surface topography, which can provide independent control for the network (Rummel and Teunissen, 1988). This sort of control, on the other hand, makes sense only if the oceanographically determining potential differences are of higher quality than the levelled ones.

Strategy iii – The GBVP Approach

The GBVP approach is an important strategy that can be used for the unification of the height datums and this method is commonly used to define the unified vertical datums over the countries or continental-wide. The solution given by this approach is used to connect different LVDs and can be used to define the datum parameters furnish with the global potential surface.

A number of geodesists investigated and studied the different quantities of the gravity field and introduced different methods to define the unified vertical datums (Balasubramania, 1994; Colombo, 1980, 1981; Heck, 1990; Heck & Rummel, 1990; Rummel & Teunissen, 1988; Tengstrom, 1965; Xu, 1992). And different boundary value problem approaches were developed and introduced for the height datum unification by Fernando Sanso since 1981. Furthermore, different overviews of the GBVP approach were studied and presented for the unification process (Sansò, 1981, 1993, 1995; Sansò & Venuti, 2002).

According to Sansò (1981), if considered the shape of the boundary and the value of the potential, it gives the Dirichlet problem, and if considered value of the potential as well as the gravity vector all over the boundary, it gives the Molodensky problem. According to Sansò (1995), the boundary value problem formulation can be used to perform a gravimetric calculation of the geoid. The general idea of removing the first-degree spherical harmonics from the gravitational potential, for the regularization of the downward continuation of a high-frequency part of the gravity, can be used to test the existence of a solitary solution to the boundary value problem for the determination of gravimetric geoid (Martinec, 1998).

As mentioned by Heck (1990), the Stokes function is commonly used to compute the geoid or quasi-geoid models for the unification of LVDs, because using the Stoke function can compute the gravity anomalies referring to the LVDs which are biased with the global equipotential surface defined by the different Global Gravity Models (GGMs). For example, vertical datum unification done in New Zealand which was originally based on normal-orthometric-corrected-precise-levelling can be taken. For this process regional gravimetric quasi-geoid model and GPS/levelling points on 13 different LVDs were used by combining the iterative process with the GBVP approach. In this case, the iterative process was used due to datum offsets which were affected by gravity anomaly bias, and each iteration step was updated with offsets computed at the previous process (Amos & Featherstone, 2009). With this iterative process, Earth Gravity Model 2008 (EGM2008) and satellite-only gravity model from Gravity field steady-state Ocean Circulation Explorer (GOCE) mission data were used to compute the datum offsets (Pavlis et al., 2012).

Another GBVP approach is the use of the highest degree satellite-only global gravity model (GGM) in grouping with terrestrial gravity differences and applying the modified Stokes kernel. According to Gerlach & Rummel (2013), if use GGM which was not based on satellite gives a 1 – 2 m error globally. But when the satellite-based GGM of a spherical harmonic degree and order 200 was used for the computation, this inaccuracy could be decreased to the level of 1 cm, and indirect bias terms may be disregarded for the GBVP approach when applying for datum unification. The findings of this study were supported by (Gatti et al., 2012) also.

Different types of GBVP approaches were proposed and studied by several other researchers to find an applicable method for vertical datum unification all over the world. Some of them are (Ardalan & Grafarend, 2004; Ardalan et al., 2010; Ardalan & Safari, 2005; Zhang et al., 2009; Zhang et al., 2020).

As mentioned Ardalan and Grafarend (2004), were presented a new theory for the computation of the high-resolution regional geoid without using Stroke's formula. For the process, they have formulated a fixed-free two-boundary-value problem with respect to a reference ellipsoid. Ardalan and Safari (2005), also used this fixed-free two-boundary-value

problem to propose a method for vertical datum unification.

A new methodology to unify the vertical datum in Shenzhen and Hong Kong is proposed, and it is based on the linearized fixed GBVP method (Zhang et al., 2009). The geodetic leveling is within a few centimeters of the height differences found using this unique method.

A bias-free GBVP approach was formulated to unify the vertical datum by (Ardalan et al., 2010), based on potential and gravity differences considered free from the datum shift.

The height datum offset values between the local and the global vertical datum are defined using the Remove-Compute-Restore (RCR) process, which is based on the GBVP approach (Zhang et al., 2020). The RCR approach was utilized to remove and restore the long wavelengths of the gravity field, and the GRACE and GOCE satellite missions were used to obtain the very accurate medium-long gravity field.

3. Sri Lankan Vertical Datum

The geodetic vertical control network of Sri Lanka, originally named Ceylon Level Net was started in 1926 and was completed in 1930. The primary level network consisted of 27 two-way level lines and 59 primary benchmarks. The zero MSL was observed using the discretely located self-recording TGs based in Colombo, and Trincomalee from 1923 to 1933. These MSL observations were used to define the origin point of the Ceylon Level Network (Jackson, 1936). But, before that, three discretely located harbors in Colombo, Trincomalee, and Galle were used to observe the tidal observations, because those locations were given the daily prediction of the tidal data of the Indian Ocean. The Great Trigonometrical Survey of India was used above harbors to determine the MSL readings using the self-recording TGs within the following periods: at Colombo and Galle 1884 – 1890, at Trincomalee 1890 – 1895. It was initially decided to use the Colombo and Trincomalee as the zero-height location for the precise leveling network because when it was undertaken, it was decided to re determine the MSL at both places within the same period and the leveling process is ongoing. Anyway, with these observations ongoing at both Colombo and Trincomalee, the Level Net of Ceylon was adjusted in 1932 by using the MSL value of Colombo as observed by the Great Trigonometric Survey of India observed by the five years observations during the 1884 – 1889 (Price, 2013).

When it considers the crustal changes and other global geophysical changes like melting of the glaciers (post glacier rebound), sea-level changes, land subsidence, etc. MSL observations done in the 1884 – 1889 period are not sufficient for the present-day work and those discretely located three TGs were used for MSL observations are not appropriate for fixing the vertical datum in Sri Lanka and also this was pointed out by (Abeyratne et al., 2009) and further mentioned the possibility of ellipsoidal height bias in Sri Lankan GPS datum.

Also, the recent research done by Prasanna et al. (2021), developed a model for the height changes to determine the relationship between the LVD and the Lowest Astronomical Tide (LAT) around Sri Lanka. This model was analyzed using IDW spatial interpolation with the assumption of spatial autocorrelation. Additionally, they stated that the absence of gravity data over Sri Lanka was a major concern for this type of study and that this global-based local geoid was suggested as a result.

4. Discussion

Many LVDs in the world were used to define the unified vertical datum using three different

strategies mentioned above for all kinds of surveying and mapping purposes.

When it comes to Sri Lanka, still Sri Lankan surveyors use the level data observed in the 1884 – 1889 period for any type of surveying activities within the country and its surrounded sea area. Two horizontal control networks such that Kandawala and Sri Lanka Datum 1999 (SLD99) are utilized to get horizontal controls, but for the vertical controls, it is still using the above-mentioned MSL-based vertical datum which was based on Colombo within the 1884 – 1889 period and having the normal orthometric height system. Those MSL observations which were established more than 130 years ago are still used for all types of surveying activities.

According to IPCC, (2014), the present global mean sea level rising rate is approximately 3.2mmyr^{-1}and Sri Lanka faced a huge Tsunami effect in 2004 due to the plate tectonic movements that happen on the Burma plate and Indian plate. Therefore, when considering the above-mentioned factors and other global geophysical changes the MSL observations done in the 1884-1889 period are not sufficient for the present-day surveying and hydrographic activities within the country and the surrounded sea area.

5. Conclusion

According to the above-mentioned geodetic literature, and the history of the Ceylon Level Network, the unification of the LVD is an important work for the present-day survey and mapping activities. The remedy for this is incorporating continuous equipotential surface like geoid as the vertical datum. Therefore, it is possible to say as for Sri Lanka, it is better to use the GBVP approach method to find the datum offset between LVD and the global geopotential model (geoid).

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Acknowledgment

I would like to give my heartfelt gratitude towards to the Faculty of Graduate Studies at the Sabaragamuwa University of Sri Lanka, my supervisors for my MPhil degree, and sincere thanks & gratitude to all the people who helped to complete this study

Authors Biography

I am KP Manuranga, Have completed my basic degree in B.Sc in Surveying Sciences (Specialized in Surveying & Geodesy). I would like to do my future studies regarding in Gravity, Height Datum Unification, and GNNS. All my studies are related to surveying and geodesy, and I like to make some effort to generate new solutions for the problems in the above-mentioned research interests.

Analyzing the effects of land use and land cover changes on paddy cultivation using Remote Sensing: A case study of Sooriyawewa, Sri Lanka

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Abstract*: Land-use and land-cover (LULC) change research is a type of environmental research that is intimately linked to socioeconomic development. At present, the LULC changes are mainly occurred due to physical developments and agricultural purposes. Paddy is the major crop and mostly grown in Sri Lanka. Hambantota district rank as fifth place in rice production in Sri Lanka. Sooriyawewa is the driest and mostly grown paddy Divisional Secretary Division (DSD) in Hambantota District, but nowadays there are so many reasons that hinder paddy cultivation. This research aims to identify the existing system for monitoring the LULC changes in paddy cultivation and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation in Sooriyawewa during the past four decades and finally examine the underlying causes for LULC changes over the paddy. For this research, downloaded Landsat images from 1980 to 2019 with a specified time gap and Supervised classification was used for the land cover classification for all images to detect the paddy variation in this area. Obtained net changes between 1980-2019 are Paddy, Other crops, Forests, Waterbodies, Built up areas and barren lands. According to the LULC changes between 1980-2019, there was a -15.50% decrease in paddy areas but built-up areas, other crops significantly increase 11.97%, 10.08% respectively. This is a temporal problem in this area and this study is essential for the relevant authorities for decision making, preparing urban development plans, where planned infrastructural development and supervision, land use planning, natural resource conservation and environmental sustainability.*

Keywords: *Land use and Land cover, Classification, Remote Sensing*

1. Introduction

At present, Land Use and Land Cover (LULC) changes are mainly occurring due to physical developments and agricultural purposes (US Department of Commerce, 2020). Land use implies human activities which directly involve to the site and land cover means the vegetation, water, natural surface, and man-made features of the site (Us Geological Survey, 1997).

Land cover can be identified by analyzing aerial and satellite images, but land use cannot be identified through satellite images (US Department of Commerce, 2020). Analyzing these LULC changes are very important for land surveyors and spatial planners because, land cover maps procure details to realize the current landscape properly (US Department of Commerce, 2020). To examine past changes, different years of land cover maps are needed, and this information is useful for authorities to evaluate past management decisions as well as possible effects of their current decisions before they are proceeded (US Department of Commerce, 2020). Rapid increment of population growth, limitations of the arable lands, plant

diseases, environmental changes (temperature variations, water shortages, floods) and climate changes are the main issues for food security in Asian regions (Huang et al., 2014). So, developing countries are increasing agricultural production to uplift the food supply and increase employment and income.

Rice (Oryza sativa) is one of the staple food crops of the world. Most Asian countries use rice as second in agriculture production (Dengiz and Formation, 2015). In the past, Sri Lanka is one of the prominent countries for rice production in the world and paddy is the major crop and mostly grown in Sri Lanka (doa.gov.lk. 2013). Main area of rice cultivating are Ampara, Kurunegala, Polonnaruwa, Matara, Hambantota, Baticola, Anuradhapura (Paddy Statistics, 2019). The study area of the research is Sooriyawewa Divisional Secretary Division (DSD), in Hambantota district, dry southeastern part of Sri Lanka and Hambantota district rank as fifth place in rice production in Sri Lanka (Paddy Statistics, 2019). Today paddy and Other Field Crops (OFC) are the most cultivated crops in Sooriyawewa (Perming, 2013). Yala (during the period from April to August) and Maha (during the period from September to March in the following year) is the main paddy cultivation seasons (Paddy Statistics, 2019) and Maha is the most paddy cultivation season in Sooriyawewa.
Paddy crops are cultivated as wetland crops in all the districts of Sri Lanka and nowadays, the total land allocated for paddy is estimated to be about 708,000 Hectares (Paddy Statistics, 2019). However, the whole area allocated for paddy cultivation is not being cultivated due to number of reasons such as water shortages during the seasons, prevailing unsettle conditions on the ground, etc (Paddy Statistics, 2019). Due to the covid-19 pandemic period, world discussed the importance of fresh and nutrient foods from small scale rural producers (Deuja, 2020). Also, Sri Lanka had to face some issues on the food security, unable to supply for the demand so, harvest estimation is very important for that. Crop production acts a huge role in food security and the economic development of a country. Most of the farmers here tend to convert paddy fields into alternative crops for economic benefits.

At present, Sri Lanka uses traditional methods for crop monitoring. Traditional methods of crop monitoring have some issues as time-consuming, subjective, expensive, limited to some extent, large errors occur during the field observations, less efficient and less accurate (Huang et al., 2013) but, Remote Sensing is a new trend in the world for crop monitoring in the proper way and very useful for evaluating natural resources and management. Also, useful for monitoring the crop conditions, the healthiness of the crops, estimate the yields. This research focuses to identify the paddy land use changes using Remote Sensing efficiently and accurately.

This research aims to identify the existing system for monitoring the LULC changes and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation during the past four decades (1980-2020) in Sooriyawewa DSD and finally examine the underlying causes for LULC changes over the paddy in this study area. This analysis reveals what will be the possible changes in the study area in the past years and what are the present land use changes taking place in the area. This is a temporal problem in this area and hopes this project is essential for the relevant authorities for decision making.

2. Methodology and Experimental Design

A. Study Area

Sooriyawewa Divisional Secretariat Division (DSD) was the target area for this study. It is situated in the Southern Province of Sri Lanka, Hambantota District, bordering Sewanagala, Hambantota, Lunugamwegera and Embilipitiya DSDs and between Latitude 6° 11' 40" to 6° 24' 20" North and Longitude 80° 55' 00 " to 81° 05' 00 East.
Sooriyawewa DSD is the driest DSD in Hambantota District (Perming, 2013)

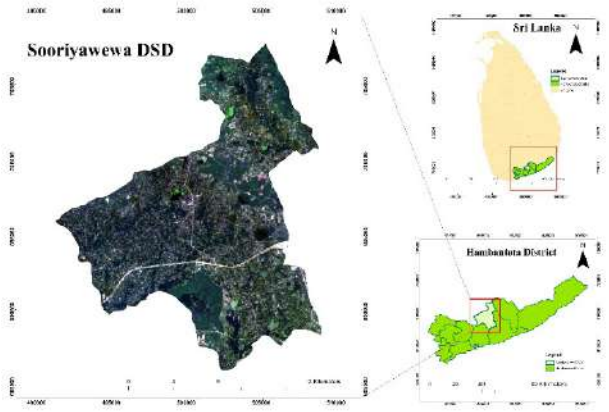

Figure 1: Study Area

Hambantota district rank as fifth place in rice production in Sri Lanka (Paddy Statistics, 2019). Today paddy and Other Field Crops (OFC), including bananas, are the most cultivated crops in Sooriyawewa (Perming, 2013). There are special features in this area for analysis. First, this area is flat, not consist with higher geological barriers for disturbing the analysis, this is a dry zone and not effect by environmental hazards such as floods, and landslides. Second, normally the area is called as a rural area, but nowadays it is changing. In near Sooriyawewa, development projects were running and the department of Census and Statistics reported the number of inhabitants increased in the past years (Perming, 2013).

Table 1: Landsat images

Satellite series	Year	Acquisition Date
LANDSAT_3	1980	1980-02-06
LANDSAT_5	1988	1988-03-02
	1992	1992-01-25
	1997	1997-02-23
	2000	2000-01-23
	2005	2005-03-17
	2010	2010-01-26
LANDSAT_8	2014	2014-01-21
	2019	2019-01-03

B. Data used

This study was conducted mainly based on quantitative analysis, and work with primary and secondary data. For this investigation, distinct Landsat images were employed on several evolution stages (Landsat 3, 5, and 8). To prevent seasonal fluctuations in this location, the images for nine distinct years were gathered with nearer acquisition dates. Maha season is from September until March the following year and chooses January to March period for downloading satellite images in each image. The Landsat images utilized in this experiment are listed in the table below.

C. Experimental Materials

1) GIS Software

All forms of geographic and spatial data are stored, managed, displayed, and analyzed using a Geographic Information System. GIS software creates visual representations of geographic data for study and presentation. The LULC categorization procedure was carried out using Arc Map 10.5 licensing software.

2) Google Earth

Google Earth is a free and open-source program. The Google Earth software was used to detect land coverings for various years and to test the accuracy of the procedure

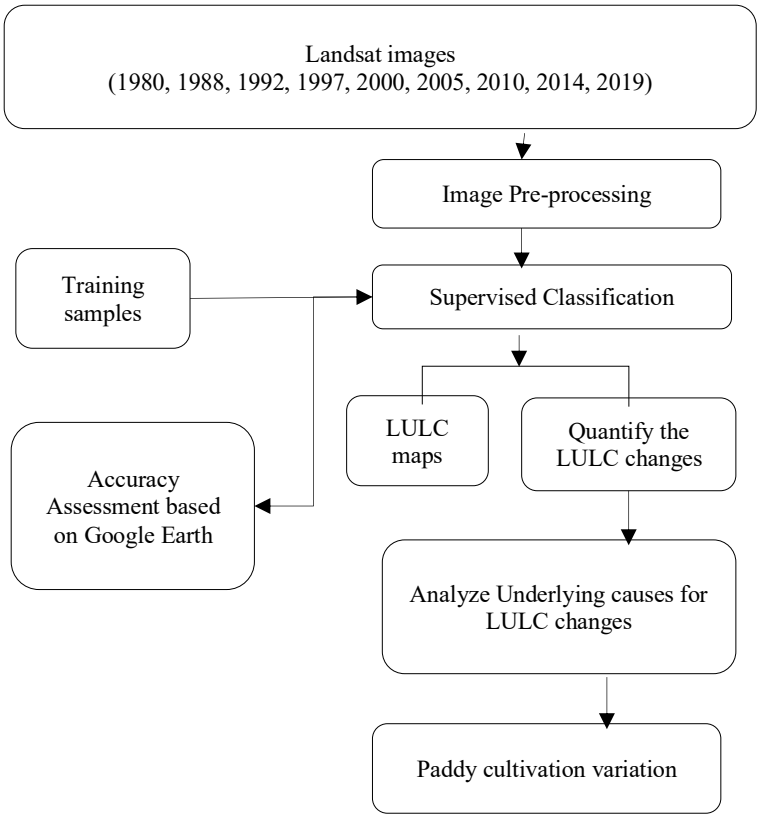

Figure 2 : Experimental Workflow

The research was conducted in three stages. First identified the existing system for monitoring the LULC changes and applicable Remote Sensing techniques. Second, quantified the LULC changes over paddy cultivation during the past four decades (1980-2020). And last, examined the underlying causes for LULC changes over the paddy cultivation in Sooriyawewa. Used past research papers to identify the existing LULC monitoring mechanism. Before the analysis, first applied single band preprocessing techniques (Radiometric calibration and atmospheric correction) to each band that use for the study.

The LULC classification is based on supervised classification. While providing training samples, supervised classification is used to recognize distinct land use classes in a particular area with maximum likelihood algorithm. Select the training samples that encompass the study area first. The experiment focused to identify paddy variation so paddy areas, other agricultural areas, forest areas, water areas, built-up areas, and barren land areas as training samples and used Google Earth to choose appropriate training sites.

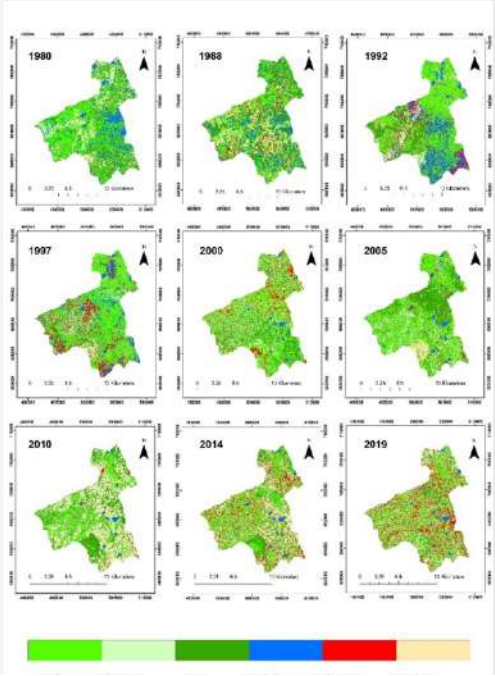

Figure 3: Supervised Classification Results

2. Results

Existing LULC monitoring systems

In the early 1950s, to show shifting patterns of land use and land cover, the researchers (Gangodawila, 1988) utilized a variety of approaches. Field inspections were utilized in addition to black and white panchromatic photographs by the researcher. To increase the accuracy of interpretation and evaluation of agricultural land, water, and resources, preliminary air photo interpretation stereoscopic pairs of images were utilized. In this (Wickramasinghe, Subasinghe and Ranwala, 2016) study, air pictures (scale 1: 40,000) from 1956 and air photos (scale 1: 20,000) from 1982 were employed. For the years 1956 through 1982, no research satellite pictures were available. As a result, aerial pictures with a scale of 1: 20,000 were utilized

at the time. From 2001 to 2010, high-quality IKONS photos (4m spatial resolution) were utilized. They georeferenced two IKONS photos and digitized them using Arc GIS 9.3 software's "on screen Digitizing" technique. Calculating the green cover change for each era and then dividing it by the number of years in that period yielded the rate of green cover change.

Crop monitoring in many countries relies on traditional data gathering approaches such as field visits and reports to estimate crop and yield (Sawasawa, 2003). These reports are frequently subjective, expensive, time-consuming, and prone to substantial inaccuracies due to incomplete ground observations, resulting in poor crop monitoring evaluation (yield estimation, area estimation). Until now, Sri Lanka only uses traditional data collecting methods for paddy monitoring.

3. LULC change analysis

The past patterns (1980–2019) of LULC variations were estimated from Landsat images using Maximum Likelihood classification, presented in Fig.3. The Maximum Likelihood classification obtained the overall classification accuracy more than 80% for each year

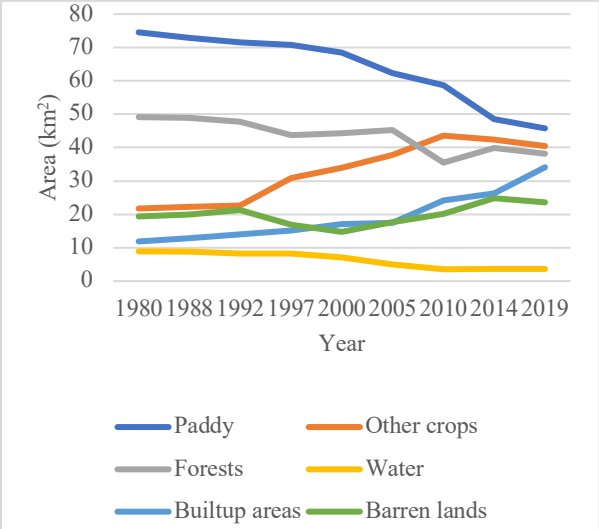

Figure 4: LULC changes between 1980 to 2019

The primary goal of this research was to discover changes in paddy areas. Diagram 4 depicts how paddy fields have evolved over the last four decades. Paddy areas have been declining since 1980, but there has been a significant drop since 2000. As well as other crops, this area cultivates a variety of crop kinds (banana, pomegranate, papaya, etc.). Other agricultural areas have expanded dramatically since 1992. The research area has low forest covering due to increasing urban development. In all directions of the research region, the decline of highly green areas was documented. However, in 2005, there was a substantial decrease. Since ancient times, water sources have been the lifeblood of human society in dozens of ways. The major challenge confronting the worldwide tourist sector is water. Instead of conserving water sources, people are encroaching on them, causing pollution and uncontrolled development plans, as well as urban growth. The declining phenomena of the previous four decades have had a direct impact on this area's agriculture, particularly rice production. Rapid, uncontrolled urban expansion shattered the natural equilibrium, making the region more unsuitable for life and agriculture. Since 2010, the government has concentrated on the Hambantota region, and

several development projects have been launched in the Hambantota District. The primary projects are Mattala International Airport, Sooriyawewa International Cricket Stadium, and the Southern Expressway. As a result, this area is growing in terms of administrative, commercial, recreational, infrastructural, telecommunications, and transportation amenities. Urbanization is accelerating for a variety of causes. Rural-urban migration, increased career possibilities, improved quality of life, and natural growth are all examples of natural growth. Although considerable urban growth is occurring in all directions in the area. All of these amenities make this study location more appealing to residents than to other people. Furthermore, the dispersion of these amenities is transforming the region into a hotspot for urban growth by attracting a rising number of business and administrative operations. In the past, these places were overlooked by rural residents, but today, individuals are drawn to these areas in search of better job prospects and a higher quality of life. The aesthetic and ecological qualities of bare lands, which are mostly unoccupied urban areas and open spaces, give environmental, social, and economic benefits to residents. The changes in bare lands during the

categorization were driven by substantial rural-urban migration and a lack of focus on conserving open areas. The extent of bare lands changed from 1980 to 2019, as seen in Fig.

4. Causes for the LULC changes

1) Water shortages

The drier parts of Sri Lanka are sometimes susceptible to water shortages due to the spatially and seasonally uneven distribution of water. The Government of Sri Lanka is aware of water management issues. The policies stress the need of conserving water. However, the work may not be simple to carry out. Although much money has been spent on restoring irrigation projects, this does not prevent individuals from using water without authorization, a subject that the farmers questioned in Sooriyawewa were concerned about.

According to several studies, Sri Lanka is experiencing a general trend of decreasing precipitation rather than increasing it (Droogers, 2004; Peiris 2006). Peiris speculates that deforestation during the last decade may be to blame for the shift, as the forest no longer regulates the hydrological cycle to the same level. They also talked about the changing monsoon patterns. Peiris (2006) also expresses concern about how agriculture that replaces forests contributes to biodiversity loss, soil salinity, and erosion, to mention a few risks when irrigation and chemical compounds are used.

2) Alternative crop cultivations

Banana, watermelon, papaw, pomegranate, and passion fruit are the most prevalent alternative crops in Sooriyawewa DSD, and a study conducted in Hambantota in 2015-2016 found that farmers chose to produce bananas in paddy areas for economic gain (Kumarage and Arunakumara, 2019). Chena cultivation in the Hambantota district begins in October when the Maha rains fall. Farmers start forest firing, also known as 'Nikini Paaluwa,' during the dry season in August (Kumarage and Arunakumara, 2019). Water scarcity, economic factors, animal damage, and, most importantly, a lack of government assistance, which includes fertilizer and seed subsidies, are the key causes for the increase in other crops.

Another significant issue raised by farmers is marketing, which is influenced by political actions as well as market demand (Perming, 2013). The producers said that because banana prices fluctuate on the market, the harvest is best timed to coincide with the months when market prices are at their maximum. In Sri Lanka, the fruit season runs from April to June, which means that the banana faces market competition and is thus sold at a reduced price. As a result, the market price rises when production is low. Paddy had a predetermined minimum price at the time the interviews were done, but this was not always the case.

Paddy production has a high starting cost, thus farmers must invest a significant amount of money. Floods, droughts, pest and disease outbreaks, and price variations are all considered risk factors in the paddy industry, thus farmers face a slew of financial challenges if their harvest is lost. Alternate crop production is regarded as one of the greatest solutions accessible to both personal and commercial farmers in the Sooriyawewa area.

3) Construction activities near Sooriywewa

During the period 2005-2015, one of the Government of Sri Lanka's top goals was to upgrade infrastructure and start numerous new projects in the Hambantota District. The Hambantota International Port, the Mahinda Rajapaksa International Airport in Mattala, the Mahinda Rajapaksa International Cricket Stadium in Sooriyawewa, the Southern Expressway, and the Magam Ruhunupura International Convention Centre were among the major projects that began during this time. These construction activities mainly caused the LULC changes in Sooriyawewa DSD.

4. Discussion and Conclusion

This study used Landsat satellite images to monitor and predict the LULC changes in Sooriyawewa DSD, Sri Lanka. The study denoted LULC changes in paddy cultivation from 1980 to 2019. The main objective of this research was to analyze the paddy area changes but there most noticeable changes in waterbodies, built-up areas and other crops. According to the LULC changes between 1980-2019, there was a -15.50% decrease in paddy areas and built-up areas, and other crops significantly increase 11.97%, 10.08% respectively.

As studied in the past years, there is a trend to convert paddy fields into alternative crops, especially, banana crops in Hambantota area (Hirimburegama, Dias and Hirimburegama). When this situation will continue in the future, there is a red alert for the staple crop of Sri Lanka. If the rice is not sufficient for the population growth, it may be exported from another country and it is highly affected the economy of the country. Hambantota district is a rapid development area since 2010, so land management for proper cultivation is very important.

Traditional methods of crop monitoring have associated issues and Remote Sensing technology is beneficial for evaluating natural resources and management. Also, useful for monitoring the crop conditions, the healthiness of the crops, estimate the yields. Most research on crop monitoring is based on Remote Sensing technologies and these studies can be done at regional and national levels and the results are useful for planning agricultural production (Unal, 2020).

In this project, identified what are the existing system for monitoring the LULC changes and applicable Remote Sensing techniques, then quantify the LULC changes over paddy cultivation during the past four decades

(1980-2020) and finally examined the underlying causes for LULC changes over the paddy. Paddy and natural resources are converting into Built-up areas creating significant impacts on the environment by reducing ecosystem services, the amount of land used for food production, increase heat waves, and health-related problems. To minimize these adverse consequences, the inclusion of a sustainable land use management plan to estimate microscale change detection in different directions is needed for Sooriyawewa by imposing restrictions on the conversion of natural resources to built-up areas. The methods and findings of this study will be helpful for concerned authorities, policymakers, government officials, and urban planners who can utilize the microlevel directional approach in Local Area Planning (LAP) to make the city liveable by plantation, conserving waterbodies, and planned urban infrastructural development in making Sooriyawewa area planned, inclusive, and environmentally sustainable. This is a temporal problem in this area and hopes this project is essential for the relevant authorities for decision making

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Abbrevations and Symbols

CA - Cellular Automata

DSD - Divisional Secretary Division

GIS – Geographical Information Science

LAP - Local Area Planning

LULC - Land use and Land Cover

OFC - Other Field Crops

Acknowledgment

We also like to acknowledge every person who helped us in different ways during the research work.

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Impact of Flood on the Built-up Environment - A Case Study of Baddegama DS Division

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Abstract: *Floods, a recurring phenomenon primarily in low-lying basin areas can be interpreted as beneficial for improving soil structure and cropland products, but they can also be viewed as one of the most catastrophic natural disasters adversely affecting human life and the environment. The main reason for the Baddegama area's flooding is the Ging River flowing through it. The purpose of this research is to prevent the damage caused due to the lack of proper understanding of the flood risk in built-up areas. To identify the riskiness of the built-up area, it should overlay the flood inundation map and built-up area map. To create a flood map, five criteria were selected according to the ideas of well-knowledgeable people who lived in the Baddegama area. In order to Land Use Land cover (LULC), slope, rainfall, soil, and water features were identified as the criteria that were affected by the flood in the area. An Analytical Hierarchy Process was used to scale the criteria, and the weighted overlay method was used to create the flood map. LULC map, as well as a built-up map, were created using a Landsat 8 image and a method of supervised classification. The built-up area map was created after performing the Normalized Difference Built-up Index (NDBI). Most built-up areas in the Baddegama are under moderate flood risk. Further, 14% of built-up areas are at high risk. The riskiness levels of the built-up area as a final output of this study could be used when establishing evacuation centers.*

Keywords: *AHP, Normalized Difference Built-up Index (NDBI), Supervised Classification, Weighted Overlay*

1. Introduction

Sri Lanka is suffering from various natural disasters, including weather hazards like cyclones, monsoonal rain, and subsequent flooding and landslides (Disaster Risk Reduction in Sri Lanka, 2019). Intense meteorological conditions, upper atmospheric instability, or low pressure, despite heavy rainfall, create catastrophic flooding and landslides are the main causes of natural disasters in Sri Lanka (De Silva and Jayathilaka, 2014). Among those natural disasters, flooding is the greatest threat to people who are living in the lowland plains of Sri Lanka (Punchihewa, 2019). Not only in Sri Lanka but also floods are one of the world's most periodic, pervasive, devastating, and common natural disasters (Bapalu and Sinha, 2005*).* Although flooding can occur anywhere on the earth's surface, some areas are more vulnerable to flooding than others. Figure 1 shows the different types of disasters from the year 1990 to the year 2018, and the huge damage that caused the disaster was the flood (Disaster Risk Reduction in Sri Lanka, 2019).

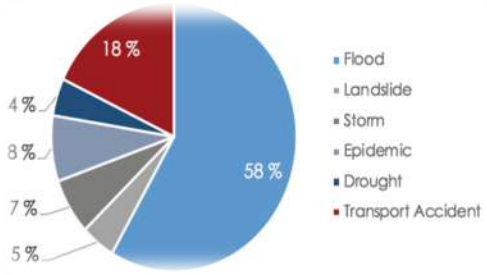

Figure 1. Disaster occurrence from 1990-2018
Source: (Disaster Risk Reduction in Sri Lanka, 2019)

Moreover, flooding is a natural calamity that may cause damage to property, infrastructure, livestock, vegetation, and even living beings (Mustaffa et al., 2016). The wet and intermediate zones get more precipitation than the dry zone, with mean annual rainfalls of 3,000-7,500mm and 2,000-3,000mm, respectively in Sri Lanka (Yoshitani, Takemoto and Merabtene, 2007). Heavy rain and high winds caused by the southwest monsoon on the 25th and 26th of May caused the flood, which affected 879,778 people and, resulted in 219 deaths and 74 misplaced. The tragedy destroyed or damaged approximately 80,000 homes, affecting the livelihoods of over 342,000 people who rely on agriculture, the market, and industry for a living (Ministry of Disaster Management, 2017). As per enumeration data, floods have been the danger that has afflicted the greatest number of households over the previous four decades (De Silva and Jayathilaka, 2014). According to the ministry of disaster management of Sri Lanka, the spread of disaster situations was confined only to 15 districts compared to the 24 districts in the year 2016, increased incidents of floods, landslides, and deaths in 2017 made the situation equally challenging.

Moreover, unauthorized construction, blocking of channel systems, filling of wetland areas, and mining of sand from rivers also cause floods (Punchihewa, 2019). As a result of the flooding, landslides are happening, because of the continuous rainfall, the soil moisture of the area has saturated. It is a disaster for the people who live in the riverside areas. When it rains heavily in the upper reaches of the river, the lower reaches of the river are subject to flooding. Most floods have been observed around major rivers in Sri Lanka. Monsoon floods, on the other hand, take longer to recede and may need evacuating people to flood relief centers for many days (Hasniza Yahya, 2020). People who travel from other districts and become trapped in a flood must have access to real-time flood information, such as road closures or diversions, accessible evacuation

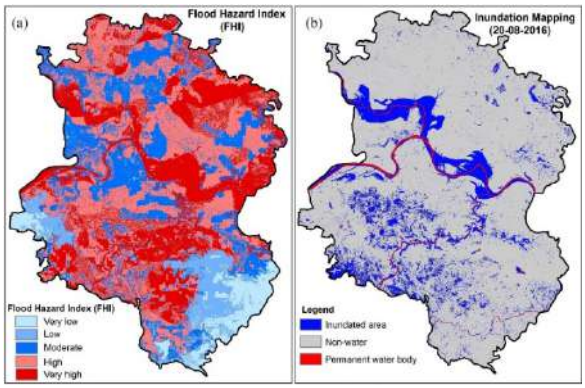

Figure 2. Flood hazard index map and Inundation map
Source: (Dash and Sar, 2020)

stations, and other pertinent information. They need to locate a secure location to stay in while they wait for support.

Remote sensing and Geographic Information Systems (GIS) can give spatial data that can be utilized for flood risk assessment, prediction, and monitoring. Flood simulation is also beneficial for flood control, particularly in helping to solve the problem of flood inundation, which is common in the lower plains (Petchprayoon, 2002). As shown in Figure 2 GIS and Remote Sensing helps to create a map of places where flooding happens regularly, and using the collected images, may enable the charting of evacuation routes. As a result of that, government authorities can make informed judgments based on the maps and locations accessible if a weather prediction is provided.

The significance of this study is that before occurring the floods next time we have an idea about the situation and it is very useful for decision-making for evacuating the victims. The study guarantees that future flood hazards are avoided or controlled and handled in a timely and cost-effective manner. The study is likewise similar to an assessment in that it involves not just suggestions but moreover management of flood hazards.

As a case study, the Baddegama area was selected. There were faced with severe flooding in the years 2003 and 2017. Even if not, each year the Baddegama area faces a flood situation. In the year 2017, homeowners of Baddegama town, and the surrounding regions have been forced to evacuate immediately owing to the Gin River Baddegama Dam's rising pressure as a result of the floods (Yapa, 2017). This research aims to identify the effect of the built-up Area during the flood.

2. Methodology

A. Study Area

Baddegama Divisional Secretariat Division (DSD) territory, with its centroid at 6.1783° N and 80.19° E, is 111 km² in area and is located in the Southern Province of Galle District, Sri Lanka. Figure 3 shows the study area of this study. There are 286 rainy days in Baddegama, Sri Lanka, and 1974mm of precipitation is accumulated throughout the year. May is the month with the greatest rain, with rain falling for 28 days and an average of 302mm of precipitation. Gin River is the main contributing factor to the flood in Baddegama Division (Aladdin, 2019).

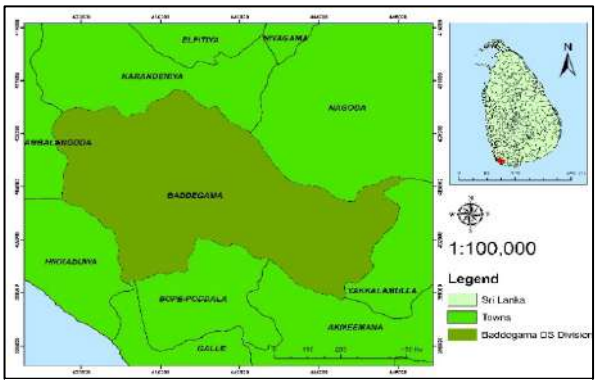

Figure 3. Study Area – Baddegama, Sri Lanka
Source: (Survey Department, Sri Lanka)

B. Data Used

Water features, types of soil, Digital Elevation Model (DEM), and land administrative

boundaries data were obtained from the Survey Department of Sri Lanka. DEM was used to create the slope of the area. Monthly rainfall data for the years 2017 to 2021 were used to prepare the rainfall map of the area. That rainfall data were obtained from the Meteorological Department of Sri Lanka. The supervised classification analysis of the Landsat 8 images satisfied the requirement for Land Use Land Cover (LULC). Landsat 8 level 1 satellite image was downloaded from the United States Geological Survey (USGS) Earth explore. (Department of the Interior U.S. Geological Survey, 2016). In the Landsat satellite series, Landsat 8 is the latest series. The main aim of the Landsat 8 satellite is to provide timely, high-quality infrared (IR) and visible images of all landmass and near-coastal areas on the Earth. Table 1 illustrates some Meta data of the Landsat 8 image, which was useful for this analysis. Another critical factor is soil, which has a direct influence on water absorption, permeability, and runoff (Mojaddadi et al., 2017; Shafapour Tehrany et al., 2017). Another important element in assessing flood sensitivity is the distance from the water features, which has been employed in previous research (Elkhrachy, 2015; Shafapour Tehrany et al., 2017).

Table 1. Meta Data of Acquired Landsat 8 Image

Satellite Series	Landsat 8 Level 1
Year	2021
Date Acquired	2021-12-26
Cloud Coverage	4.11%
Cloud Cover Land	6.84%
Weather	Sunny
Map Projection	UTM
UTM Zone	44
Datum	WGS 84
Grid cell size reflective	30.00m

Source: (USGS Landsat 8 Data Users Handbook)

Furthermore, bands 2, and 3,4,5,6 used out of the 11 bands. From them, bands 2, 3, 4, and 5 were used to prepare the Land Use Land Cover Map. And bands 5, 6 were used to perform the Normalized Difference Built-up Index (NDBI). The wavelength and resolution of the above-mentioned bands are illustrated in Table 2.

Table 2. Wavelengths and Resolutions of the Bands

Band No	Band	Wavelength (μm)	Resolution (m)
2	Blue	0.45-0.51	30.00
3	Green	0.53-0.59	30.00
4	Red	0.64-0.67	30.00
5	Near Infrared (NIR)	0.85-0.88	30.00
6	Short Wave Infra-Red (SWIR)	1.57-1.65	30.00

Source: (USGS Landsat 8 Data Users Handbook)

Criteria Finding

In identifying the factors and criteria for flood, the views of well knowledgeable persons living in the Baddegama area were taken into consideration. The Analytical Hierarchy Process (AHP) method was used to assign weights and scales to the criteria and the comments of 36 knowledgeable persons were taken into account.

C. Methodology Applied

Figure 4 illustrates the methodology that was applied for this research. Rainfall is a significant contributor to flood generation (Tehrany, Pradhan and Jebur, 2014). Average monthly rainfall data were used to perform the spatial interpolation of the surface. The monthly average rainfall data were obtained from the five gauge stations around the study area. Three spatial interpolation techniques as Kriging, Spline, and Inverse Distance Weighted (IDW) were used to create the rainfall map relevant to the study area. Finding the Root Mean Square Error (RMSE) is the method to find the best suitable interpolation technique (Das and Wahiduzzaman, 2022). Through the Root Mean Square Error (RMSE), found that IDW is the best suitable interpolation technique for mapping the rainfall data. Following equation 1 describes the way to find RMSE, and Table 3 illustrates the RMSE of three spatial interpolation techniques. Figure 5 shows the final rainfall map.

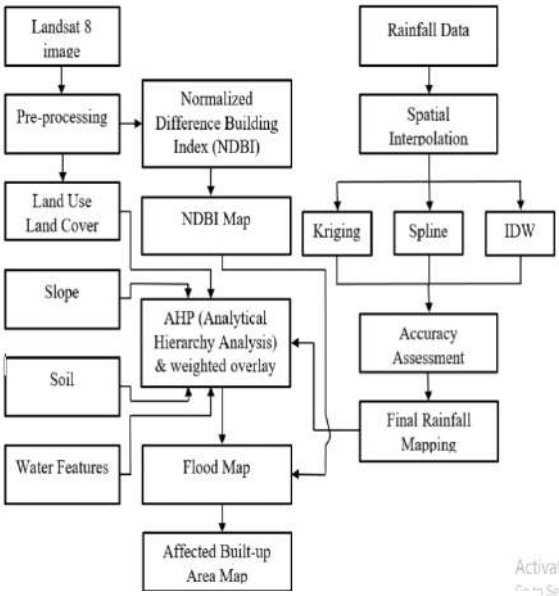

Figure 4. Methodological Framework

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \hat{X}_i)^2}{N}} \qquad (1)$$

(Das and Wahiduzzaman, 2022)

Where;

X_i = Actual Observation Value

$\hat{X}_i$ = Estimated Value

N = Number of Years

i = Variable

Table 3. RMSE of Gauge Stations

RMSE	Wathurawila Gauge Station	Hiniduma Gauge Station
IDW	14.49260	15.03738
Spline	21.94607	17.25700
Kriging	15.03667	15.97120

Bands 2, 3, 4, 5, and 6 of the Landsat 8 image were subjected to preprocessing. The Land Use Land Cover Map (LULC) was created using Supervised Classification. According to the Land Use Land Cover classification, the Baddegama DS Division was divided into 7 classes, open water area, paddy area, forest area, tea cultivated area, rubber cultivated area, coconut cultivated area, and built-up area. With the help of Field Observations and Google Earth pro software, train the training samples. Furthermore, an accuracy assessment was done to prove the authenticity of the created Land Use Land Cover map. The accuracy assessment of the supervised classification is illustrated in Figure 6. Supervising classification and accuracy assessment are important when preparing a land use land cover map (Rwanga and Ndambuki, 2017). Figure 7 shows the final LULC map. Normalized Difference Built-up Index (NDBI) was performed as shown in equation 2, by utilizing bands 5 (Near Infra-Red) and 6 (Short Wave Infra-Red) of the Landsat 8 image. The accuracy assessment of the Built-up area map is shown in Figure 9. The NDBI values vary from -1 to +1. The positive NDBI values represent urban land areas, whereas negative NDBI values imply non-urban land areas (Zha, Gao and Ni, 2003)

$$NDBI = (SWIR - NIR)/(SWIR + NIR)$$

(2 (Zha, Gao and Ni, 2003)

Land Use Land Cover data, rainfall data, soil data, slope data, and water features data layers were used to create a flood map (as a high-risk area, moderate risk area, and low-risk area) of the Baddegama DS Division. For that, the Analytical Hierarchy Process (AHP) and Weighted Overlay Method were used. AHP is the method to find solutions spatially (Tiryaki and Karaca, 2018).

Then, by overlapping the built-up area and flood map, looked at how much of the built-up area would be subject to different flood levels. Moreover, calculate the area of Land Use Land Cover types according to the different flood levels.

3. Results and Discussion

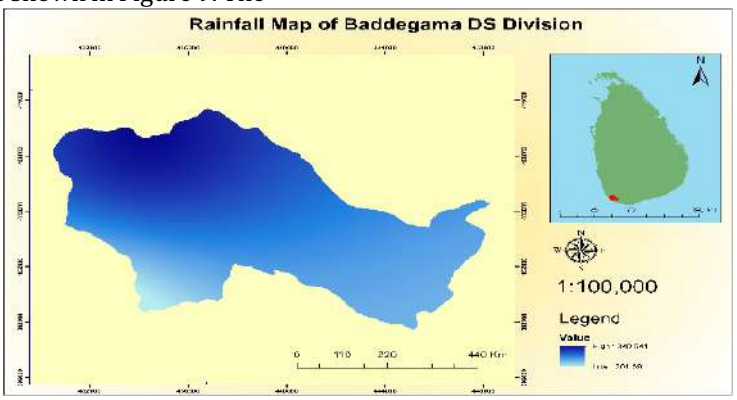

Figure 5. Rainfall Map of Baddegama DS Division

Raster value	Water	Paddy	Forest	Tea	Rubber	Coconut	Built-up	Total	User accuracy
Water	31	0	0	0	0	0	2	33	94%
Paddy	4	25	0	0	0	0	0	29	86%
Forest	0	0	15	1	0	1	1	18	83%
Tea	0	0	1	9	1	0	0	11	82%
Rubber	1	2	0	0	23	1	1	28	82%
Coconut	0	0	0	1	1	8	0	10	80%
Built-up	0	0	0	0	0	0	35	35	100%
Total	36	27	16	11	25	10	39	164	
Producer accuracy	86%	93%	94%	82%	92%	80%	90%		

Figure 6. Accuracy Assessment of Land Use Land Cover Map

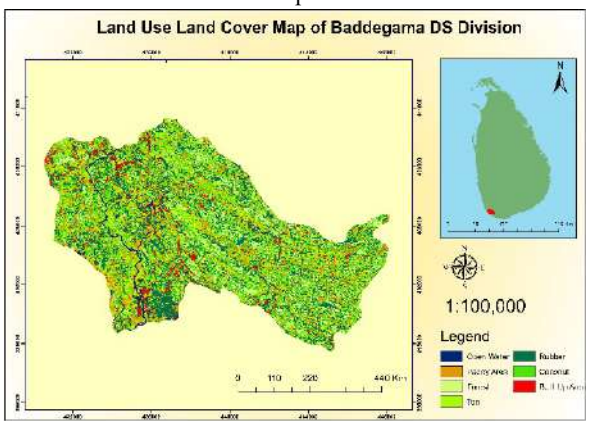

Figure 7. Land Use Land Cover Map of Baddegama DS Division

Table 4. Scales of the Flood Criteria

	Conditions	Scale
Soil	Alluvial soils	4
	Bog and half-bog soils	5
	Red-Yellow podzolic soils	2
	Red-Yellow podzolic soils(flat)	3
Land Use Land Cover (LULC)	Open Water	5
	Paddy Field area	5
	Forest Area	2
	Tea cultivated area	4
	Rubber cultivated area	3
	Coconut cultivated area	2
	Built-Up Area	1
Distance from Water Features	0-100m	5
	100-500m	4
	500-1000m	3
	>1000m	2
Slope	Flat Terrain	5
	Gentle Slope	3

	Steep Slope	1
Rainfall	201-243mm	1
	243-269mm	2
	269-294mm	3
	294-321mm	4
	321-349mm	5

Table 5. Weights of the Flood Criteria

Criteria	Weights (%)
Soil	7
Land Use Land Cover	13
Water Features	19
Slope	27
Rainfall	34

Table 6. Extent of Built-Up Area in Different Flood Risk Condition

	Low-Risk Area	Moderately Risk Area	High-Risk Area
Built-Up Area(Km^2)	5.727	9.669	2.496
Percentage	32%	54%	14%

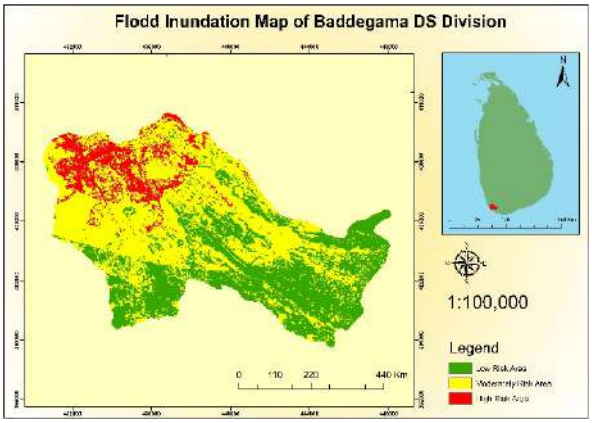

Figure 8. Flood Inundation Map of Baddegama DS

According to the rainfall map prepared by using the IDW interpolation technique, the highest rainfall has been received in the upper catchment areas of Ging River. The maximum rainfall is about 340mm recorded from those areas. It is important to make the LULC map in a manner suitable for the year 2021 by doing a supervised classification. Because even if this is a DS division, some Land Use Land Cover types may change. After studying the LULC map, it appears that most of the land use in the Baddegama area is paddy cultivated. Hence, the groundwater level in these areas is always high. It also directly affects the occurrence of floods in these areas. Also, the crops of tea, coconut, and rubber are spread over the entire area. As shown in the flood inundation map, the high-risk areas are the upper areas of the Ging River. By performing Normalized Difference Built-up Index (NDBI), the built-up area can be extracted very easily and a built-up area map can be prepared for the year 2021. As for the flood risk in built-up areas, about 54% (9.699 Km^2) of built-up areas are moderately

	Built-Up Area	Non Built-Up Area	Total	User Accuracy
Built-Up Area	33	06	39	85%
Non Built-Up Area	07	34	41	83%
Total	40	40	80	
Produce Accuracy	83%	85%		

Figure 9. Accuracy Assessment of Built-Up Area Map

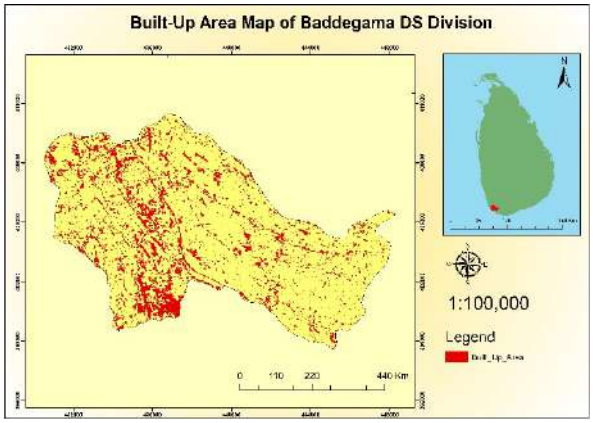

Figure 10. Built-Up Area Map of Baddegama DS Division

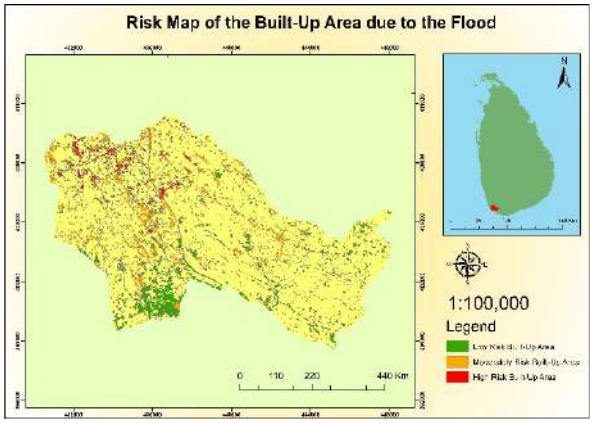

Figure 11. Flood Risk Map of the Built-Up Area

risky flood areas. Moreover, 14% (2.496 Km^2) of built-up areas are in highly risky flood areas. As well as 32% (5.727 Km^2) of built-up areas are in moderately risky flood areas. Although the amount of built-up in high-risk flood areas is low, the amount of built-up in moderately risky areas is high. As a percentage, it is about 40 %.

IV. CONCLUSION AND RECOMMENDATION

It can be said in this study, that to cause the flood in this area, the huge contributing factor is the Ging River, which flows across the Baddegama DS Division. With very high precipitation in Ging river's upper water catchment areas, the built-up areas in those areas are more vulnerable to flooding.

The final risk map of the built-up area can be recommended to find a suitable place to provide shelter to the evacuees in case of sudden flooding. Then the buildings in high-risk areas can be avoided and suitable places to build evacuation centers can be found. The final output could have been accurate if the resolution of the Landsat image was less than 30m. Further, it can be checked whether the places currently used as evacuation centers are suitable or not.

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Acknowledgment

Sincere gratitude forward to the Survey Department of Sri Lanka and the Meteorological Department of Sri Lanka for providing all digital data layers and providing rainfall data for the success of our research. Furthermore, I wish to sincerely thank all the lecturers in the Faculty of Built Environment and Spatial Science. Finally, we would like to acknowledge every person who helped us in different ways during the research work.

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The Use of Unmanned Aerial Vehicles for Façade Surveying Application in Sri Lanka

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Abstract**:** *Unmanned Aerial Vehicle-systems (UAVs) or Drones have reserved an important place in the construction and engineering industries over the last few decades. Drones are employed in various parts of the construction and engineering industries, including project creation, project management, and inspection, construction surveying, construction safety, construction inspection, volume measures, Modeling in 3D, and other related services UAV technical advancements and structure from motion methodologies have resulted in UAVs being typical platforms for 3D data collecting. Drones appear to be an ideal choice for urban applications due to their flexibility and capacity to reach inaccessible urban areas. Reconstructions from drone data have the potential to drastically reduce labor costs for rapid upgrades of already reconstructed 3D cities. However, a rigorous quality assessment is required, particularly when updating existing scenes acquired from different sensors. Many authorities demand as-built surveys to prove the placement of a facility at a specific moment in time. These are very vital for the site's upkeep and future expansion. Total station was employed to accomplish this duty in the past, but it is more expensive, time demanding, and requires more qualified surveyors to complete. The objective of this research is to examine the use of Unmanned Aerial Vehicles (UAV) system for façade surveying in Sri Lanka. The study's findings demonstrate that the UAV's ability to produce as-built survey mapping can be realized, and that it also simplifies as-built survey work by saving time and eliminating the need for trained surveyors. As a result, UAVs are ideal for engineering tasks*

Keywords: Unmanned Arial Vehicle, Orthomosaic, Structure from Motion (sfm), As-built

1. Introduction

In this highly developed era, numerous new technologies have been created to help surveyors in their work in the geospatial industry. Using a total station is the traditional method of conducting a "as-built" survey that is the most accurate. Although this method is expensive, time demanding, and requires the surveyor's competence to handle. These unmanned Aerial Vehicles (UAV) are rapidly being employed for a variety of purposes in the construction industry, including mobile surveillance, environmental monitoring, and as-built surveys. The UAV is light, tiny in size, and easy to manage, and it takes less time and energy to fly across a large region or a long range. This UAV technologies enable each project to retrieve data with the right level of accuracy, whether absolute accuracy is needed for the design, engineering, and construction phases, or relative accuracy for data collection. Accuracy is critical in an aerial mapping job if competent results are to be obtained. In terms of UAV accuracy, as camera resolution has grown, it has the capacity to digitize the globe with greater precision than previous research

by discovered that the use of UAVs can be a more cost-effective and time-consuming method in building an aerial photograph map.
We are already seeing an increase in demand for urban planning applications, where easily cheap UAVs are very effective. They are critical for smart city management and monitoring (Gruen, 2013; Mohammed et al., 2014). They can indeed be utilized for rapid change detection and disaster response as miniature flying vehicles (Qin, 2014). Drones look to be an ideal alternative for construction surveying due to their adaptability and ability to access tricky urban areas. One of the most common consequences of UAV urban application is three-dimensional building models. Although laser scanning data is frequently used to create building models (Dorninger and Pfeifer, 2008; Borkowski and Jóków, 2012; Perera and Maas, 2014), there has been very limited work reported on modeling using LiDAR equipped UAV. Drones equipped with photogrammetric or recording devices are commonly utilized to offer information for building reconstruction (Haala et al., 2012; Feifei et al., 2012). The collected pictures, when combined with various Structure from Motion approaches and reconstruction workflows, allow us to develop 3D building models with varying levels of detail.
The proposed research in this study explored optimal ways for doing as-built surveys using UAV. This study compares an as-built survey with an image mosaic of the Bachelor accommodation block on the Southern Campus taken with a UAV.
In this study various measurements are computed and presented in quantitative analysis to acquire a deep understanding of the output's quality. Basically, the comparison step will show how far that UAV orthomosaic images can be accurate for the conventional surveying techniques.

This drone technology is unique in above sense and surveys can be completed at record speed with high quality data. In other words, one of the most common uses of drones is to measure areas that are otherwise inaccessible to vehicles and people. The technique provides a cost-effective alternative to surveying, allowing for surveys to be completed in hours rather than days or weeks. As a result, UAVs are critical in assisting with as-built surveys. Furthermore, the equipment and software that will be utilized for this study are technologically based, thus employing this alternative method will not only save the time demanding job, but it may also minimize the cost of the as-built survey work.

Sri Lanka, being a developing country, needs to find new ways to improve its development. In the construction industry, we are still lagging behind in terms of creating 3D facades and BIM models. Cameras linked to cutting-edge technology have transformed and expedited the construction process. Drones are becoming increasingly important in the construction industry for site surveying, building inspection, auditing, and building energy modeling. In fact, in industrialized countries, manual field inspection methods or traditional methods of identifying the facts of associated structures may not be used. In this research study, the integration of UAVs with the most recent Building information models, as well as the digitization of the construction process, will be discussed, as will the utilization of these combinations and the development of the 3D façade. This is a literal merger or integration of UAVs with BIM.

2. Methodology

The study procedure begins with site planning and preparation, which includes site review of the selected area and drone training sessions, as shown in the Figure 1.

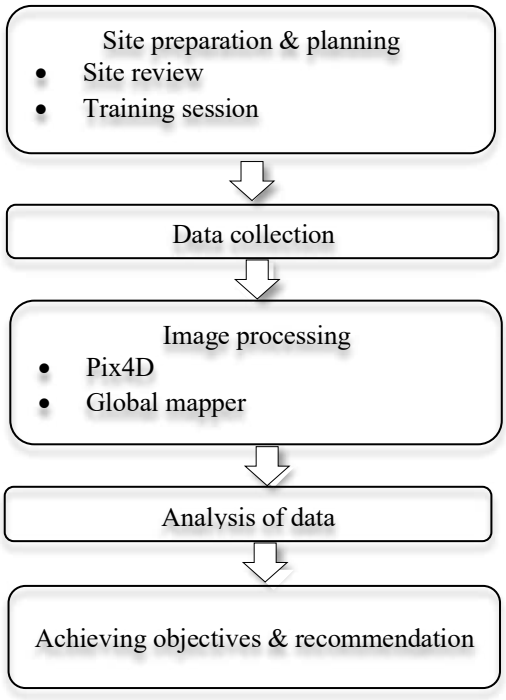

Figure 1: Conceptual Framework of the Study

The field work was divided into two stages, pre-flight and in-flight. Before flight planning and preparation to acquire in the planning area of flight and training sessions under the supervision. Collect images in order to obtain and check for defects in drone capture images. During this process, the drone will capture images, but the pilot will judge and monitor its flight. Pilots must also be wary of flight failures. This is also to improve connectivity in order to maintain a safe distance from the building wall structure even if the collision prevention is in place. The weather should be fine for the drone, and a broad exposure in the morning is suggested.

The next stage after image acquisition is image processing. Pix4D and Global Mapper are used forimage processing. Then the images were
processed in three stages:

- Initial processing.
- DSM and point cloud.
- Mosaic orthography and index.

Process the image using the objective design plan of the selected area. This data is obtained from Pix4Dmapper and passed to Global Mapper, which takes overlapping images and generates 3D point cloud output using Structure from motion techniques. This technology derives the 3D texture of the landscape and the objects on it from overlapping images, resulting in 3D point cloud images. Data collected by drones is usually used for terrain-based calculations. For this study, the building was measured for

identification, and a comparison of design objectives with actual on-site construction is made. For this research study, the data collection analysis was divided into two

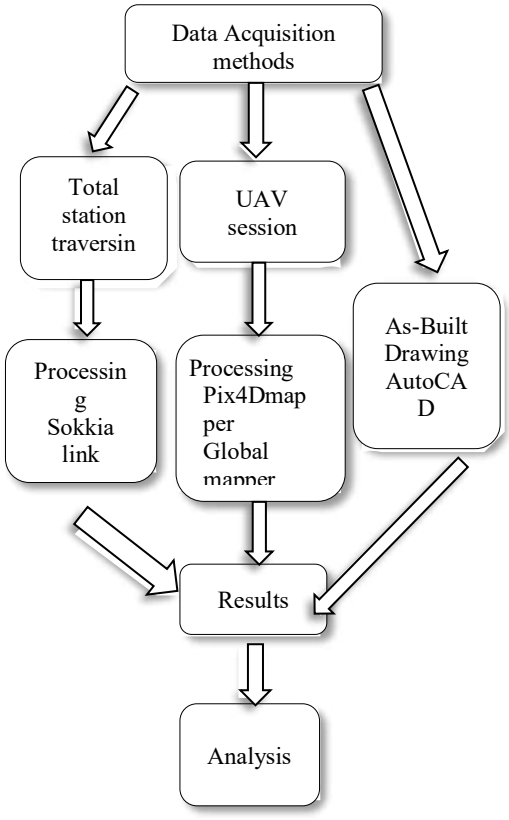

Figure 2: Data Collection Workflow

phases. A focused method is to use an UAV to collect, process and analyze relevant data for the digital output of an as-built survey as shown in Figure 2.

For the accuracy assessment of this study need to conduct total station traversing data for the conformation of the as-built details with the conventional accurate method. Therefore, it is required to establish control points via go through with the traversing and levelling. Finally, it was required to take the as-built survey details through

3. Results and Discussion

All images obtained during the flight of the UAV must be processed with the Pix4Dmapper tool to produce orthogonal photogrammetry. Information such as location is extracted from products processed by the Pix4Dmapper and Global Mapper applications, statistics about the area and measurement items in the selected building.

A. Image processing

Each drone image must be processed with the Pix4Dmapper software and generate a complete orthogonal image that meets the mapping requirements as shown in Figure 3.

Figure 3: Orthomosaic image of Bachelor residential building of Southern Campus

B. Proposed drawing of the study area

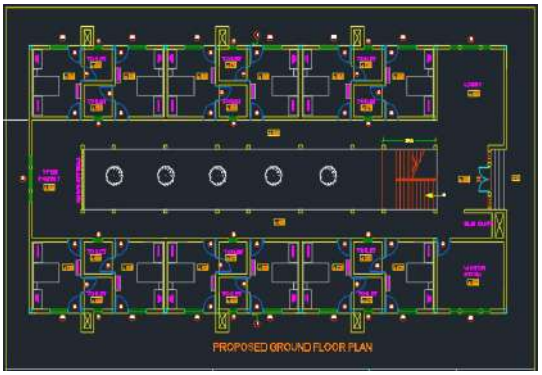

Figure 4: Proposed Auto CAD drawing of the building

Figure 4 shows the proposed AutoCAD drawing for the bachelor accommodation. With the help of AutoCAD software, data about the generated study area is designed to collect reliable data for dimensions and measurements that can be compared with orthogonal mosaics.

D. Measurement analysis

Using the data generated by Pix4Dmapper and transmitted to Global Mapper, the mosaic images was used for the comparisons of measurements between actually built on the site and proposed prior to the construction of the bachelor's residence building. Based on Table 1, it shows each measurement of the front façade of the building. When considering the wall, its having most accurate data for the building while having ±0.001m variant. And also, the captured data of the front door gives maximum 0.005m variant accuracy compared to the As-Built and UAV images. Therefore, those UAV images can be applicable and used for as-build survey mapping.

Table 1. The front elevation measurement data of AutoCAD & As-built

Feature Name	*Auto CAD (m)*	*As-Built (m)*	*Differences (m)*
Height of window (verticle)	1.200	1.202	±0.002
Width of window (verticle)	0.600	0.618	±0.018
Hight of window (horizontal)	0.600	0.562	±0.038
Width of window (horizontal)	1.200	1.256	±0.056

Table 2. The front elevation data of Orthomosaic & As-buil

Feature Name	*Auto CAD (m)*	*Orthomosaic (m)*	*As-Built (m)*	*Differences (m)*
Height of window (verticle)	1.200	1.204	1.202	±0.002
Width of window (verticle)	0.600	0.620	0.618	±0.002
Hight of window (horizontal)	0.600	0.560	0.562	±0.002
Width of window (horizontal)	1.200	1.254	1.256	±0.002

The as-built details were captured using the total station, and the orthomosaics details were acquired using drone images and processed using the pix4D and Global mapper software were analyzed and shown in above Table 1 and 2. By the way, the taken details are nearly same. In fact, both of these measurements vary by less than 0.003m

Table 3. The side elevation measurements

Feature Name	*Auto CAD (m)*	*As-Built (m)*	*Differences (m)*
Height of window (verticle)	1.200	1.202	±0.002
Width of window (verticle)	0.600	0.618	±0.018
Hight of window (horizontal)	0.600	0.562	±0.038
Width of window (horizontal)	1.200	1.256	±0.056

Based on above Table 3 it clearly shows the basic measurements of side elevation of the building. The differences are ±0.002m and ±0.003m in height
and width of the building respectively in between UAV images process through the global mapper and as-built drawings.

Table 4. Measurements of windows

Feature Name	***Auto CAD (m)***	***Orthomosaic (m)***	***As-Built (m)***	***Differences (m)***
Height of side elevation	3.600	3.192	3.194	±0.002
Width of side elevation	34.972	34.312	34.315	±0.003

When comparing each section relevant details from the table show and proved that the data from the UAV images can be used for as-built survey purposes and mapping.

Table 5. The measurement data of Auto CAD & As-built in windows

Feature Name	Auto CAD (m)	Orthomosaic (m)	As-Built (m)	Differences (m)
• Height of wall front elevation	3.600	3.192	3.193	±0.001
• Width of wall front elevation	19.150	19.030	19.031	±0.001
• Front door (Height)	2.100	2.080	2.082	±0.002
• Front door (Width)	1.800	1.750	1.755	±0.005
• Door frame (Height)	2.200	2.150	2.152	±0.002
• Door frame (Width)	3.200	3.190	3.193	±0.003

Considering the taken measurements of the windows in between in proposed drawing and the Auto CAD details are not severely vary as front and side façade measurements, but this is also having such variations when it constructed.

4. Conclusion

According to the findings of this research, the as-built survey mapping is completed at bachelor residential building of Southern Campus. The use of UAV can provide a variety of results that can be used for a more complete study of building mapping capabilities, particularly in the as- built survey area. The process analysis produced outputs such as a Pix4Dmapper file, orthogonal images of the building, a proposed comprehensive drawing plan and details, and a site layout plan.

As a result of the study, the findings can be used for a variety of purposes and in greater depth based on job requirements. For example, the Pix4Dmapper file and the orthogonal images from this work can be used to create true 3D images with accurate surface rates, including substructure locations and gradients on some surfaces. In addition, files generated by Pix4Dmapper can be used as suggested image.

The chosen method of UAV for built survey mapping has been proved to be suitable for the aim of this study depending on the results of the research, when compared to the current procedure, there are numerous advantages to employing this strategy. Choosing UAV routes for hardware mapping purposes is a sensible decision because it helps both parties. Furthermore, it is appropriate for the most recent technological requirements.

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Acknowledgment
I would like to express my heartfelt appreciation to the research supervisor for allowing me the opportunity to conduct the research and for offering vital guidance during the research and report preparation. Finally, I'd like to offer my heartfelt appreciation and gratitude to everyone who assisted us in various ways.

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Factors Affecting the Implementation of E-Procurement for Government Sector in Sri Lanka

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Abstract: *Procurement is known as a substantial instrument in both public and private sector organizations. However, the manual procurement system creates considerable issues, and it can affect to the country. Therefore, the countries are tempted to implement the E- Government Procurement system because it helps to generate an income more effectively. E-procurement was built to reduce corruption and conspiracies, increase public accountability, and enable the purchase of goods and services more effective, efficient, and affordable. The main purpose of this study is to measure the relationship between E-GP implementation and technology, organizational and environmental factors. The population for this study included procurement divisions in Departments, State Managed Boards, Authorities, Commissions, Corporations, Bureaus, Institutes and Institutions, and Government Banks. Data were collected via a cross-sectional questionnaire-based survey. Relevant respondents were chosen from a sample of 162 firms using a convenient and random sampling techniques. This resulted in an overall response rate 43%. This study uses quantitative research methods to identify the variables affecting the adoption of e-procurement. All variables from technology, organizational and environmental context are positively correlated with the dependent variable of E-GP implementation. Results revealed that human capacity and awareness was the most important factor. This study suggests, for further researches to determine other independent factors which influence for electronic procurement implementation.*

Keywords: *Procurement, promise system, E-GP implementation*

1. Introduction

Modern economic growth and social progress have been driven by technological innovation and globalization in many regions of the world. Governments are utilizing modern technologies more and more to secure their people and maintain public safety (Kim & Kim, 2020). ICT (information communication technology) has been adopted by governments in both developed and developing nations to increase public efficiency, increase transparency, and encourage increased participation in civic affairs. As a result, the majority of the countries have grant public participation in government bidding (Prasteyo , 2019) processes by facilitating access to opportunities provided by these organizations, such as procurement processes (Asare & Prempeh, 2017).

The procurement is known as the process of acquiring goods and services for a firm (Premathilaka and Fernando, 2018). Latest supply chains have made procurement a key component as a competitive strategy for establishing and keeping strong connections. Over the decades, it has evolved and changed in many countries. Government procurement policies and procedures have previously undergone reviews in the past to improve efficiency and reduce the cost (Toroitich, et al.,2017). Mohammed (2017) stated that the governments frequently use the public procurement process to get consumers the basic goods and services they need. Better use of public resources and services is made

possible by efficient and accurate public procurement. Transparent and accountable procurement can increase a country's GDP (Gross Domestic Production), which has a significant impact on the expansion of the economy. Additionally, a crucial requirement for establishing a proper procurement system is effective public investment. When it comes to purchasing products and services, the government is the biggest purchasing agency in any nation. According to Mohammed (2017), the government of Sri Lanka is the most significant buyer in the country's domestic market. In 2015, the government of Sri Lanka spent around 597 billion rupees on public procurement, which is equivalent to 5.3% of the country's GDP. This is because the government is responsible for meeting the demands of its inhabitants. National Procurement Agency (NPA) published rules and procurement manual are Sri Lanka's most critical compliances for purchasing goods and services from the government. The government issued procurement rules in 2006, defining the procurement techniques it uses. According to Thai (2001), public procurement is a crucial role of the state that requires it to meet requirements for products, systems, and services in a timely way.

2. Literature Review

There were severe failures in public procurement in Sri Lanka under the different regimes, which cost billions of dollars and damaged the economy, ecology, and society of the country as a whole (Ekanayaka , 2015). With the existing manual procurement system in place, Sri Lanka's government procurement is now dealing with several weaknesses (Mohammed, 2017). Currently, there is a shortage of information that can be easily accessed about public procurement opportunities. It is essential of procuring entities that they announce tenders in the government Gazette as well as in media that are published nationwide. Manual procurement management methods have a number of limitations, but two of the most significant ones are that they need a lot of manpower and a lot of time. Due to the significant amount of human participation that is present during each stage of the procurement process. In most cases, the preparation of bids involves a significant amount of human and material resources, and this is particularly true for bids that are highly specialized. The manual procurement system has an effect on the suppliers as well since it requires a significant amount of time and effort to put up bids. In addition, there is a lack of transparency for the company's suppliers since all of the company's procurement operations take place inside. In Sri Lanka's procurement system, anti-competitive activities have also surfaced as an issue in recent years. Anti-competitive behaviors have a substantial effect on the escalation of procurement corruption. These behaviors include accepting unsolicited bids for big projects and modifying specifications to suit the supplier. Both of these practices are anti-competitive. In addition to that, Liyanage (2005) has investigated the procurement performance of a total of 64 tender boards, 32 of which were locally funded and 44 of which were foreign funded. The results of this analysis are shown in Table 1 below.

Table 1. Survey Results of Sri Lanka Procurement Performances of Tender Boards

Progress of Tender Boards (CATB)	**Local Funded Tender Bards (32)**		**Foreign Funded Tender Boards (44)**	
	No. of Tenders	Percentage	No. of Tenders	Percentage
Completed as scheduled	11	34%	17	38%
Delayed from three months	21	66%	27	62%

Source: Liyanage (2005)

E-procurement (electronic procurement) which is a subset of e-commerce (electronic commerce) can be regarded as a primary component of e-government processes. It is responsible for the automation of a company's procurement of goods and services, with the goals of increasing transparency, efficiency, effectiveness, dematerialization, and competition through the activities of the procurement process (Gardenal (2013) as cited by Bandara 2020). Considering of these positive outcomes, e-procurement is still bieng used by very less amount of countries during the past decades (United Nations, 2013). Sri Lanka government sector organizations also lag in e-procurement implementation. Even Sri lanka government has implemented a Electronic governement procurment (E-GP) system named "promise" (https://www.promise.lk/), a very less number of public entities have been adopted this system in to their procurement departments.

Strategic factors heavily influence E-procurement adoption because E-technologies improve firm performance, increasing competitive advantage. the Internet has become an influential source of competitive advantages when integrated into firms' terms of strategies Tsuma & Kanda (2017). The advancement of Information and Communication Technology (ICT) creates new opportunities for ent erprises all over the world, hastening rivalry among firms and professions. Despite the fact that effective communication is a vital element for the procurement and consultation process, the use of IT in public procurement in the Sri Lankan construction industry is not as prevalent as in other sectors, despite the that the other developed and developing countries are practicing and benefiting from it Amarapathy et al. (2013).

According to previous studies, many countries have encountered a variety of issues while attempting to implement electronic government procurement. Those studies revealed a variety factor may affect in order to adopt the E-GP system. Therefore, technological, organizational, and environmental aspects could have an impact on the adoption of E-GP, according to previous study articles. There is a considerable knowledge gap in identifying the relationship between the factors influencing the adoption of e procurement. Therefore, the objective of this paper is to measure the relationship between E-GP implementation and technology, organizational and environmental factors.

A. Key Fcators for Electronic Governement Procurement Implementation

Davila et al. (2003) conducted a study in North America using coefficient analysis to determine which companies are moving quickly into these technologies, how

experimentation is taking place to learn about the business opportunities that may emerge through these technologies, the risks and benefits associated with them, and the expected evolution of e-procurement technologies in the near future. The information was collected from a large number of managers who were active in e-procurement, both as users and as suppliers. According to the findings of this survey, just 34% of respondents had been active in any technology-related effort relating to E-Procurement for a period of one year or more. According to users of electronic procurement, just 15% of the supplier base is capable of delivering items over the internet. On the other hand, e-procurement software is acquiring a significant amount of acceptability (25%), and it is anticipated that it will continue to retain its dominant position in the near future. Bangladesh is a developing nation, and as such, it has undertaken research on examining the obstacles and implementation involved in implementing an electronic government procurement system. The information for this study was obtained from 217 government workers. When attempting to adopt an electronic procurement system, they were forced to deal with a number of obstacles since they lacked the necessary ICT infrastructure. The conclusions of the research indicate that just 9.3 lac lines are being distributed around the nation, despite the fact that the population of the country is 15.74 million. The population of the nation reveals that 0.58% of people make use of telephone lines, 0.3% of people have subscriptions to fixed-wired services, and 2.2% of people have subscriptions to mobile internet services (Liton & Habib, 2015) In governement organizations, there is a knowledge gap regarding the IT tools, apps, and procurement. In addition, the individuals have less competence in IT, and some of them have less information about procurement (Altayyar, 2017). A research carried by Arunga & Paul (2017) , they have collected information from respondents about the degree to which technical skills have influenced the implementation of e-government procurement in Kenya. According to the findings, the majority of respondents (33%) have strongly agreed with to a very great degree, 29 % of respondents agreed with to great extent, 26 % of respondents indicated that it was a moderate aspect, and 8 % of respondents agreed with very little extent. Implementing E-Government Procurement necessitates a strong link between educational outcomes and technical skills (Liton & Habib, 2015).

Gunasekaran & Ngai (2008) stated, human capacity and awareness are important factors in e-procurement adoption, top management must appreciate its advantages. Many managers don't grasp E-intangible Procurement's and strategic advantages. Many organization members vote against E-Procurement because of financial and short-term advantages

According to Premathilaka & Fernando (2018), suppliers must to be concerned about every development and problem pertaining to electronic procurement. When consumers recognize the benefits that the E-GP system brings to their activities, adaptation to the system is a lot simpler and quicker. The present standards and manuals for procurement in Sri Lanka are very difficult to comprehend and adhere to, according to the country's suppliers. E-GP systems have the potential to increase the availability of government guidelines and manuals to suppliers. These systems also have the potential to assist suppliers in reducing the likelihood that they will make procedural errors, which will ultimately reduce the likelihood that they will fail to comply with bid specifications. According to Prasetyo (2019) the top management aspect is a more significant component to consider when implementing E- GP systems to organisations, and it provides more options to achieve better results in procurement for the company.

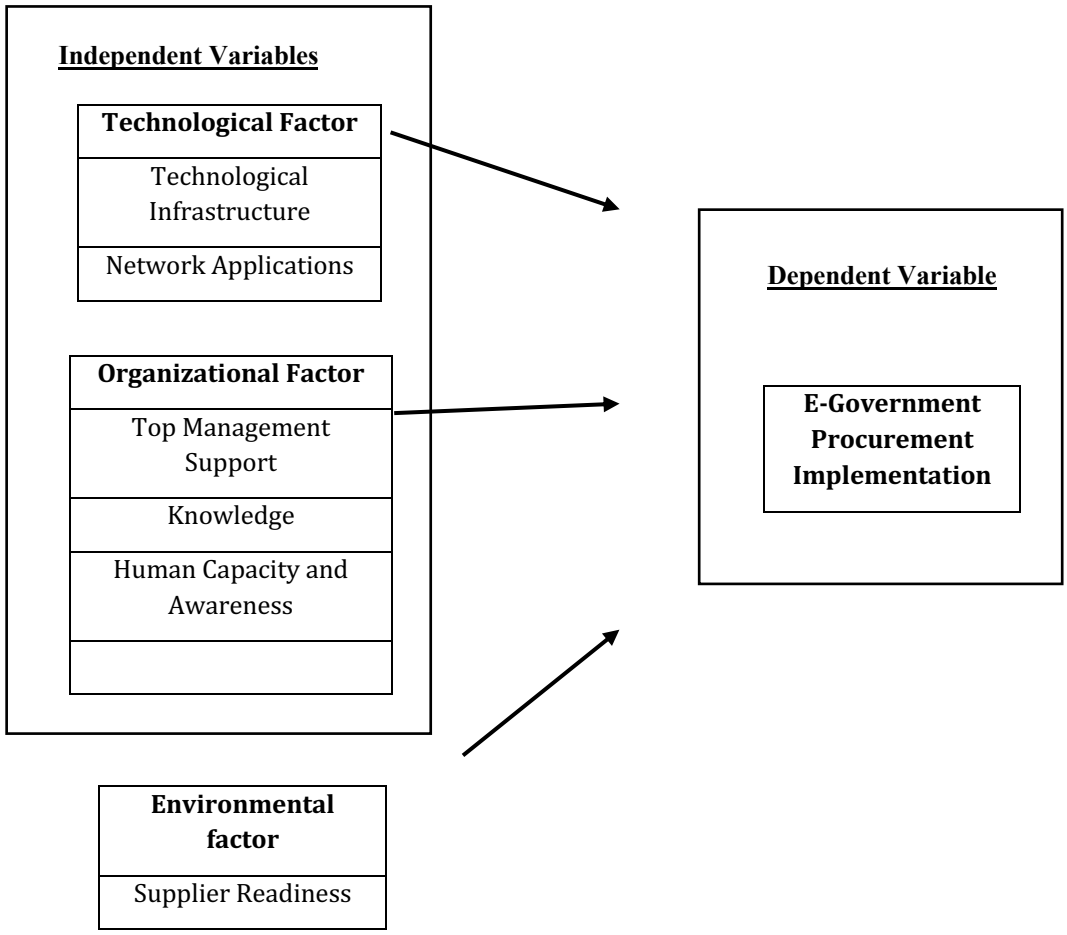

Figure 1. Conceptual Framework

Source: Authors' compilation based on literature review

The above figure 1 represents the things that researchers should find throughout the research cycle, and it will be used to examine the effect of technical, organizational, and environmental aspects on the implementation of electronic government procurement. Technological, organizational, and environmental factors are the independent variables. The reason for use E-Government Procurement as a dependent variable is that implementing E-Procurement for the public sector varies depending on a variety of factors within independent variables like technology, organizational and environmental factors.

3. Main Hypothesis of the Study

There is a substantial and positive association between the factors found from the literature review and the adoption of e-procurement in public sector organizations in Sri Lanka. The following are the hypotheses that may be drawn:

H0: There is no relationship between facilities of technology infrastructures and E-Government Procurement implementation.

H1: There is a positive relationship between facilities of technology infrastructures and E-Government procurement implementation.

H0: There is no relationship between facilities of network applications and E-Government Procurement implementation.

H2: There is a positive relationship between facilities of network applications and E-Government procurement implementation.

H0: There is no relationship between facilities of top management support and E-Government Procurement implementation.

H3: There is a positive relationship between facilities of top management Support and E-Government Procurement implementation.

H0: There is no relationship between facilities of knowledge and E-Government Procurement implementation.

H4: There is a positive relationship between facilities of knowledge and E-Government Procurement implementation.

H0: There is no relationship between facilities of human capacity and awareness and E-Government implementation.

H5: There is a positive relationship between facilities of human capacity and awareness and E-Government implementation.

H0: There is no relationship between facilities of supplier readiness and E-Government Procurement implementation.

H6: There is a positive relationship between facilities of supplier readiness and E-Government Procurement implementation.

4. Methadology

The quantitative research methodology was used for this study in order to measure the relationship between E-GP implementation and technology, organizational and environmental factors. For this research unit of analysis was "national level government organizations" and key informant was the departments which delegated for procurement activities. According to the government information center, the population of the study consisted of Departments, State Managed Boards, Authorities, Commissions, Corporations, Bureaus, Institutes and Institutions and Government Banks.

According to the Morgan's table, 162 organizations considered as the sample which is 61% of the population. This resulted in an overall response rate 43%. Convenience and random sampling were the sampling techniques which are used to select the sample of the study.

Data was collected from primary sources using questionnaires. Survey was consisted of two major sections. The purpose of the first section was to gather demographic information about the respondents and assess their awareness and implementation of Promise E-GP system into their organizations. The second part of the questionnaire consisted of thirty questions that were connected to one of four categories of e-procurement adaption factors: technology, organizational, environmental, and E-GP implementation. In order to build a scale for the items included in the second section of the questionnaire, a Likert scale with five points was used. Statistical Package for Social Sciences (SPSS) version 20 was used to analyze the data and correlation analysis were used. Pearson Correlation analysis was used to measure the strength of the relationship among variables. Reliability analysis measures internal consistency, how closely variables are connected.

5. Results of Discussion

A. Correlation Analysis

The significance and degree of relationship of the variables, as well as the percentage of variation in the dependent variable influenced by the independent variables, were all determined through the use of correlation analysis. Correlation is a statistical method for determining how closely two variables are linked. The results of correlation analysis are summarized in Table 2.

Table 2. Summary of correlations

Variables	E-GP Adoption	Infrastructure	Network Applications	Top Management Support	Knowledge	Human Capacity and Awareness	Supplier Readiness
E-GP Adoption	1	.436 (.000)	.483 (.000)	.535 (.000)	.515 (.000)	.716 (.000)	.562 (.000)
Infrastructure	.436 (.000)	1	.079 (.516)	.091 (.452)	.291 (.015)	.301 (.011)	.251 (.036)
Network Applications	.483 (.000)	.079 (.516)	1	.526 (.000)	.339 (.004)	.345 (.003)	.202 (.094)
Top Management Support	.535 (.000)	.091 (.452)	.526 (.000)	1	.275 (.021)	.535 (.000)	.195 (.106)
Knowledge	.515 (.000)	.291 (.015)	.339 (.004)	.275 (.021)	1	.496 (.000)	.456 (.000)
Human Capacity and Awareness	.716 (.000)	.301 (.011)	.345 (.003)	.535 (.000)	.496 (.000)	1	.551 (.000)
Supplier Readiness	.562 (.000)	.251 (.036)	.202 (.094)	.195 (.106)	.456 (.000)	.551 (.000)	1

Source: Authors' compilation based on survey data

According to the correlation summary that is shown in Table 2, all of the correlations that were assessed between the independent variables and the dependent variable were significant at the level 95% confidence level. The Pearson Correlation Coefficient was computed at 5% significance level to determine the relationship between technological infrastructures and E-GP implementation. According to the findings there is a positive moderate correlation (r = 0.436) between technological infrastructures and E-GP implementation. Also, researchers found that the relationship was significant at 5% as (p=0.000 <0.05). The results indicated that there is a positive moderate correlation (r = 0.483) between network application and electronic government procurement implementation. in addition, the study observed that the correlation was significant at the 5% significance level as p = 0.000 <0.05.

From the organizational context, there is a positive moderate relationship (r=0.535) between top management support and E-GP implementation and the results indicated that as p = 0.000< 0.05, the correlation was significant at 5% significance level. The Pearson Correlation Coefficient was computed at 5% significance level to determine the relationship between knowledge and E-GP implementation. Based on the results, there is

a positive moderate relationship (r = 5.15) between knowledge and E-GP implementation. Researchers found that the correlation was significant at 5% significance level. Furthermore, as shown in table, there is a strong positive relationship (r=0.716) between human capacity and awareness and E-GP implementation, and it was significant at 5% significance level (p=0.000<0.05).

From the environmental context, The Pearson Correlation Coefficient was computed at 5% significance level to determine the relationship between supplier readiness and E-GP implementation. According to the results as shown in the table, there is a positive moderate relationship (r= 0.562) between supply readiness and electronic government procurement implementation and researchers identified that the correlation was significant at 5% significance level (p=0.000< 0.05).

6. Conclusion

This study provides a significant contribution to measure the relationship between E-GP implementation and technology, organizational and environmental factors. Based on the results, it is possible that officials who responsible for procurement activities are aware of the most significant factors that influence of electronic procurement system into their organizations. Accordingly, they can focus on particular factors which need to be developed in their organizations. However, based on the results of correlation analysis, researches can conclude that all independent variables (Technological Infrastructure, Network Application, Human Capacity and Awareness, Knowledge, Top Management and Supply Readiness) were important in implementing electronic government procurement system in public sector organizations. All variables from technology, organizational and environmental context are positively correlated with the dependent variable of E-GP implementation. in addition, results revealed that human capacity and awareness was the most important factor as shown in the table. Furthermore, based on the results supply readiness was the third most important factor for E-GP implementation as r= 0.562. According to the results, technological infrastructures were the least important factor for the implementation of E-GP.

This study suggests, for further researches to determine other independent factors which influence for electronic procurement implementation like government factors. In addition, since this study has focused on public sector organizations, future researches can conduct their assessment on private sector institutions. There are few limitations in this study. Researches could collect only 43% of respondents because of the prevailing situation in the country as some government officers were not found frequently in the offices. As this research is based on government sector, researches had to follow certain government rules and regulations when collecting data from officials.

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Acknowledgment

The authors would like to sincere gratitude to all the participants who spend their valuable time participating in responding questionnaires and contributing to the study.

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Impact of Material Management on Cost Overruns in the Construction Projects in Sri Lanka

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Abstract*: The construction industry is considered to be a main contributor for development of an economy of a country. Accordingly, in Sri Lanka also the contribution of the construction sector plays a major role towards the economic growth. Meanwhile, cost overruns are inevitable consequences within the construction industry and material management identified as one of the key causes to occur cost overruns within construction projects. Relationship between material management and cost overruns was not investigated much in conjunction within the Sri Lankan construction industry in past studies. In that sense, this study aims to identify the impact of material management on cost overruns in the construction projects in Sri Lanka. Moreover, issues and solutions for proper material management in construction projects were identified as the key findings in this study. The study was conducted as mixed research approach where both qualitative and quantitative data were acquired through questionnaire survey and semi-structured interviews. The impact and relationship of material management and cost overruns were identified via regression analysis and correlation analysis with the aid of SPSS software package. The issues and solutions for proper material management were identified through the manual content analysis. The major issue of material management was identified as the wastage of materials in construction sites. It causes to incur high additional costs in the construction projects. Finally, the study was further elaborated the conclusions and recommendations to overcome cost overruns through proper material management in the construction projects in Sri Lanka.*

Keywords: *Material Management, Cost Overrun, Construction Projects*

1. Introduction

Cost is identified as one of the key parameters in a construction project. Cost overruns are identified as inevitable consequences which are global concerns in the construction industry (Durdyev, Ismail and Bakar, 2010). The magnitude of cost overruns is in different fluctuation levels from project to project. However, improper material management is one of the key causes for cost overruns which reduces the contractor's profit, resulting in significant losses and putting the project in jeopardy (Lenin et al., 2014). Therefore, any cost overruns occur within the project required to minimize as much as possible so that, it won't affect severely for the project success. Therefore, with proper material management, construction projects' goals and objectives can be achieved specially without any cost overruns.

Construction Materials can be defined as major and mandatory constituents in construction projects, since without the materials any of construction projects cannot be built. In that regard, cost for the materials in constructions are known to make a huge contribution to the total project cost. Depending on the type of the project, the total cost of materials can account up to 60% or more of the whole cost of construction (Gulghane and Khandve, 2015; Vipin and Rahima Shabeen, 2019). In Sri Lankan context, this issue is encountering a massive portion out of the prevailing problems in

construction projects. Material wastage has become an immense issue in the Sri Lankan construction sector since it happens beyond allowable limits (Kulatunga, Amaratunga, Haigh and Rameezdeen, 2006). Therefore, the way to mitigate the cost overruns through proper material management in construction industry in Sri Lanka is required to be investigated. The study is limited within the Sri Lankan construction context. Accordingly, the aim of this research is to identify the impact of material management on cost overruns in the construction projects in Sri Lanka and objectives were listed as 1) to study the concept of material management in construction projects 2) to identify the relationship between the material management and cost overruns in the construction projects in Sri Lanka 3) to identify the issues of material management on cost overruns in construction projects in Sri Lanka and finally 4) to suggest the solutions to overcome cost overruns through proper material management in construction projects in Sri Lanka.

2. Literature Review

A. Material Management

Material management refers to the availability of sufficient quantities and quality materials at the required time to avoid construction delays (Vipin and Rahima Shabeen, 2019). Therefore, material management should be contemplated at all phases of the construction process and throughout the project duration (Kasim, 2006). Material management is critical since any significant contribution made in this area would drive a long way toward increasing project profitability and return on investment (AparnaShruthi and Venkatasubramanian, 2017). Kasim (2006) stated that material management is specially challenging for large and complicated projects that need the use of sophisticated technologies and processes.

B. Components of Material Management

After referring the past studies related to the material management following key components of material management were identified.

1. Material Planning

According to Jusoh and Kasim (2017a) the identification of material requirement, material documentary maintenance, delivery frequency and temporary facility planning are included in this phase. If the material planning procedure is not followed accurately in a construction project, the entire project will be unsuccessful and the project won't be completed on time. But if it was properly maintained, the entire project cost will be reduced through low material wastage (Madhavarao, Mahindra and Asadi, 2018).

2. Vendor Analysis

In this phase material prices, quality, delivery time, inventory held by suppliers and flexibility are assessed to select the most suitable vendor (Jusoh and Kasim, 2017a). The proper vendor analysis process is highly important to enhance the quality of the project and it could affect in increasing the project performance while overcoming the barriers (Vipin and Rahima Shabeen, 2019).

3. Storage and Inventory

Storage and inventory in construction projects are critical since the time between ordering and receiving items is highly unpredictable (Jusoh and Kasim, 2017b). Misron, Khoiry and Hamzah (2018) defined that material storage management is about placing material inside the stores properly and releasing them to the site when required. However, this is a recurrent process in construction sites.

4. Material Purchasing

According to Arijeloye and Akinradewo (2016), in material management the purpose of purchasing process is to supply the required materials with proper quality and budget margin at accurate time and location. Material purchasing procedure includes

overview of the purchase, material order request, placement of the order, keeping and matching the records, ordering and arriving of materials, follow up purchase order and transfer materials (Madhavarao, Mahindra and Asadi, 2018).

5. Supply and Distribution

Distribution and transportation of materials is considered under the logistics part of the construction projects. Availability of transportation enhances material procurement on site. Inadequate transportation can lead to increased waiting time which translates into delays and eventually impacts negatively on project outcomes (Tunji-Olayeni et al., 2017). There could be several problems that might arise regarding the supply and distribution of materials such as supply delays due to quick purchase, wastage during stockpiling, handling and transporting of huge material quantities without meeting the production needs on site (Kasim, 2006).

6. On site Material Handling

According to Arijeloye and Akinradewo (2016) movement, placement and usage are the main constituents in handling of materials. The requirement for a proper handling is due to the expensiveness of materials and variety of quality standards based on the significance of materials which makes the handling process important. The focus on on-site material handling must be directed to minimize wastage, vandalism, theft and shortage (Kasim, 2006). In order to have much effective handling of materials on site is to maintain good method to cover and supply all materials as needed, including raw and processed materials, arranging all works and maintaining materials (Madhavarao, Mahindra and Asadi, 2018). If the handling of materials within the site is strictly adhered to the guidelines, it can help to minimize waste and contribute directly to increased profits and productivity (Arijeloye and Akinradewo, 2016).

C. Cost Overruns in Construction Projects

According to Rajakumar (2016), cost overruns refer to the comparison between the estimated cost and original incurred cost. A cost overrun, also known as an elevation in cost due to high unpredictable cost because of any error in actual cost calculation during the budgeting process (Vaardini, Karthiyayini and Ezhilmathi, 2016). A completed project may not be considered as a successful venture unless and until it meets the budgetary constraints imposed on it (Azhar, Farooqui and Ahmed, 2008). Vaardini et al. (2016) stated that it is unavoidable from having cost overruns which surpass 100% of estimated cost in underdeveloped and developing countries. In that regard, cost overruns characterized the majority in constructions in developing countries (Durdyev, Ismail and Bakar, 2010). Nevertheless, cost overruns have the capability to crash the projects while making instable consequences for all parties involved (Aljohani, Ahiaga-dagbui and Moore, 2017). Vaardini et al. (2016) emphasized that improper resource management, poor planning, improper site management, faulty financial control, poor climatic conditions, lack of proper planning and scheduling and material rate fluctuations as the most crucial factors which can lead to cost overruns in construction projects.

D. Relationship between Material Management and Cost Overruns

As per the cost analysis of infrastructure projects, materials and plant cost can be summed up to 70% of the total cost and depending on the type of project, the level of mechanisation and plant employed whereas commercial and housing projects account for roughly 45-50 % (Donyavi and Flanagan, 2009). Since construction materials are major cost components in any construction projects, material management is considered as one of the frontiers for cost reduction to increase profitability and productivity (Napoleon Kuebutornye et al., 2018). Koriom et al. (2019) express that because of the lack of adequate execution of materials management, construction contractors had to suffer from low productivity, project delays and cost overruns

throughout the whole time. According to Donyavi and Flanagan, (2009) cash flow is the decisive for the existence of any business if there is early purchase of supplies, capital may be held up and interest expenses on the excess inventory of material may be incurred. Materials may subject to deterioration or theft during storage. Moreover, if there are no supplies for relevant tasks, delays and additional costs may be incurred. Therefore, construction material management has become an important function in the construction projects due to its key role in to project cost (Jusoh and Kasim, 2017a).

By referring to the previous studies on material management and cost overruns in Sri Lankan construction industry, there were studies done based on the impact of material management systems in high-rise buildings in Sri Lanka and the application of modular coordination (MC) to material management in construction industry where they were focused on reducing the material wastage. But in both of them the effect to the project cost was not discussed further.

3. Research Methodology

The mixed research approach was employed in this research by using both quantitative and qualitative methods where the quantitative analysis was conducted to identify the impact and relationship between material management on cost overruns and qualitative analysis was conducted to identify the issues on proper material management and suggest solutions to overcome prevailing issues. The target population selected for the study among the construction professionals are the project managers, quantity surveyors, site engineers and store keepers. The conceptual framework which was developed for the study was illustrated in the Figure 1.

Accordingly material management was established as independent variable and cost overruns were established as dependent variable in this conceptual framework. Under the main independent variable, there were six sub independent variables established as material planning, vendor analysis, storage and inventory, material purchasing, supply and distribution and on-site material handling. Accordingly, both null hypotheses (H_0) and alternative hypotheses (H_1) were developed as follows to test the relationship between the variables.

Null hypotheses (H_0) – There is no relationship between the independent variables and the dependent variable.

Alternative hypotheses (H_1)– There is relationship with the independent variables and the dependent variable.

In this research, simple random sampling and purposive sampling techniques were employed as sampling methods. Qualitative data was collected through semi structured interviews which includes open ended questions and quantitative data was collected through questionnaire survey which includes close ended questions. All together 10 number of construction professionals were interviewed

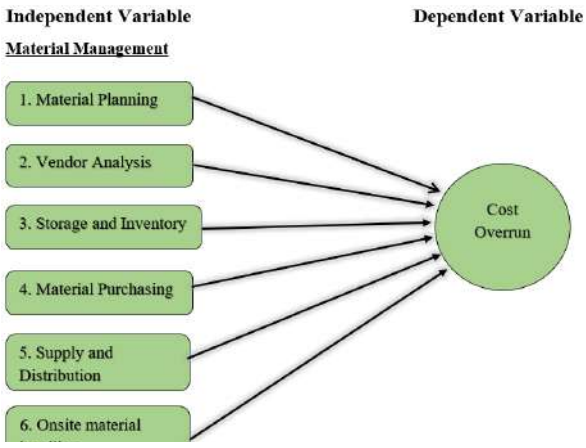

Figure 1. Conceptual Framework

for the semi-structured interviews and their details are represented in Table 1.

Table 1. Interviewees' Details

Interviewee Code	Designation	Organization type	Experience
ER-01	Project Quantity Surveyor	Contractor	15 years
ER-02	Senior Quantity Surveyor	Contractor	27 years
ER-03	Project Manager	Contractor	30 years
ER-04	Project Engineer	Contractor	21 years
ER-05	Quantity Surveyor	Consultant	17 years
ER-06	Store Keeper	Contractor	12 years
ER-07	Resident Engineer	Consultant	28 years
ER-08	Civil Engineer	Contractor	19 years
ER-09	Chief Quantity Surveyor	Consultant	32 years
ER-10	Store Keeper	Contractor	16 years

The questionnaire survey was distributed among 40 construction professionals but only 38 responses were received with 95% response rate. Among the 38 construction professionals who responded to the questionnaire, 16 were quantity surveyors, 7 were project managers, 10 were engineers and 5 were store keepers.

Regression analysis was performed to identify the impact between the independent and dependent variables and the degree of the relationship between independent and dependant variables was measured by the correlation coefficient with the aid of SPSS software. The manual content analysis was used to identify the issues of material management on cost overruns and the solutions were suggested to overcome the issues related to material management.

4. Research Findings

A. The Impact of Material Management on Cost Overruns in the Construction Projects

The regression analysis was employed to identify the impact between these two variables through the SPSS software. Regression analysis is the analysis of relationship between dependent and independent variable as it depicts how dependent variable will change when one or more independent variable changes due to factors. The formula for the regression analysis was developed as follows.

$$Y = \alpha + (\beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6)$$

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	714	340		2.101	044
	AMP	181	092	.339	1.965	058
	AVA	084	129	093	.647	522
	ASI	319	094	386	3.414	002
	AMAP	210	107	264	1.958	059
	ASD	068	144	066	.471	641
	AOS	036	140	034	259	797

a. Dependent Variable: ACO

Figure 2. Coefficient table derived from SPSS

The formula is derived by the simple equation of $Y= \alpha+ \beta X$. Accordingly, Y is the dependent variable while X is the independent variable here. α is the constant and β is used to define the slope between the variables.

Figure 2 which consists of coefficients was directly derived from the SPSS software as screenshot where it depicts the values to prove the relationship between the dependent and independent variables in related to the regression analysis formula through the unstandardized B (β) value.

Y = {0.714 + [0.181*(AMP)] + [0.084*(AVA)] + [0.319*(ASI)] + [0.210*(AMAP)] + [0.068*(ASD)] + [0.036*(AOS)]}

AMP – Average of material planning
AVA – Average of vendor analysis
ASI – Average of storage and inventory
AMAP – Average of material purchasing
ASD – Average of supply and distribution
AOS – Average of on-site material handling
ACO – Average of cost overrun (dependent variable)

Accordingly, as per the results obtained it depicts the variance of the cost overruns which affected by the independent variables of material management.

Based on the results of the regression analysis, storage and inventory variable has the highest impact with the dependent variable with 31.9% variance of cost overruns in Sri Lankan construction projects. On site material handling was identified as the least impact variable with the 3.6% variance of cost overruns in the construction projects.

B. Relationship between the Material Management and Cost Overruns in the Construction Projects

Based on the analysed data, all the significance values obtained for independent variables were recorded less than 0.05 which portrayed that all the independent variables have a relationship with the dependent variables. Further, the Pearson correlation value acquired for all the independent variables were recorded above 0.7 except for on-site material handling. Vendor analysis independent variable has the highest correlation value as 0.777 and the lowest as on-site material handling with a value of 0.683. Therefore, all the independent variables except on site material handling were remarked to have a strong and positive relationship with the dependent variable of cost overrun. Although on site material handling has a positive relationship with the dependent variable as well. This signifies that all the alternative hypotheses that were developed for the study was satisfied.

C. Issues of Material Management on Cost Overruns in the Construction Projects in Sri Lanka

This set of issues were identified through the means of a questionnaire survey and analysed through frequency analysis under manual content analysis. Table 3 represents the issues related to material management on cost overruns in the construction projects in Sri Lanka.

Table 2. Issues of Material Management on Cost Overruns in the Construction Projects in Sri Lanka

Code	Rank	Issues	Frequency	Percentage
E	1	Wastage of materials	31	81.6%
C	2	Low quality material purchase	24	63.2%
F	3	Price escalation of materials	23	60.5%
A	4	Improper storage management	19	50%
G	5	Improper material handling	16	42.1%

D	6	Inaccurate material ordering	15	39.5%
K	7	Poor coordination and supervision	15	39.5%
H	8	Lack of proper record keeping of materials	14	36.8%
B	9	Lack of project personnel related to material management	13	34.2%
L	10	Improper material planning	11	28.9%
M	11	Lack of timely delivery of materials	9	23.7%
I	12	Improper material distribution among sub-contractors	7	18.4%
J	13	Improper supply chain management	6	15.8%

Furthermore, Figure 3 illustrates the graphical interpretation of the issues related to material management in construction projects in Sri Lanka

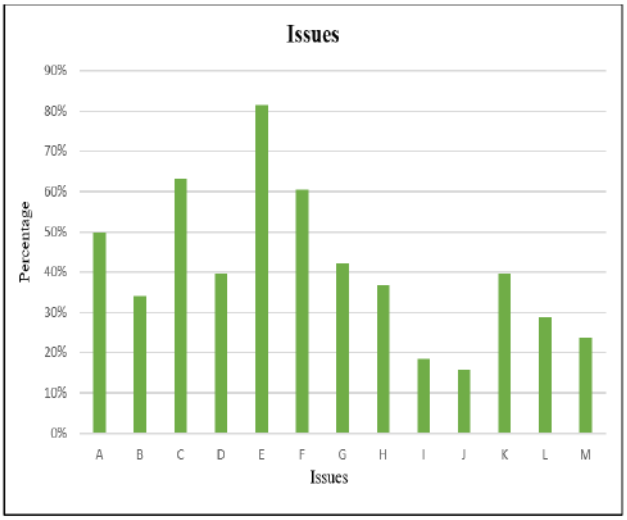

Figure 3. Issues of Material Management in the Construction Projects in Sri Lanka

As per the data illustrated in table 3 and figure 2, total 13 issues were identified which were associated with material management on cost overruns in the construction projects in Sri Lanka. Accordingly, the key issue was identified as the high wastage of materials which denoted by letter "E" in the figure. Further, issues of low-quality material purchase, price escalation of materials, improper storage management and improper material handling also identified as some significant issues which effects to the cost overruns in the construction projects in Sri Lanka.

Apart from that lack of project personnel related to material management, inaccurate material ordering, lack of proper

record keeping of materials, improper material distribution among the sub-contractors, improper supply chain management, poor coordination and supervision, improper material planning and lack of timely delivery of materials also identified as the issues prevailing in the construction projects in Sri Lanka which related to the material management.

D. Solutions for Material Management to overcome Cost Overruns in the Construction Projects in Sri Lanka

As per the experts' opinions, this critical issue of material wastage is long lasting from project inception to the completion of the project. In regards that they highlighted; professionals who are involving in each stage should ensure to minimize the overall material wastage of the project. Accordingly experts suggested the solutions related to material management to overcome cost overruns in the construction projects as selecting competent suppliers after proper assessment of material test certificates for the selected materials, maintaining of proper documentation for material inflows and outflows throughout the whole construction duration, introducing specific professions related to material management such as material managers/material coordinators, timely planning of material requirements with reference to the construction programme and deducting any material wastage amounts from sub contractor's payment certificates beyond the allowable limits. Further experts suggested to adhere with some common concepts such as building information modelling (BIM), value engineering (VE), 3R concept and life cycle costing once they are involving in material management in construction projects in Sri Lanka.

5. Discussion and Recommendation

The study was conducted to investigate the impact of material management on project cost overruns in Sri Lankan construction projects. As per the research findings, all the alternative hypotheses (H_1) were satisfied while indicating that there is a strong and positive relationship between the material management and cost overruns in Sri Lankan construction projects. On the other hand, it was identified that storage and inventory have the highest impact to dependent variable of cost overruns out of the defined independent variables based on the regression analysis formula. Meanwhile, wastage of materials attained the majority out of the issues discovered. In order to adhere proper material management in the construction projects, professional experts suggested some common concepts such as BIM, value engineering, 3R concept and life cycle costing in Sri Lankan construction projects.

Further, some recommendations were drawn in this research to implement Enterprise Resource Planning (ERP) systems with the requirement of major customisation along with characteristics of the local construction industry, to prepare separate comprehensive document system for material management at sites, to implement Advanced Work Packaging (AWP) where combining engineering and procurement in the early stages of the construction project to align with the construction scheduled work scope. This Advanced Work Packaging (AWP) method can make sure the construction will be completed along with the design without allowing any reworks. Other than that, Just in Time (JIT) approach is also identified to be an effective practice which can eliminate waste production within the project through proper delivery of materials. Further, allocating competent personnel for the material management at site, conducting regular meetings to discuss upon prevailing issues related to material management and forming a separate executive team to assess the material management in the construction projects also recommended.

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Acknowledgment

I would like to express my sincere gratitude towards all individuals and organization which guided me throughout the whole time period for their immense guidance, supervision and encouragement contributed towards the successful completion of this research.

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Specialized Software Usage among the Quantity Surveyors in Sri Lanka

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Abstract*:In the construction sector, the role of the Quantity Surveyor (QS) is critical by the constant review of designs in our construction industry. Many software configurations have emerged in the market as a result of technological advancements that solve current challenges. The objectives of this study were identify the level of specialized softwere usage among the quantity surveryors, determine the barriers to adapting advanced QS-related software in QS practice, determine the benefits of specialized software usage and determine the strategies for overcoming the barriers to implementing advanced QS-related software. Data was obtained through ten interviews and fifty questionnaire responses to achieve the objectives. 70 questionnaires were distributed for data collection, and 50 responses were obtained, resulting in a response rate of 71.42 percent. The study found that MS Excel and Auto CAD are the most often used quantity surveying software in Sri Lanka. The main sub barriers were the installation cost of the software, lack of experience with the software, and the lack of senior and firm support. Major benefits identified were Faster, increased productivity and accuracy.*

Keywords: *QS-related software, Quantity Surveyors in Sri Lanka*

1. Introduction

The quantity surveyor's work is made more difficult by the constant review of designs in our construction industry. When the building projects get more complicated, the ongoing desire for more accuracy in the Quantity Surveying industry presents a difficulty (Doyle and Hughes, 2000). The nature and scope of services given by quantity surveyors within and beyond the construction industry have changed significantly during the last decade (Smith, 2003).

Many software configurations have emerged in the market as a result of technological advancements that solve current challenges (Reddy, 2018). According to a cursory look at the websites of most QS software providers, the modules incorporated into each software focus on core QS functions (Cartlidge, 2006). Many commercially created modern software applications are aimed at assisting quantity surveyors in their work. While some QS companies have accepted the usage of some of the tools, it is well known that others have yet to do so (Okumbe and Verster, 2008).

These modern software settings serve to speed up the traditional procedure and also come with a number of other benefits, such as easy revisions (Reddy, 2018). The most significant impact on productivity comes from the usage of modern software. It makes quantity surveying activities more efficient. If the functions are completed on time, at a cheap cost, and efficiently, any country can benefit (Smith, 2003).

But the thing is, the construction sector has been slow to adapt to modern technologies (Olanrewaju *et al.*, 2020). Quantity Surveyors aren't really concerned about enhanced IT adoption (Usman and Said, 1986). Most of the quantity surveying firms see technology adoption as just a difficulty to apply to construction activities. Many quantity

surveyors rely on few of IT application skills (Mui *et al.*, 2002).

2. Literature Review

A. Information Technology in Quantity Surveying Practice

Currently, the use of information technology in construction, particularly in the field of quantity surveying, plays a significant role. Computers, networks, software, and even fax machines and telephones are all part of information technology. Its objective is to make information interchange and administration easier, and it has a lot of promise in the construction industry's information process. These new technologies will surely have a significant impact on how businesses function on a daily basis (Rivard, 2000). Therefore, the use of technology in the building business is gaining popularity around the world (Shen et al., 2003).

B. Benefits of Software Usage

The use of software saves a significant amount of time because the new applications' measuring values are immediately written down, and even very intricate calculations may be completed in a few minutes. Furthermore, the measures can identify quickly and easily (Reddy, 2018). With the use of IT in traditional practice, the productivity of quantity surveyors rose (Li, Irani and Love, 2000). Increased productivity, lower operational costs, direct value extraction from files, and improved collaboration among QSs are all advantages of employing software (Agyekum, Ayarkwa and Acheampong, 2015). When compared to traditional methods, the use of specialist estimation software during takeoff delivers more accurate data (Faizul, 2012).

C. Issues Arising When Using the Traditional Methods

The majority of quantity surveyors nowadays use AutoCAD software to perform quantification work. Quantity surveyors capture measurements with AutoCAD, However, just the most basic tasks may be completed with it. The QSs needs to apply quantities in manually to Excel. Therefore Excel takes a significant amount of time and effort. The main downside of this method is that modifications are difficult to make, and the quantity surveyor must redo the entire procedure. The quantity surveyor's work is made more difficult by the constant review of designs in our construction industry (Reddy, 2018).

When compared to using modern software, the traditional way of taking off takes longer. The BQ cannot be made until all of the measurements have been completed. This takes a long time; especially when the construction project is large and the shapes are uneven (Seeley, 1997).

D. Factors to Adopt Software

This hurdle makes it difficult for these businesses to take use of specialized estimation tools. There are also additional hidden costs associated with computers, such as the cost of antivirus software, software and hardware maintenance fees, and monthly or annual software subscription fees. The cost of investing in specialized software is excessively high, and the quantity surveying firm cannot be certain of a long-term return (Murtaza and Ashrafi, 2008).

Due to a lack of knowledge, information, and training, quantity surveying organizations find it difficult to deploy software. They are reluctant to use technology because of their lack of knowledge with modern IT applications. Many quantity surveyors still don't know how to use computers. Furthermore, workers do not participate in training sessions to increase their IT knowledge and skills. This circumstance arises owing to the expensive cost of training, as well as a lack of time and enthusiasm (Mui and Tat, 2008). The most of senior executives seem to be against software advancements. They tend to prefer the conventional method of AutoCAD quantity takeoff (Reddy, 2018).

3. Methodology

The primary data for this study was gathered using a simple random sample method and purposive sampling method with only quantity

surveyors in the Sri Lankan construction industry as respondents from various contracting firms and consulting firms. The secondary data for this study was gathered using a comprehensive literature survey to determine the barriers and benefits of the advanced QS-related software in QS practice. Data was obtained through ten semi structured interviews and fifty questionnaire responses to achieve the objectives. 70 questionnaires were distributed for data collection, and 50 responses were obtained, resulting in a response rate of 71.42 percent.

Table 1: Sample and Population

Type of data collection	**Population**	**Sample**	**Sampling Tchnique**
Literature survey	Web articles, Online journals	30	Secondary data
Detailed Questionnaire	For the population various kind of Quantity Surveying professionals considered.	50 Quantity Surverying professionals have been selected to the sample	Simple Random Sampling Method
Semi Structured Interviews	Experienced Quantity Surveryors from Sri Lankan construction Industry.	10 Quantity Surveryors who have more than 5 year's experience	Purposive Sampling Method

4. Results

The data gathered from the questionnaire and the semi structured interview ware used to assess the levels of software usage among Sri Lankan quantity surveyors. The frequency table was implemented to accomplish the above objective

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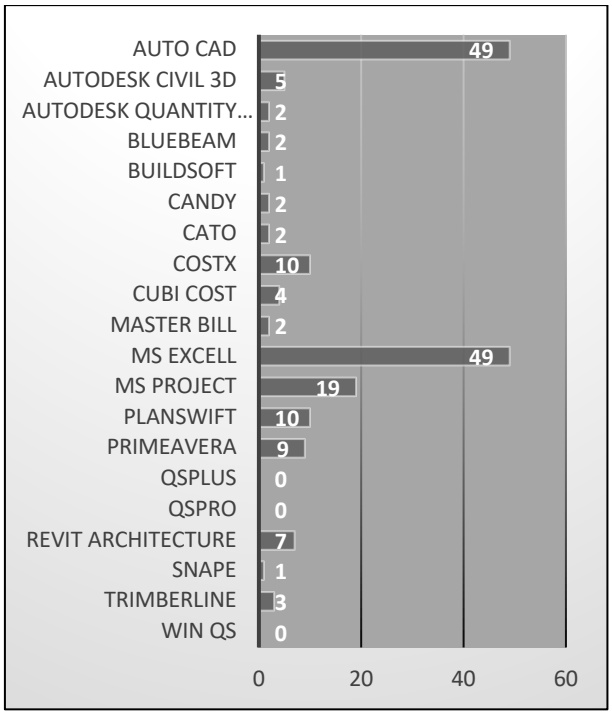

Figure 1: Usage of QS related software obtained through Questionnaire

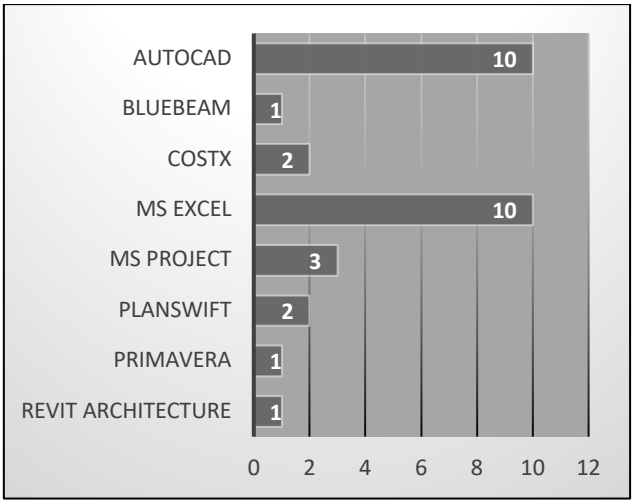

Figure 2: Usage of software obtained through conducting interview

Barriers of the software usage have been identified through the literature review chapter. The information was obtained using a questionnaire and interviews, and it has been analyzed using the Relative Important Index (RII) approach

.

Table 2: Ranking the sub factors of the readiness

No	Factor	Weighted total	Relative Index	Rank
1	Less senior and firms support	199	0.796	1
2	Security and accuracy fears	186	0.744	4
3	Backward mind set	190	0.760	3
4	Discomfort with new software	184	0.736	5
5	Scarcity of first-hand software experts	194	0.776	2

Table 3: Ranking the sub factors of the knowledge

No	Factor	Weighted total	Relative Index	Rank
1	Lack of understanding or training in software	215	0.860	2
2	Lack of Education Qualifications about QS software	214	0.856	3
3	Lack of experience with the software	216	0.864	1

Table 4: Ranking the sub factors of the Cost

No	Factor	Weighted total	Relative Index	Rank
1	Installation cost of the software	205	0.82	1
2	The maintenance cost of the software	200	0.80	2
3	The additional hidden cost of the software	195	0.78	3

The literature survey found the benefits of software usage, which were then investigated using the RII approach. The information was gathered via a questionnaire and structured interviews.

Table 5: Analysis of the benefits of the software

No	Factor	Weighted total	Relative Index	Rank
1	Faster	237	0.948	1
2	More accurate	234	0.936	3
3	Storage of data	223	0.892	7
4	Increased productivity	236	0.944	2
5	Professionalism	225	0.9	5
6	Reduced paper work	233	0.932	4
7	Lower operational cost	193	0.772	9
8	Minimal errors	224	0.896	6
9	Safe	213	0.852	8

The data gathered from the interview sessions was used to identify strategies for overcoming the barriers to implementing advanced QS-related software in practice**.** Interviewees highlighted some strategies, and the following frequency table was implemented to accomplish the objective.

Table 6: Analysis of the Strategies for overcoming the barriers to implementing advanced QS-related software

Strategies	Frequency	Percentage	Item
Seminars aimed at top management professionals to motivate them to utilize specialized software.	4	40%	**A**
Curricular integration of specialized software training at universities or colleges.	8	80%	**B**

Increased the supply of information on specialist software via social media by emphasizing the advantages.	3	30%	**C**
By conducting workshops, both quantity surveyor students and quantity surveyors improved basic computer literacy and software understanding.	6	60%	**D**
Encourage quantity surveyors to learn about software by watching videos on YouTube	7	70%	**E**
Provide low-interest loans to small construction and consultancy organizations for software purchase.	3	30%	**F**
Purchase software during the discount seasons.	2	20%	**G**
Use track software	1	10%	**H**

5. Discussion

According to the results of the questionnaire MS Excel and Auto CAD are the most commonly used quantity surveying software in Sri Lanka for their QS-related works. According to the interview data, MS Excel and Auto CAD were the most widely used soft-wares for quantity surveying practices by all the professionals. MS Project, Planswift, CostX, Primavera, and Revit Architecture software usage is less when compared with the usage of MS Excel and Auto CAD. According to the results, it is proven that quantity surveyors aren't really concerned about enhanced IT adoption.

The main sub barriers were identified according to the questionnaire were installation cost of the software, lack of experience with the software, and the lack of senior and firm support. According to the interview data, most of interviewees highlighted that high installation cost of the software, high maintenance cost of the software, less knowledgeable person for specialized software, lack of support from management, high training cost, afraid to adapt to the new software due to security accuracy fears, backward mind set and scarcity of first-hand software experts as barriers. The cost of both software and hardware installation is extremely expensive. Most small businesses with limited financial resources consider these expenditures to be prohibitively high and would prefer to operate manually while looking for funding to invest in information technology (Mui and Tat, 2008). When comparing the results with the literature review, it is proven that factor again.

Major benefits identified through the questionnaire were faster, increased productivity and accuracy. According to the interview data, most of interviewees highlighted accuracy of the work, minimum errors, speedy, increased the productivity of whole project, improved efficiency, easiness, and transfer files easily, increased security and reduced paper works as benefits of the specialized software. It is proven that factors again through the literature review. When comparing the results with the literature review, it is proven that factor again. The use of software saves a significant amount of time because the new applications' measuring values are immediately written down, and even very intricate calculations may be completed in a few minutes. Furthermore,

the measures can identify quickly and easily (Reddy, 2018).

6. Conclusion

MS Excel and Auto CAD are the most often used quantity surveying software in Sri Lanka. CostX, Planswift and MS Project are the best software that can be used for a developing country like ours. According to the results, it is proven that quantity surveyors aren't really concerned about enhanced IT adoption.

The main sub barrier to the cost factor is the installation cost of the software. The main sub barrier for the knowledge factor is lack of experience with the software, and the main sub barrier for the readiness factor is lack of senior and firm support. Major benefit identified through the questionnaire is "Faster". Other benefits of the usage of specialized software are accuracy of the work, minimum errors, speed, and increased productivity of the whole project, improved efficiency, easy of transfer of files, increased security, and reduced paper work as the benefits. Curricular integration of specialized software training at universities or colleges was the best strategy for overcoming the identified barriers.

7. Recommendation

Recommendations provided for overcoming the barriers to implementing advanced QS-related software in QS practices. Management decisions are carried out by top management professionals of the QS firms. They are not concerned about the new technologies due to a lack of information regarding new software. Therefore, the seminars are aimed at top management professionals to motivate them to utilize specialized software by emphasizing its advantages.

Quantity surveyors are not concerned about the enhanced technologies due to lack of information regarding new software. Many QSs are reluctant to move from what they are used to new software. Most quantity surveyors think that the method they are used to is the most accurate and easiest. Therefore should change their thinking patterns by supplying correct information. It is more beneficial if the supply of information on specialist software via social media is augmented by emphasizing the advantages of using it. Private institutes or software companies can increase the computer literacy of quantity surveyors. They will have a better understanding of how software works, what functions it serves, and in what contexts it can be employed. Quantity surveyors and student quantity surveyors can perform effectively in the construction industry if they have a thorough understanding of soft-wares. Seminars, lectures, workshops, and the addition of new modules to courses are some of the activities that public or private institutions can do to improve computer literacy and knowledge of software. And also, Despite the fact that there are a variety of universities and degree courses in Quantity Surveying, only a few institutions exist that provide software knowledge. Therefore, it is more beneficial to have curricular integration of specialized software training at universities or colleges.

You Tube is one of the simplest and most cost-free ways to learn. There are a lot of videos on YouTube about various software programs. Anyone who is interested in learning new software can learn it at any time.

Most small QS firms with limited financial resources believe that the new software's costs are prohibitively costly, and would rather operate manually while seeking funding to invest in information technology. If the government provide low-interest loan facilities to them through financial barrier can be overcome. Some software companies give discounts during some seasons. During the discount seasons, QS companies can purchase software at a lower cost than before.

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Barrier Analysis to Implement Building Information Modeling (BIM) Execution Plan in Sri Lankan Construction Industry

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Abstract*: Building Information Modeling (BIM) can bring the project team significant advantages. BIM can be used to improve the project's delivery and usage throughout its life cycle. The concept of BIM is currently being used in the construction industry worldwide. Currently, technologies such as 3D 4D 5D BIM are being used in the construction industry. And, lot of countries are using a BEP.*

A well-conceived BEP on your BIM-enabled project, make sure the advanced design technologies are successfully deployed. In contrast, the BEP focuses on improving work and model flow throughout the project to promoting specialized interests for each individual stakeholder. Currently, BEP In light of the benefits BEP offers, it is practiced all over the world, but due to numerous obstacles, it is less common in Sri Lanka.

This study examined current BIM techniques in SL, BIM adoption in Sri Lanka, BIM awareness in the country's construction industry, how an execution plan can help with BIM implementation, The challenges to modifying an implementation strategy for the Sri Lankan construction industry, suggestions for overcome the identified barriers.

Through this study, suggestions for removing the identified barriers are also acknowledged. Less understanding of the idea and its advantages, government support for traditional practices documentation approach and problems in lack of knowledge were identified as foremost barriers for successful implementation o were determined to be the main obstacles to the successful implementation of BEP. Additionally, findings suggested that Sri Lankans must undergo cultural changes BIM practices, difficulties, and raising awareness among those involved in the construction industry.

Keywords: *BIM, BEP, SRI LANKA*

1. Introduction

The growth of the nation's economy is significantly influenced by the construction sector. The industry is currently facing a number of difficulties that have an impact on project goals and steady growth (Holmes & Troy, 2022). According to the Rameezdeen (2006), Sri Lanka's construction industry creates a wide range of goods, from single homes to significant infrastructures like roads, power plants, and petrochemical complexes.

Nayanthara De Silva (2008), stated that the main issues in Sri Lanka were the varying workload in the construction industry, unfair competition from foreign contractors, skills drain, shortages, and the high cost of skill development.

Raufdeen Rameezdeen (2002), has analyzed because of its extensive nature, involvement of a large number of stakeholders, and complex newer projects, contractual relationships distribution of responsibilities and authorities between parties, scope of assigned duties, and uniqueness of the construction products, the construction industry gradually becomes more complex. Therefore, implementing cutting-edge

software like BIM has many advantages for a construction project.

Hence, adopting an advance software like BIM gives many benefits to a construction project. BIM provides a common data environment for all the participants to exchange their data. The paradigm that will help create a shared working space for all stakeholders is revolutionary. (Epasinghe, Jayasena, Kolugala, & Wijewickrama, 2018). In addition, benefits of BIM include cost and resource savings, increased efficiency and shorter project lifecycles, improved communications, more opportunities for prefabrication and modular construction, and higher quality results (Reyes, et al., 2020).

But it's important to comprehend the state of BIM roles now and what the sector's needs will be in the future. There may be barriers in the construction industries that need to be identified and removed before BIM can be implemented. Cost, law, experts, interoperability, awareness, culture, processes, management, demand, project scale, technology, skills, training, contract, and standard are some of the 15 categories of barriers. The study provides important information for future research to remove obstacles to BIM adoption. (Z. Sriyolja, 2021)

On your BIM-enabled project, the BIM Execution Plan (BEP) aims to create a fundamental framework for the successful application of advanced design technologies. The BEP focuses on streamlining work and model flow throughout the project as opposed to siloed interest optimization. (GERCEK, TOKDEMIR, ILAL, & GUNAYDIN, 2017). In addition, Kelly (2016), stated that BEP benefits such as Communications, Collaboration, saving time Sharing data and stronger execution. Thus, in light of the advantages BEP offers, it is used widely around the world, whereas Sri Lanka uses it less frequently due to numerous obstacles.

The study presented here investigates the barriers of the implementation BEP in construction industry and the gravity of them. The literature review investigates the barriers to implement the BIM and execution plan of BIM. Applicability of the suggestions to the Sri Lankan construction industry was analyzed.

2. Literature Review

A. Building Information Model (BIM)

In 1982, Autodesk was the first to introduce 2D computer aided design (2D CAD). Better documentation, accurate drafting, and time savings are all benefits of 2D CAD. BIM has an advantage over traditional CAD 2D models in that tasks associated with project planning, design, construction can all be successfully carried out using the BIM model (Anil Sawhney, 2017). Moreover, the collection, creation, and also exchange of shared structured data, 3D models and intelligent was also involved by BIM. Jian Li (2014) pointed out that pre-handling with BIM software further simplifies the clash detection process.

B. SL and global Level of BIM using

In the present BIM is using all across the globe. Jung and Lee (2015) pointed out, the global BIM uses among the nations that use BIM extensively on a global scale are the United States of America (USA), Canada, France, the United Kingdom (UK), Russia, Republic of Korea, the Philippines, Taiwan, Singapore, Taiwan, the Netherlands, Thailand, Saudi Arabia, Lebanon, Jordan, Iran, , India the United Arab Emirates (UAE), South Africa, Argentina, Mexico, Egypt, Italy, Qatar, Brazil, and Chile. And also, the governments in a few of the nations have taken the lead in implementing and growing BIM within their own national borders. University of Westminster (2019) explained that the implementation of BIM has received a prompt response from the UK construction sector. Since their customers might not be familiar with BIM, small and medium-sized businesses (SMEs) are less likely to have adopted it.

According to M.S. Siriwardhana (2018), the government should be the first to initiate this journey. BIM is necessary for consumers to

deliver a smooth project by cost, achieving time, and quality targets. When considering about BIM implementation in Sri Lanka, 55.55% of construction company owners do not interest in BIM in to the projects.

And also, they are responsive on the essentiality of BIM for the local context.

C. BEP

X. Sun & J. J. McArthur (2015) stated that to a specific project or set of projects, a BEP is a useful ool that offers a systematized workflow and general pathway for strategic BIM execution. In addition, Sun (2015) directs the overall vision of project, outlines the uses of BEP, and acts as a record of the understandings of the stakeholders. And also, it is known as a "living document" which needs to be reviewed continuously across the course of the project.

D. Importance of BEP

Implementing BEP gives many advantages. (JOHN MESSNER, 2019) define that information which included in a BEP as BIM objectives, model quality control procedures, collaboration process, technology infrastructure requirements, project deliverables, model structure and delivery strategy.

plans. (Sun J. J., 2015) Because a BEP is a living document, the project members should cooperate in real time to ensure accepted attention is offered to each project. Apart from that, BEP concentrate on the benefits of the project, no one is going to be delayed with analyzed data which very often cause damaging delays to project outcomes. And also, sharing information of project group should have straight access to BIM operation data in a way that is simply shareable and can be updated repeatedly. Well-built implementation composing a BEP contribute to keep items accountable and moving to make sure a strong finish on budget and on time. Furthermore, Ahmad Ridzuan Abu Bakar (2020) demonstrate a review of the Building and Environment (Protection Plans (BEPPs) stated that the BEP framework was a main reason for the project's evolution. The framework of document should include the process, strategy, data, infrastructure, personal and ethics to improve the understanding of the members in project team.

Ramage(2022) stated that there are two models of BIM, such as pre-contract BIM plan and post-contract plans. Precontract plans are made available to potential bid design suppliers during the tendering process. The

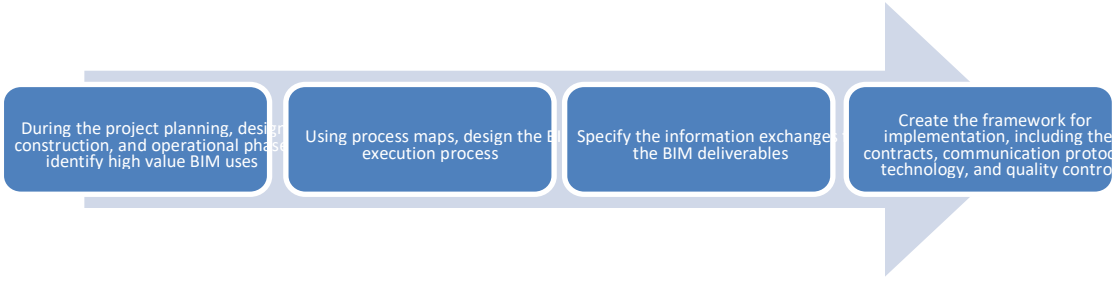


Figure 1. BIM Project Execution Planning Guide

(Chimay Anumba, 2010) identified the advantages of BEP such as helping to supervise prospects and responsibilities and also communication with teams at the very beginning of the construction projects, each construction project have various requirements depend on, and internal standards and regulations. To achieve project goals easily it's better to have an execution

supplier will implement their suggested strategy, and other information, available capacity. There is also post-contract award BEP created after the contract is awarded to the selected contractor or contractors. Post BEP important chapters are about planning, management documentation, standards

and technical solutions. Further, (Chimay Anumba, 2010) identified the information which are included in a BEP such as, Information about the BEP, the project, and important project contacts , Project objectives and BIM goals include organizational roles and staffing, design BIM process, exchanges of BIM information, requirements for BIM and facility data, collaboration processes, model quality control processes, infrastructure requirements for technology, project deliverables ,model structure and delivery strategy and contracts.

The BEP will present for the protocol establishment for the improvement, transmission, and exchange of digital information. It interprets expectations of LOD for model elements at different stages of the project. And also issues a detailed design of the process for implementing BIM throughout the lifecycle of project. (BIM Project Execution Plan, 2018). According to Otmar Hrdina (2016), BEP provides a history of documents and outlines the goals for a BIM project. The plan should specify define appropriate BIM applications, such as design authoring, design reviews, cost estimation, etc.

(Chimay Anumba, 2010) stated each potential supplier to the BIM project generates a pre-contact award that details the abilities) of their digitalization infrastructure. The designer and the contractor team develop the post-contract BEP, which includes operational details about administration and creation of the project.

E. BIM Project Execution Planning Procedure

Four-step structured procedure for creating and implementing a BEP

F. Global usage of BIM execution plan

To confirm BIM implementation runs productively, various reference documents have been improved, such as guidelines, modelling techniques, standards and work process manuals, with BEPs. The examples of the documents are NATSPEC national BIM guide, AEC (CAN) BIM Protocol, national BIM model protocol, design guidelines BIM manual rail Baltic, the New Zealand BIM handbook, CIC building information modelling standards, the guide to building information modelling, application guide BIM Luxembourg CRTI.B, AEC (UK) BIM protocol
(Ahmad Ridzuan Abu Bakar, 2021)

Not only that, the New Zealand BIM Handbook (2019) has described the definition of BEP production as to issue a framework that will ensure all parties know the benifits and responsibilities of projects that execute BIM. It sets goals and people's responsibilities and outlines how the process will be implemented in the project's life cycle. (Ahmad Ridzuan Abu Bakar, 2021). Anyhow, some of the BEP's structure outlines were different depending on its priority. Moreover, some BEP's include additional chapters to give good knowledge. Hence, further investigates and contrasts of the guidelines will demonstrate) available patterns that found in BEP frameworks. (Ahmad Ridzuan Abu Bakar, 2021). Despite, Otmar Hrdina (2016) has researched that there is requirement to create common guideline or template which will be legally supported and used in contracting.

G. Barriers

When considering the barriers to implement BIM, (Salman Azhar, 2011) stated that the rights of the BIM data should be determined as the very first legal risk. Inhibitions or incentives that protect stakeholders from fully realizing the potential of the model are to be avoided. The question of who will oversee data access into the model is another problem that needs to be addressed. According to (National Business School (NBS) statistics 2017), lack of internal BIM modeling expertise results in higher cost of training, Cyber security can create from external and internal, or system failures are other sets of issues to implement BIM. 65% of clients do not understand the

advantages of BIM. Thus, BIM adoption in small businesses are less.

Implementing a performance-based system effectively is hampered by conventional procurement practices. Collaboration may be disadvantaged by resistance to change "human factor". (University of Westminster, 2019).

Gayathri Nagalingam (2013) defined unlike many other practices of construction, there are not having any document or treatise on BIM that instructs on its application or usage. Sri Lankan construction industry has an issue on lack of technology is not a huge obstacle for BIM implementation and also technology can be adopted. Decision on whether to acquire BIM would be on the balance of costs and benefits. In absence of knowledge and experience, it is difficult to know the benefits.

Shijing Liu (2015) explained that to the issues on AEC Industry such as, national standards are less and Incomplete, High application cost, implementation process, Lack of skilled workers, Lack of professionals, Organizational and Legal barriers. (George Kekana, 2015) exposed that the barriers to implement BIM in South Africa duty of care of using BIM, Intellectual property Design delegation, Data translation and professional responsibility, Insurability. And also Shijing Liu (2015) specified the researchers and practitioners have to develop suitable solutions to overcome these challenges and other associated risks. As a number of practitioners, researchers, software vendors and professional organizations are taking actions to overcome these challenges, it is expected that in the AEC industry the adoption of BIM will continue to increase.

3. Methodology

A. Research Approach

The goal of this study is to find ways to get around obstacles in the way of BEP implementation in Sri Lanka's construction sector. To learn more about the value of and obstacles to implementing BEP, a literature review was conducted. The mixed approach used in this study's research involves combining quantitative and qualitative data collection and analysis methods.

B. Data Collection

This study first used a questionnaire survey to collect primary data, and then it used the questionnaire survey results to guide semi-structured interviews.

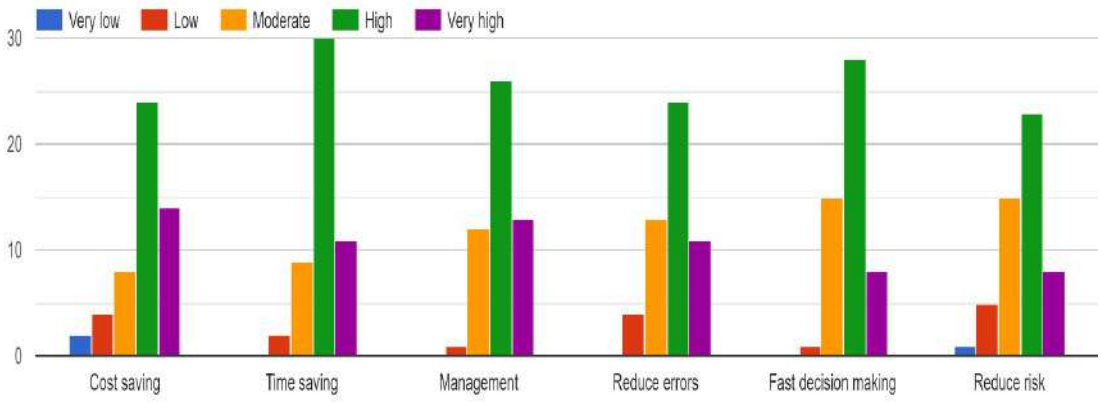


Figure 2. Significance of BIM

The questionnaire was sent out to experts in order to get a useful response.The questionnaire was developed using the information gathered during the literature review. A Likerttype scale with a maximum of five points was used in the questionnaires. This scale was used to determine how much the respondents agreed or disagreed with the factors that were presented to them.65 randomly chosen professionals were given the questionnaire, and 50 of them responded. Quantity surveyors accounted for 46% of the responses, followed by engineers (16%), architects (12%), academic professionals (8%) and others (18%).

C. Data Analysis

The frequency distribution method was used to analyze and present the data from the questionnaire survey in graphs, tables, and figures. Interview data was recorded, and content analysis was used to examine it.

4. Discussion

The questionnaire was circulated among sixty-five (65) numbers of selected professionals and received fifty-two (52) responses. Out of the responses, forty six percent (46%) was quantity surveyors, fifteen percent (15%) was engineers, twelve percent (12%) was architects, ten percent (10%) was Academia

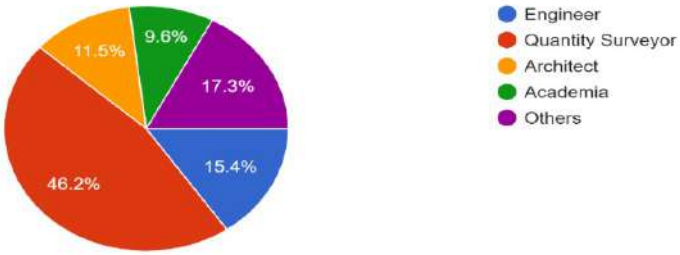


Figure 3. Percentage of professional responses

Gathered data was analyzed through the frequency distribution method under descriptive statistics. Figure 2 shows the significance of implementing Building Information Model in Construction Industry in Sri Lanka.

Findings proved that Implementing BIM would improve many factors which can be helpful to increase the productivity of construction industry in Sri Lanka such as cost saving, time saving, management, reduce errors, fast decision making and reduce risk. Figure 3 shows the level of impact of implementing BIM and to which extent the experience and knowledge of the professionals would impact in Sri Lankan construction context.

Even though there are plenty of advantages and significances of implementing BIM, number of limitations and barriers for implementing BEP in Sri Lanka were found. According to findings, Professionals have suggested number of ways to overcome the barriers to implementation of BEP. Survey results for this is denoted in figure 4.

Furthermore, from the survey circulated, provided strong recommendations to improve the use of BIM to improve efficiency, effectiveness and productivity of Construction projects and the products in Construction Industry in Sri Lanka. Increase the awareness of the BIM identified through literature was surveyed and illustrate in figure 4.

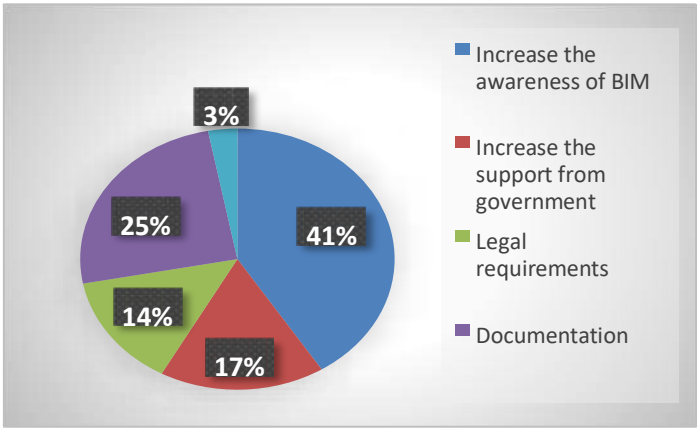
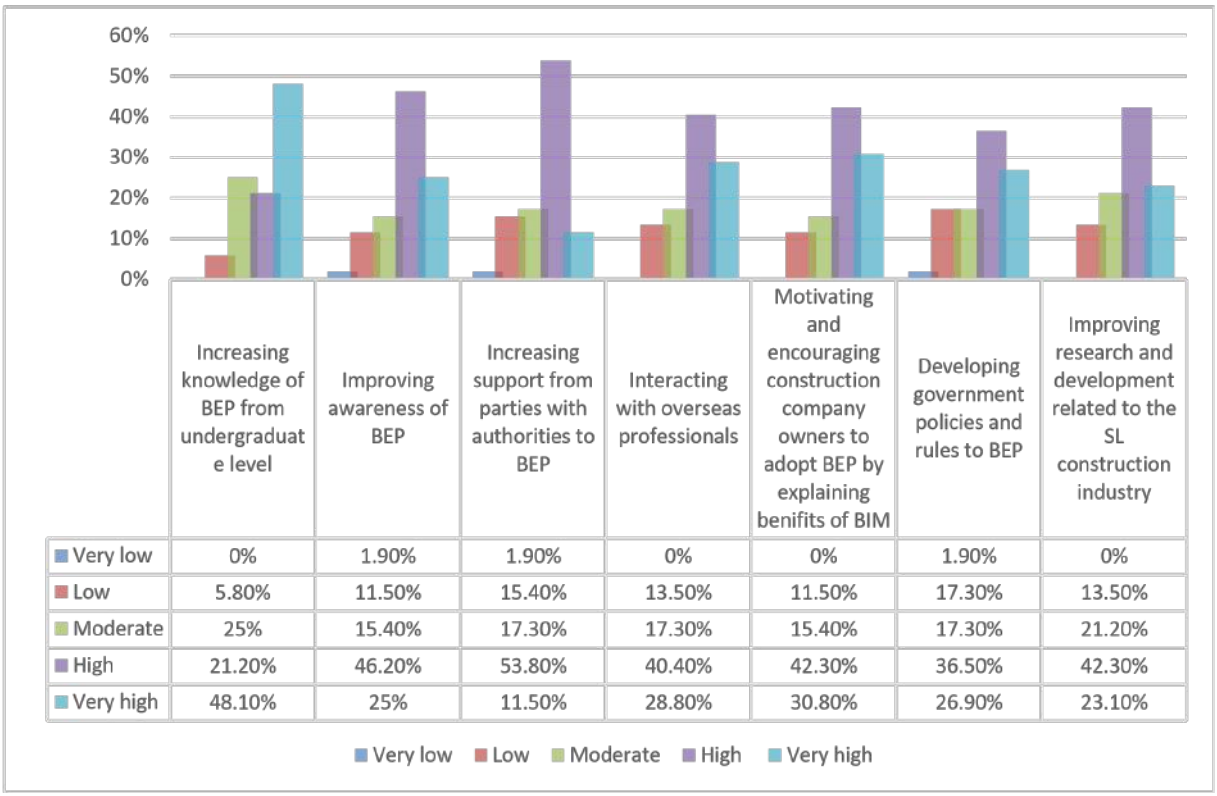


Figure 4: Barriers to BIM execution plan implementation

The pie chart shows the frequent and most suggestions which identified through the questionnaire survey. Further they confirmed the proper documentation and improved government support with satisfying legal requirements will improve this technology barrier which take place in Sri Lanka when implementing BEP.



	Increasing knowledge of BEP from undergraduate level	Improving awareness of BEP	Increasing support from parties with authorities to BEP	Interacting with overseas professionals	Motivating and encouraging construction company owners to adopt BEP by explaining benifits of BIM	Developing government policies and rules to BEP	Improving research and development related to the SL construction industry
Very low	0%	1.90%	1.90%	0%	0%	1.90%	0%
Low	5.80%	11.50%	15.40%	13.50%	11.50%	17.30%	13.50%
Moderate	25%	15.40%	17.30%	17.30%	15.40%	17.30%	21.20%
High	21.20%	46.20%	53.80%	40.40%	42.30%	36.50%	42.30%
Very high	48.10%	25%	11.50%	28.80%	30.80%	26.90%	23.10%

Figure 5: Strategies to Implement BIM execution plan in SL

It was suggested as strategies to overcome barriers to Implement BEP in Sri Lanka, including training programs,

workshops which can give practical knowledge to construction professionals, establishing clear legal procedure following proper documentation, and adopting necessary changes to legal arrangements in documentation from pre contract to post contract stage, and encourage professionals and new comers to the industry to use BIM with having BEP in Sri Lankan Construction Context, and enhancing the trust among stake holders about BEP.

Subsequently, five semi structured expertise interviews were conducted. Data collected through interviews were analyzed using content analysis method. Table displays interviewers' demographic profile. Forty percent (40%) had 0 – 10 years of experiences in construction industry while sixty percent (60%) had over 10 years' experience. Eighty percent (80%) of them had engaged with local BIM implementing projects whereas rest had foreign experience.

Table 1. Years of experience

Category	Type	Response	Percentage
Years of experience	0 – 10 years	02	40%
	Over 10 years	03	60%

In addition to findings of quantitative analysis, several other barriers of implementing execution plan of BIM in Sri Lanka found by semi structured interviews which conducted. Further interviewees confirmed that most of the ongoing and completed projects have been using BIM for the different stages in their projects, but they have not adopted with the execution plan of BIM in their projects. Further most of the major projects executing in Sri Lanka get the consultancy by foreign professionals and they are not adopting to the documentation of BIM execution plan in

projects in Industry. Interviewees suggested the required prospects to improve the BEP in Sri Lankan Construction Industry, including the aspiration of providing awareness and practical knowledge from the basics of the undergraduate's level. With the acknowledgement of the industry professionals to use BIM in industry the CDPs and Seminars were conducted in the necessity of reaching the outcome. The support given by the professional bodies such as IQSSL, IESL, RICS to the Industry about the BIM and BEP is suggested to be increased as well. The implementation of a BIM hub which provides support and knowledge for local industry professionals is proposed to come into fruition by incorporating with foreign professionals. Getting support from government authorities to have legal policies and regulations to do documentation and give legal advice about the BEP is an essential requirement too. Providing background to improve the use of BIM software in the life span of construction projects while doing researches and developing to improve the use of BIM in Construction Industry of Sri Lanka, basically the sum up the essence of the entire dissertation.

5. Conclusion

BIM is a process as well as a technology. BEP play a significant role in the BIM concept. Moreover, an execution plan offers a framework or a direction for a building project. Despite the advantages, there are numerous obstacles to BEP adoption in the construction sector. The results showed that the primary obstacles to the adoption and implementation of BEP were Lack of documentation, legal barriers, professionals are lack of knowledge of BIM in SL, not enough support from SL government financial crisis in SL, lack of interconnected relationships between construction professionals & IT professionals

in SL and resistance to change. It is advised for that increasing knowledge of BEP from undergraduate level, improving awareness of BEP, increasing support from parties with authorities to BEP, interacting with overseas professionals, motivating and encouraging construction company owners to adopt BEP by explaining benefits of BIM, developing government policies and rules to BEP, improving research and development related to the SL construction industry, attract investors from foreign countries to the construction industry and maintain proper documents.

Additionally, results showed that the effective use of BEP applications helps to alleviate the restrictions and that the significant BIM application capabilities previously mentioned contribute to improving the effectiveness and efficiency of the Sri Lankan construction industry. By accomplishing all project objectives, it will result in the completion of the building construction project. Finally, implementing these suggestions should result in higherquality, more effective, and efficient project delivery in Sri Lanka's construction industry.

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Potential of Architecture on Therapeutic Educational Spaces for School-Aged Children with Autism Spectrum Disorder in Sri Lanka

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Abstract*: Autism Spectrum Disorder (ASD) is a neurodevelopmental condition known by deficiencies in social communication and the expression of repetitive or/and unusual behaviours. The prevalence of ASD today is getting high while affecting a significant percentage of the population of Sri Lanka. Hence, implementing a processed institutionalizing plan of the condition could become more relevant presently.*

This study explores the significance of applying specific spatial design approaches to accommodate mainstream and special education classrooms in the Sri Lankan educational context. Moreover, it seeks the awareness of Sri Lankan Architects on ASD and its association with spatial attributes in creating therapeutic learning environments for children with ASD in Sri Lanka.

Keywords: *ASD, Autism, Spatial Healing, Therapeutic Educational Spaces, Autism-Friendly Architecture*

1. Introduction

"Around 1 in 50 people are autistic. About 60% of autistic adults are under or unemployed. 87% of us have a mental illness. Autistic people are 9 times more likely than the general population to die by suicide. We have an average life expectancy of just 54 years. And we deserve better…" (Houting, 2019)

According to Research on 2016 by UNESCO recently, there is a sharp increase in the frequency of this autistic condition, specifically in low and middle-income (LAMI) countries, such as Sri Lanka.

The challenge of designing spaces for children with ASD is that the two scenarios do not match due to their different symptoms. They are different sensitivities and different levels of functioning. On the meaning of words, these children have extraordinary reactions to the environment and may require a well-structured learning environment with clear boundaries for each activity. They need a comfortable distance between themselves and others.

Ideally, spaces ought to design individually to allow for individualized symptoms and to help individuals with ASD build a tolerance to environmental stimuli. Hence the schools need to facilitate the learning experience of child's individual requirements such as light, colours, scale and form, which are to be explored by this study.

A. Need for the study

Autism awareness is growing in Sri Lanka, but slowly. Whatever the case may be, it affects a significant percentage of citizens. As a part of awareness and acceptance of ASD, some institutions, programs, societies, and communities relate to the condition. But among these activities, architecture's contribution is much less mentioned but equally important as others in the process of institutionalization in the general context of Sri Lanka.

Thus, there are no well-defined special needs schools and inclusive schools for children with

ASD under well-defined written principles, theories, and guidelines about the environmental considerations under creating learning environments for school-aged children with ASD. Furthermore, there is a lack of research examining the impact of the built environment and architectural conditions on Children with ASD based on their psychological and physical needs in the Sri Lankan context.

B. Research Aim and Objectives

This study aims to explore the contribution of environmental psychologically-physically friendly Architecture to developing skills, emotions, and mental statements of children with ASD as a part of institutionalizing the Autism Spectrum Disorder in Sri Lankan Society.

The objectives of the study are to;

- Identifying possible architectural approaches and design parameters through the relevant architectural theories and practices for designing for ASD
- Identifying the benefits and challenges of designing autism-friendly therapeutic spaces from case studies
- Exploring the impact of architecture on autistic children and possible design strategies for designing an autism-friendly learning environment for ASD in the context of Sri Lanka

C. Literature Review

1) Understanding Autism Spectrum Disorders:

Up to 2% of the global population has ASD. The exact number is hard to pin down, but millions of people are affected worldwide.

Autism is a neurological disability that causes by an outstanding brain abnormality in a person. Even though autism can diagnose at any age and it defines as a developmental disorder because the symptoms usually appear within the first two years of life. Although it can be a lifelong disorder, treatments and services can improve a person's symptoms and ability to function. (Health, 2018).

There is a wide variation in the type and severity of symptoms people experience. The spectrum identifies disorders from mild to severe, including Asperger Syndrome, Atypical Autism or Pervasive Developmental Disorder not otherwise specified (PDD-NOS), Childhood Disintegrative Disorder, and Autism Syndrome; who have some degree of social skills, empathy, communication, and flexible behaviours issues.

D. Sensory Processing

Typically, people receive information about a space based on all of their senses as a group: smell, sight, taste, sound, and touch. This ability is known as sensory integration/ sensory processing and is needed to achieve a clear perception of a situation and to decide how to respond. But people with ASD have deficits In sensory processing, due to the incompetence to process information from several senses at once.

Individuals with ASD are particularly sensitive to the surrounding environment, primarily because of sensory processing deficits. For many, sensory processing deficits, such as sensitive eyesight or hearing, can make the built environment a distracting and even frightening place. (Gaines, et al., 2016)

An American Psychologist Carl H. Delacato defines a range of three different sensory processing capabilities: Hyper-sensitive, hypo-sensitive, and interference. Just as the symptoms of autism vary across a spectrum, these different characteristics of processing can be arranged on a spectrum.

Hyper Sensitivity – sensory overloaded: Children with hyper-sensitivity are more susceptible to sensory information received because they are more sensitive to their physical environment than interference.

Hypo Sensitivity – sensory-seeking: individuals often create or generate their own sensory experiences for pleasure or to block other unpleasant stimuli. They need to be sensory overwhelmed or have more sensory stimuli to successfully process sensitive information.

E. ASD in Sri Lanka:

A 2009 study found an autism prevalence of 1.07%, affecting 1 in 93 children between 18 and 24 months. As the study only used a small sample size and global autism numbers are rising, the prevalence still today might be higher in any case.

Many individuals make out with ASD live in less developed countries such as Sri Lanka, where services to meet their needs are inadequate or non-existent.

In 2017, the Enable Lanka Foundation published an Autism Toolkit adapted to the Sri Lankan context and translated into Sinhala. But, there are not sufficient information materials in Sinhala and Tamil to create awareness and overcome the social stigma associated with special needs and disabilities.

Also, there is a lack of other resources, such as the availability of specialists in rural areas. And these families need to be empowered and build their capacities to meet at least a few of their children's needs.

There is also a disturbing lack of facilities and opportunities for adults with Autism. ASD does not cure or stop affecting people with the rise of age. Therefore, safe living facilities and employment opportunities for adults with special needs ought to implement in the country. Moreover, there is a need to develop culturally appropriate and sensitive screening and diagnostic tools to assist with more sensitive and accurate diagnoses. (Muttiah, 2015)

F. Autism and architecture:

Architecture is responsible for making environments that include the needs of all types of people. The specific needs of people should not be an exception. Though autism has a high prevalence, the instructions for developed architectural implementations become special in autism needs. (araghi, 2014)

However, today, other disabilities are obviated by converting the built environment into "accessible". Dianne Smith (2009) claims such when referring to people with certain cognitive, sensorial deficiencies and many disabilities which we determine to be "less visible". Among these, we can find people with ASD, for whom the supposition regarding how spaces are to be perceived and inhabited is far from a certainty and who, due to their deficits, sometimes have to make an enormous effort to be able to assimilate and understand the environment surrounding them, provoking a "blockage" as far as the composition of the surroundings is concerned, which in turn leads to a state of crisis.

Therefore, the architectural environment is a factor which directly affects those individuals with "less visible" deficiencies, as the architect John Jenkins confirms. (Humpreys, 2015)

In such theories, autistic behaviors are credited to a form of sensory malfunction when assimilating stimulatory information from the surrounding physical environment. It is the conceptual pivot of this research that the architect, through the design of this sensory environment, has control over the nature of this critical sensory input. By understanding the mechanisms of this disorder and consequent needs of the autistic user, this environment may design favorably to alter the sensory input and perhaps, modify the autistic behaviors, or at least create an environment conducive to skill development and learning. (Mostafa, 2008)

Architecture requires a filled physical interaction. Creating responsive, sensory environments like these—physical spaces that support increased mind-body connection, help develop skills, and expand social interaction—could be a powerful tool for dealing with ASD. (Mortice, 2016)

And the most important fact is that Architecture can address the needs of occupants with ASD. That is because buildings accommodate the needs of their occupants through spatial configuration, acoustics, lighting, temperature, air quality, furnishings and finishes. A common hypothesis in the literature is that modulating these features of the physical environment can help all occupants relax and focus. (Shell, et al., n.d.)

Architecture and interior spaces can be modified to positively influence the behavior individuals

with ASD often exhibit by modifying factors such as colour, texture, sense of closure, orientation, acoustics, ventilation, etc. (Mostafa, 2008)

G. Designing the Learning Environments for Children with ASD

Autism is not a “one size fits all” disorder; each boy and girl is different. It emphasizes that no two children with ASD have identical educational needs. (SDCAadmin, 2020)

But, in a recent survey conducted by Tech Learning (2015), “92% of teachers believe classroom design has an impact on student learning.” These teachers believe there is a direct link between classroom design and student performance and engagement. And the importance of designing schools where all students can achieve their highest level of potential despite any physical or mental limitations. (Architecture, n.d.)

H. Given guidelines and design approaches

Many architects professionally work for autism and do research related to providing guidelines for architectural spaces for autism-friendly learning environments.

Here are some significant studies where a scientific method of investigation seeking to analyze the architectural impact on autistic behaviors through the development of quantitative numerical data is employed.

1. In the studies by an Arch. Magda Mostafa in 2008,

- Soundproof spaces for speech practices give 'promising indications' of attention span, response time and behavioral character.
- Compartmentalized space creates 'separate defined zones' to help reduce distraction and improve productivity.
- Use of sensory zoning on behalf of functional zoning.
- The use of 'Universal' spaces can make children feel overwhelmed and unpredictable.
- Allowing circulation in one direction according to the daily schedule makes spaces legible.
- Providing a visible 'option to escape' positively influences children's behaviors.

2. In the studies by Sanchez, Vazquez and Serrano in 2011,

- Providing diffuse and natural lighting will reduce children's distractions from the light.
- The visual background also should be neutral and uncluttered as possible.
- Using durable fixings will limit the eventual manipulation.
- 'Snoozelin' rooms (multisensory stimulation spaces) can help children 'attune their sensory perception'.
- Using suitable colour coding or providing graphical cues to make spaces 'legible, predictable and imaginable' reduces the anxiety caused by the limited ability to speculate.

3. In a study by Kinnaer, Baumers and Heylighen in 2016,

- Using visual links with external features (e.g. landmarks) through openings helps their perception to recognize the order and understand the changes of the inside places.
- Every function needs a fixed place to minimize the lack of engagement.
- "Everything in its place" makes possessions on display.
- Using replaceable elements when needed (e.g. carpet, tiles) instead of fixed ones diminishes impersonal environments.
- The material environment should be predictable, comprehensible and controllable. Solid elements of buildings provide reassurance both physically and mentally.

- Stimulating sensory spaces and less stimulating escape spaces account for occurrences of hypo and hypersensitivity. Beneficial to be completely separate from the main area (perhaps on a slightly different level).

2. Methodology

This study runs through main three study methods; literature review, case study analysis and, analysis of interviews of purposeful sampling.

Literature Review **–** To understand the impact of the environment on their behavioral patterns and the intervention of architecture to derive specified architectural parameters.

Case Studies **–** To compare and analyze existing models with specific architectural parameters identified in the literature, and to understand the design conditions in schools for ASD in Sri Lanka to understand the architectural contribution to creating a therapeutic learning environment for school-age children with ASD.

Interviews **–** To further study the Sri Lankan context for the accuracy of the final discussion comprising the Sensory Symptoms against the environment of children with ASD in Sri Lanka and to understand the possible architectural applications to the realistic environment specifically about the Sri Lankan context.

In particular, were used to collect data from 15 caregivers who are directly in contact with the children with ASD,

- 3 Doctors
- 2 Therapists (speech therapists, physiotherapists)
- 7 specially trained teachers
- 3 Nurses

After studying much literature on relevant theories and sensory processing, the following parameters has identified as significantly influencing architectural aspects of designing therapeutic learning environments for children with ASD by responding to their unique sensory processing.

I. Location
II. Spatial Sequencing/ Organizing
    a. Zoning/ Layouts
    b. Transitions and legibility of building
III. Special Architectural Features
    a. Lighting (Natural /Artificial)
    b. Volume
    c. Colour scheme
    d. Openings
    e. Materials (Walls / Ceiling /Floor)
    f. Interior arrangements and Furniture
    g. Services and Installations
IV. Safety and Security
V. Recreational Spaces, Outdoor and landscape

3. Case Studies

International case studies: Under the discovered main architectural parameters, the Architectural and Spatial qualities of five international centres were studied. They are,

1. New Sturn autism centre
2. Eaden autism institute
3. Netly Autism Centre
4. Melisa Nellesen Center for Autism at UVU
5. Bancroft Raymond and Joanne Welsh Campus

After comparing each, the following features were identified as mutual features.

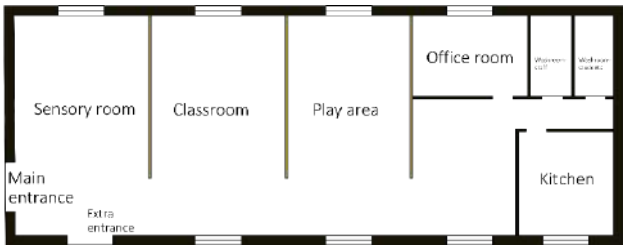

Figure 1. Plan: Autism Child Development Center
Source: Author

Table 1. Common features of all case studies

Parameter	Mutual Features
Location	Easy accessibility The strong connection with the natural environment Availability of open spaces
Spatial Sequencing/ Organizing	Legible simple layout Connected Spaces
Special Architectural Features	Simple, flexible furniture Enhanced volumes of spaces Colour use, white, grey, light greens, blues and browns Natural daylight in the buildings or mimicked natural light
Safety and Security	Building arrangements, orientations and layouts to create a naturally safe surrounding
Recreational Spaces, Outdoor and landscape	Provision for play spaces and sensory experiences.

Source: Author

Table 2. Summary of the local case study

Parameter	Feature
Location	An urban context
Spatial Sequencing/ Organizing	Simple layout, connected spaces, but not provided sufficient spaces
Special Architectural Features	Less furnishing classroom with flexible arrangements. Not any special feature
Safety and Security	Iron drills are used for all openings One way entrance
Recreational Spaces, Outdoor and landscape	Having an abounded playground with damaged equipment

Local case study: Autism Child Development Center, Maharagama. (The only government-run, educational therapy centre for children with ASD, Sri Lanka

4. Discussion

Research by psychologists, sociologists, and professionals, confirms that children with ASD have environmental adaptation challenges.

Often they have difficulties with understanding or adapting to spaces, and they face a continual struggle to adapt to build environments which take no notice of their neural abilities and sensory perceptions. In between their special

sensory processing, it becomes challenging and distracting.

They are sensitive to the environment they bump into and have difficulties processing the information they get.

A specially designed learning environment for autistic children begins with an understanding of the range of symptoms across the spectrum. These Architectural suggestions must support the person-environment relationship. And the designers must evaluate sensory reactions to the built environment

On the other hand, the literature has proven that many design considerations for a learning environment for autism spectrum disorders are good practices for all educational spaces.

A. Analysis of Interviews

This study has conducted an extensive interviews with some selected caregivers in two stages.

1) Interview Stage 1 – School-Aged Autistic Children in Sri Lanka

Many autistic children have unique sensory needs. Anything in their environment, whether built or natural, can easily influence attention, auditory input, visual input, and movements.

According to the three positions of the Autism Spectrum, their spatial requirements differ. But especially the children who can identify as belonging to the two ends of the Spectrum show significant reactions to the environment than others. Some of them have been mentioned many times in the interviews. Comparatively, literature findings on ASD and interviews with caregivers show that a child's sensory symptoms and behavioural patterns do not differ with the location but depend on the context interaction. Every child with ASD has exceptional strengths and capacities which need individualized and distinguished programming.

2) Interview Stage 2 – Current Architectural Contribution to Autism-Friendly Environments in Sri Lanka

The main challenge faced at the beginning of the study was the gap between architecture and autism services in Sri Lanka. The professionals who work for ASD have no idea about Architecture and what it could do for the physical and psychological well-being of an autistic child.

Many medical facilities or special educational facilities for children with special needs are designed using colourful themes, pictures, elements, and various play instruments preferred by other children but not autistics.

However, some changes can be seen that the professionals tried out autism centres' building interiors by themselves as per their experience with those children, without any knowledge of Architecture. Moreover, they have mentioned the presence of some aspects that are most needed but which could not adjust by themselves. Such as the building setting, spatial sequencing, escape spaces, naturally flow transitions and way findings, adaptive volumes, and selection of suitable building materials.

B. Analysis of Case Studies and Results of interviews

All selected international case studies are unique. They all came out as outcomes of ASD-based research designed buildings, considering to maximize the area of services they provide. Among them, many are award-winning centres for their significant architectural contribution.

However, in the local context, most existing autism centres are not autism-friendly designs. Most of these buildings are once used or houses located in an urban or suburban setting based on accessibility and distance to community resources ignoring soothing views and natural features.

While international case studies follow various retreat and recreational spaces, local autism centres were not encouraged to facilitate enough retreat and recreational spaces, even providing sound play areas.

In addition, clearly defined transitions and way findings are missing in these buildings compared with international case studies to navigate children to the classrooms.

As a plus point, some of the interiors of these local classrooms create some good conditions by using light colours and simple, light-

weighted, wooden or plastic furniture in suitable scales and less flexible arrangements.
But not especially concerned about acoustic solutions inside the classrooms. They also tried to take more intake of sunlight into the building. But non-using any indirect lighting technique or applications. That makes children bother by direct lights sometimes. Moreover, these classrooms were not concerned with enhancing or reducing the volume of spaces.
With their experiences, professionals know that the environment is one of the main things that impact these children's calmness and attention to commence treating, teaching or training them. Besides, the opposite is also there. The architects are not most aware of ASD. In addition to the Architects, many professional practices do not have enough awareness of ASD, even some medical-related professionals.

5. Conclusion

Autism spectrum disorder is developing worldwide due to several factors. A study led in Sri Lanka in 2009 described a prevalence of more than 1%. However, the Ministry of Health has not yet implemented a proper methodology to obtain accurate information to calculate the annual growth rate of autism in Sri Lanka. According to that, there is a lack of autism-friendly housing, urban and building environmental alternatives, and continuing education programs that cater for the needs of people with ASD.
After understanding the user perception and how to improve the spatial qualities of the educational environments for autistic children by bridging the gap between ASD-specific architectural requirements and the practice of architecture in Sri Lanka and after exploring precedents in developed countries, case-based fundamentals were derived through the study.
In comparison, those design approaches adopted in the Sri Lankan context proved not standard. Because presently, individuals with ASD are an unconsidered user group in the built environment in Sri Lanka due to their specific need for the built environment.
The challenges that children with ASD face can mediate through the assistance of specifically designed architecture. Or else, poor spatial planning will prevent those individuals from their self-esteem and achieving independence equal to every human while complicating their lives and having disfavors throughout life.
When designing for ASD, the architects and designers should understand that each individual has different sensory needs due to their behavioral patterns, besides architecturally addressing the needs of variance within the autistic spectrum. At every step of the design development process, the architect must consider how these uses can affect their senses, allowing children with hyper-sensitivity and hypo-sensitivity to educate in a space that is understandable and comfortable. Hence that design will allow them many opportunities to explore themselves. Because of the incorporation of architecturally designed space helps to maximize students' learning progress.
Finally, hope this study will inspire the community to understand how different people grasp spaces and encourage architects to develop the understanding and resources to go beyond designing internal flexibility and security objectives in the Sri Lankan context to create an architecture that suits such individuals.

Furthermore, Biophilic design, bio-inspired design, patterned complexity, reduced monochromatic environments, the potential of organic layouts and forms, and fractal patterning—organized complexity, to research further for creating autism-friendly architecture to get more advanced impact.

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Acknowledgment

This space takes to thank the following people, without whom not have been able to complete this research. Archt. Anjana Nawarathne, Archt. Niluka Lakmali and the Department of Architecture of General Sir John Kotelawala Defence University for their advice and cooperation in carrying out this research throughout the COVID pandemic.

Special thanks to the medical officers of Lady Ridgway Hospital for Children, Mrs Nandika Kodikara and the officers of the Ministry of Health Sri Lanka, Mrs Indrani Marambage and the officers of the Ministry of Education, HTN Fernando Physiotherapist in Revival physiotherapy center-Nawala and all professionals who assisted. And finally, express heartfelt gratitude to everyone who supported this study.

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Preventive Measures for Fire Accidents in Apartment Buildings in Sri Lanka

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Abstract*: Owing to the increasing population, lands have become scarce. Therefore, the prices of land also have increased. To address this issue people, tend to buy apartments than have their plots of land and construct a house. The height and complexity of these residential buildings may easily lead to fires and there will be property losses, injuries, and deaths every year worldwide. Mostly nowadays people are looking at the fire safety of all these apartments due to these incidents. The research aims to identify a better preventive measure for fire accidents in residential buildings in SL. An extensive Literature review was carried out to discover the current practice in worldwide fire prevention. This study was conducted using a Questionnaire survey with apartment building occupants to identify the fire safety measures currently practice in the SL context regarding the ICTAD fire regulations. Simultaneously, statistical data related to fire incidents in SL for the past few years and major reasons for SL apartment building fires were collected from the fire department. The collected data were analyzed based on three building height categories. From the findings, faulty wirings were identified as the major reason for apartment fires, most of the occupants are unaware of these regulations and some of the buildings are also not facilitated with required fire safety. Finally, it was highly recommended to conduct demonstration programs for public awareness and do practice the fire regulations.*

Keywords: *Apartment Buildings, Fire Regulations, High-Rise*

1. Introduction

The potential for an accidental or planned fire to endanger life, structural, and property safety in a building is referred to as a fire hazard in a building (Kodur et al., 2019a). Due to high population density and land values, high-rise and super-high-rise buildings have become increasingly popular as the urban economy develops (Liu et al., 2012). Along with their height, complicated structure, and numerous activities, high-rise structures are more likely to be caught fire (Nimlyat, 2017). Even a minor fire might be devastating if it spreads to the dwellings (Yatim, 2009).

In most residential complexes with many tenants, fires can result in higher injury or death owing to emergency evacuation complications (Shokouhi,2019). A high-rise building's vertical travel distance is also considerable, making evacuation more difficult (Ma & Guo, 2012).

Due to the extreme damage, it causes to buildings and infrastructure, fire can have severe consequences for human society. In relation, numerous people are killed or seriously injured as a result of fires (Shokouhi, 2019). According to the United States fire department, a fire breaks out in a residential area every 85 seconds, accounting for about 80% of all fire-related deaths. In London, fires in apartment buildings are responsible for 78 % caused by unintentional fires. Between 2007 and 2010, residential areas accounted for approximately 39% of all fires in China. (Shokouhi, 2020). According to surveys, at least 75% of fires are avoidable. (Shokouhi, 2019).

The Marco polo apartment fire (Honolulu), The Torch Tower fire (Dubai), and the Grenfell Tower fire (London) can be described as three

simply preventable fires. On June 14, 2017, a tragic fire broke out at the 24-story Grenfell Tower in west London, killing at least 80 people. The 86-story Torch Tower in Dubai caught fire for the 2nd time in 2 1/2 years on August 3, 2017. The fire started on the 26th story and quickly spread to the roof. According to reports, the tower's 38 flats and 64 outside levels were destroyed. The fire is said to have started when cigarette butts were thrown into a potted plant (Wieczorek, 2017).

The selected research topic is more important with the higher demand for residential buildings in Sri Lanka as well as worldwide. With better safety of the residential building environment, people will tend to buy apartment complexes than have their plots of land and construct houses. Since much research has been done on fire hazards in buildings only a few studies have been done on fire prevention and at the same time, only one has been found with a residential building's fire. That is one of the main significance of this research.

The research aims to suggest preventive measures for fire accidents in apartment buildings in Sri Lanka. Identifying the reasons for fires in residential buildings in Sri Lanka, the current situation in SL residential buildings fire prevention, the current situation in worldwide residential buildings fire prevention, and establishing fire preventive methods for residential buildings in SL are considered the pillars toward this aim.

2. Literature Review

With the rapid development of cities today, more and more multi-storied skyscrapers are rising to greater heights (Zhang, 2017). Complicated structures and high heights of buildings may result in more likely to catch fire (Nimlyat et al., 2017). In recent decades, residential building fires were on the upswing, and several incidents, casualties, and other fire indexes represent a higher percentage of overall fires (Zhou, 2017).

According to the statistical data of WHO, more than 300,000 deaths happen yearly, and more than 95% occur in low- and middle-income countries (Shokouhi et al., 2019). In accordance with the surveys 75% of fires are preventable (Shokouhi et al., 2019).

The Grenfell tower fire in west London, the Torch tower fire in Dubai, and the Marco Polo apartments in Honolulu can be identified as tragic residential fire incidents that happened in the recent decade and were identified as simply preventable fires. On June 14, 2017, the Grenfell Tower which consists of 24 stories experienced a tragic fire that broke out with a minimum number of 80 deaths. According to the reports, the source of the fire was a refrigerator on the fourth level and there were no automated fire sprinklers to keep the interior fire under control. The fire grew and spread to the external surfaces. When started, the highly flammable modern building cladding allowed the fire to quickly spread up and along and eventually throughout the whole structure (Wieczorek, 2017).

The existing fire preventive measures can be classified under four groups: general fire safety strategy, building regulations, and standards, building safety features, and firefighting operations (Kodur et al., 2019c).

A. Preventive Measures for Fire in Residential Buildings Taken by Worldwide

This fire prevention involves preventing the fire from starting, controlling extinguishing fires once they start, and preventing fires from spreading within a facility (Kironji, 2015; Benson, 2020). The fire prevention measures topic are included fire-safety furniture, fire-safety materials, fire resistance structures methods of escape, and methods of access (Chow, 2004). Buildings required firefighting equipment, fire detecting equipment (alarm systems), suppression (automatic s prinkler systems), fire protection and prevention systems (fire sand buckets, fire extinguishers, fire blankets, hydrants, horse reels, wet and dry risers) that are not mostly available in 3rd world countries (Murage, 2012; Kihila, 2017; Nestory, 2017). Fire preventive measures commonly used in worldwide residential buildings with

regard to fire alarms, detections sprinklers, etc... are listed out below respectively (Lamont, 2018)

Table1: Façade-related fire preventive measures used worldwide (Lamont, 2018)

Characteristicsof the building	**Construction**	**Concrete & structural steel**
The Protected mean of Evacuation &alert	Fire Alarms	Even though common pathways have a fire alarm system that can sound from all levels, it is known "stay put" if there is no "all out" fire alarm option where the alert sound in every condominium. This is since an alert in a common passage may go unnoticed by the apartment occupants. The establishment of a well-maintained fire alarm system, as the early discovery of fire, allows inhabitants to be noticed, allowing them to escape.
	Fire Detection	Automatic and manual detecting systems should lie within the structure.
	Height of the building	With the height, the preventive measures should vary as the height and the evacuation time is having a proportional relationship.
	Management	All the active and passive fire systems are to be maintained properly.
	Control of Smoke	Smoke controls should place on the evacuation routes to make the route clear from smoke.
Extinguishersand containment	Sprinkler system	These sprinklers should place throughout the building but not outdoors and on balconies and properly maintained.
	Fire access	The perimeter access should be with the building and easily accessible.

Furthermore, Passenger elevators cannot be used during a fire evacuation as it's frequently de-energized because of the fire. Due to that, elevators with specific equipment (capacity of at least 1000 kg) for rescue should be installed when developing high-rise structures (Poliakova & Grigoryan, 2018). Fire protection systems must be regularly maintained, inspected, and tested to remain operational (Kironji, 2015).

Table 2: Mandatory fire protection measures

Purpose Group	**Height**	**Portable Fire Extinguishers**	**Horse reels**	**Landing Valves**	**Sprinkler system**
1. Resi	Up to 18 m @floor area <800m^2	Relevant	Not Relevant		
	Up to 18m&floor area >800m^2	Relevant		Not Relevant	
1. (a)	18-30 m	Relevant			Not Relevant
	More than 30m	Relevant			
1. (b)	Up to 18m	Relevant	Not Relevant		
1. (c)	Floor area < 300 m^2	Not Relevant			

(*Colombo Municipal Council*, 2018)

B. Classifications and fire standards in Sri Lankan Residential Buildings

The Fire Department of SL has classified the residential buildings for the mandatory fire protection purposes

I.A.1 Purpose group classification

1. Residential (Dwelling)

1(a). Apartments or flats - multiple residencies in a single block of the complex that shared facilities.

1(b). A residential Unit- A flat with a single or many residencies in a single block of construction that exceeds 300m^2 / usable floor height from the ground that exceeds 6m but less than 18m

1(c). A single house is defined as a unit with a floor area of no more than 300m^2 and a usable floor height, of not more than 6m. (*Colombo Municipal Council*, n.d.)

Mandatory fire protection measures to be included in the proposed residential buildings in Sri Lanka by Fire Service Department (Colombo Municipal Council)

Table 3: Mandatory fire protection measures 2

(Colombo Municipal Council, 2018.)

Purpose Group	**Height**	**Manual call points**	**Fire Detection**	**Voice Examination**	**Fireman Communication**
1. Resi	Up to 18 m @floor area <800m^2	Not relevant			
	Up to 18m & floor area >800m^2	Relevant	Not relevant		
1. (a)	18-30 m	Relevant		Not relevant	
	More than 30m	Relevant			
1. (b)	Up to 18m	Not relevant			
1. (c)		Not relevant			

2. Methodology

This shows the pathway which was utilized to achieve the aim and objectives of the study. It describes the design approach, research methodology, and techniques used in data collection including analysis. Journal Articles, electrical publications, and e-books were referred to gather information on the specific study area for literature review. The data is gathered from Fire Department SL and the questionnaire survey was conducted with close-ended questions. The purpose of the questionnaire survey is to collect data regarding the practice of ICTAD fire regulations currently in SL high-rise residential buildings. Finally, the recommendations for issues in current fire regulation practice are discussed.

3. Research Findings and Analysis

This chapter aims to implement a well-structured quantitative analysis of the collected data. The Survey was based on the Fire Regulation codes published by ICTAD for buildings. The primary objective of the survey is to find out the fire preventive measures currently practice in SL residential buildings by the fire regulations. The survey was done using 35 people who live in Apartment buildings all over SL. It included 21 questions under 5 sections, the General Section (Apartment Location, Stories and no of Apartment units, etc.…), Means of Escape, Gas Installation, Fire Extinguishers, and Alarm system.

The following table shows the data collected from the Fire department for the fire incidents reported for the past five years and the major reasons.

Table 4: Fire incident report from 01.01.2015 to 31.12.2020

	BUILDING FIRES	APARTMENT FIRES	%
2015	113	14	12.5
2016	116	16	13
2017	122	19	16
2018	182	41	23
2019	152	26	17.5
2020	143	23	16.5

Faulty electric wiring, unawareness, ignorance, children's activities, gas leakages, and failure in electrical equipment can be identified as Major reasons for occurring Fires in Sri Lanka

A. Questionnaire Survey

Fire regulations published by ICTAD for Apartment Buildings are categorized based on the building heights. As it was not practicable to obtain the total building height from the occupants, the number of floors in each apartment was obtained and an assumption was made as the floor height is 3.5 m including slab thickness for the ease of data analysis.

Table 5: Building categorization based on no of floors

Height	No of Floors
Up to 18 m	5
18 m – 30 m Height	6 - 8floors
More than 30 m	9 story upwards

Each data was analyzed based on the above categorization.

1) Up to 18 m

From the responses for the General Section, none of them experienced a fire drill at the apartments. When considering the building location, 50% of the buildings are in bit-traffic areas, 33.33% and 16.67% are in high-traffic areas and non-traffic areas respectively. At the same time, 66.67% of the buildings have perimeter access. For the question of assembly points, 33.33% of the buildings do not have an emergency assembly point, 50% are on the ground floor and 16.67% are in Top floor.

Responses for the section "means of escape" derive that, only 33.33% of the buildings are equipped with sprinkler systems, and all the testing and maintenance are done once a year.

By ICTAD fire regulations each building should have at least consist of 2 staircases. Nevertheless, only 33.33% of the buildings are having 2 staircases and at the same time, only 16.67 % have more than 2 staircases. On the other hand, if the building is not sprinkled the maximum distance between the apartment and the staircase/s shall be 30 m. 33.33% of the buildings comply with this regulation and still, 33.34% is not. In the count of passenger lifts, 50% of the buildings in upto 18 m category are not facilitated with passenger lifts, with 33.33% and 16.67% having "less than 1000kg" and "more than 1000 kg" lifts respectively. Simultaneously fire doors are only provided with 33.33% of the building and from that, all are self-closing and opening in the direction of escape.

The findings for the section, installation of gas, described that all the buildings in this category only consist of individual cylinders, and according to the regulations if any building consists of individual cylinders shall place outside the building in an open area. The count for this question, for "no", was equal to the answer "yes".

Responses for the section, fire extinguishers, and alarm systems, illustrated that only 33.33% of the buildings are provided with fire alarms in common corridors, rest o66.67% of the buildings are not provided with fire alarms. "Yes", accounted for 16.67% of the count of hydraulic horse reels provided in the building, and all the horse reel cabinets are locked. At the same time, only 16.67% of the building provided Fire Extinguishers 1m above height as it is not mandatory with buildings up to 4 stories.

I.A.2 18 m – 30 m Height

The categorization findings for apartments with 6-8 floors are discussed below.

According to the general section, of the questionnaire "never" had the highest count of fire drill experience at 70%, followed by "once a year" at 20% and "once in 6 months" at 10%. 50%of the buildings are in bit traffic areas and 40% are in high-traffic areas. In the consideration of the building perimeter access, 70% accounted for "yes" for the count of building perimeter access. In the count of the emergency assembly points, for both "ground floor" and "no emergency point" was equal to 50%.

Under the Section, means of escape for the given 18m-30m height building category, 60% were not having sprinklers, which means they are not by the guidelines. All the frequency of testing and maintenance of the sprinkler systems accounted equally for never, once a month, and once a year 33.33%. At the same time, only 30% of the buildings are having two staircases and the rest 70% of the buildings consist of only one stairway. Only 50% of the unsprinklered buildings are designed with approximately 30 m travel distance according to the fire regulations and still, 10% are not. Less than 1000 kg, and 1000 kg or more than 1000 kg tied for the highest count of the capacity of the passenger lift/s with 40%, followed by no passenger lifts at 20%. In consideration of the fire doors, only 60% of the buildings have been provided with fire doors. Nevertheless, 33.37% are not self-closing and opening in the direction of escape.

In the consideration of LPG installation, 70% of the buildings have individual cylinders which is higher than the count of the centralized gas system at 30%. Nevertheless, only 14.29% of the individual cylinders placed in an open area on the exterior comply with the fire regulations.

Common corridors had the highest count of fire alarms and location at 50%, followed by no fire alarms at 40% and each apartment at 10%. On the other hand, only 60% of the buildings in this category have hydraulic horse reels and count for "is the horse reel cabinet locked?" Both "yes" and "No" accounted for 50% equally. In the consideration of fire extinguishers both "no fire extinguishers provided" and "one meter above floor level" was 50% equally.

I.A.3 More than 30 m

This is the final building category in the ICTAD Fire Regulations. According to the responses for the fire drill experience, 71.43% of the occupants had never experienced it, and 21.43% and 7.14% experienced it once a year and once in 6 months respectively. On the other hand, only 21.43% of apartments are located in non-traffic areas. The count of the building perimeter access, for "yes" (71.43%) was higher than "No" (28.57%). The count of emergency assembly points, "ground floor" had the highest count at 57.14%, followed by intermediate floors, top floors, and no emergency at 21.43%, 14.29%, and 7.14% respectively.

In the consideration of sprinkler systems 85.71% of the buildings are sprinkled which is mandatory for this building category. 58.33% of the sprinklers are tested and maintained once a year. Nevertheless, 25% accounted for "never" in the count of the frequency of testing and maintenance. At the same time, 42.86% of the

buildings consist of more than two staircases. 35.71% and 21.34% accounted for two stairways and only one stairway respectively. The maximum travel distance of apartments which are having one stairway is 14.29%

"1000 kg / more than 1000 kg" capacity lifts accounted for 78.57% which is mandatory for high-rise buildings for the safe evacuation in fire incidents and 7.14% of the buildings consist of both "less than 1000 kg "and "1000 kg / more than 1000 kg" capacity lifts. 92.86% provided with fire doors. Nevertheless, 7.69% of them are not self-closing and opening in the direction of escape.

Centralized gas systems accounted for 71.43% and only 28.57% of the buildings provided individual cylinders. Nevertheless, 25% of the individual cylinders are only placed in an open area on the exterior to comply with the fire regulations.

To the responses given, 71.43% of the buildings do have fire alarms in common corridors which is higher than the count of fire alarms in each apartment unit (21.43%), simultaneously 7.14% are yet there with no fire alarms. At the same time, all the buildings above the 30 m height category are equipped with hydraulic horse reels which are mandatory in ICTAD fire regulations. Nonetheless, 71.43% of the horse reel cabinets are locked. The count of Fire extinguishers and their location, one meter above floor level accounted for 78.57% and 5 m above floor level accounted for 14.49% respectively. At the same time, 7.14% of the building still do not equip with fire extinguishers

4. Conclusion

A. Up to 18 m

Occupants never experienced a fire drill. The majority of the buildings are not sprinklered (66.66%). Equally 33.33% of the buildings do not have emergency assembly points & perimeter access.50% of the buildings consist of only 1 stairway. 50% of the un-sprinkled buildings have more than 30 m travel distance. 50% & 33.33% of the buildings have no passenger lifts & less than 1000 kg lifts respectively. No Fire doors for 66.66% of the buildings. Only 50% of the individual gas cylinders are placed in an open area on the exterior. The majority of the buildings do not have Fire Alarms, Hydraulic horse reels as well as Fire extinguishers. Buildings are provided with a Hydraulic horse reel; all the cabinets are locked.

B. 18-30 m Height

70% never experienced a fire drill. No emergency assembly points & perimeter access for 50% & 30% respectively. 60% of the buildings are not sprinklered & 70% consist of only 1 stairway. 40% & 20% of the buildings have less than 1000kg & no passenger lifts respectively. 60% are not provided with fire doors & 33.33% of provided fire doors are not self-closing and opening in the direction of escape. Only 14.29% of the Individual cylinders are placed in an open area on the Exterior. Nor fire alarms & fire extinguishers for 40% & 50% of the buildings respectively. Hydraulic hose reel only provided with 60% and 50% of the cabinets are locked

C. More than 30 m Height

More than 70% never experienced a fire drill which is critical. 57.14% of the buildings are having emergency assembly points on the ground floor, 14.29% on the top floor, and 14.29% yet with no emergency assembly point. 28.57% do not have building perimeter access.14.29% of the buildings are not sprinklered & 25% of the sprinklered buildings, 25% are never tested or maintained. 21.43% responded to only one stairway. 14.49% of the buildings have less than 1000 kg passenger lifts. No fire doors for 7.14% & 7.69% of the provided fire doors are not self-closing and opening in the direction of escape. 28.57% are provided with Individual cylinders & only 25% of them are placed in an open area on the exterior. 7.14% are not provided with Fire Alarms & 71.43% are provided in Common corridors. No fire extinguishers are provided for 7.14% & 14.29% are provided with 5m above floor level. Although all the buildings provided Hydraulic

Horse reels 71.43% of the horse reel cabinets are locked.

Furthermore, according to the findings from the fire department, annual apartment building fires are also in a considerable range. Unawareness and the ignorance of the building occupants were identified as major reasons for the fire and it was further confirmed by most of the responses to the questionnaire survey.

5. Recommendation

Recommendations of the research can be summarised as follows;

- Fire drill practice is recommended once in 6 months or at least once a year which is not experienced in any day of some apartments.
- Apartment buildings are recommended to construct in bit traffic areas or no traffic areas with perimeter access for the easily accessible at an emergency of fire.
- The ground floor and top floor is recommended as emergency assembly points for buildings up to 18m & 18-30 m height category. If the emergency assembly point designed at the top level, it shall be easily assessable to the fire fighters. It is mandatory to design buildings more than 30 m with intermediate emergency assembly points as it is not practical to climb downall the stairs at an emergency and it is also important that all the occupants are aware on these assembly points which was found that some tenants are not aware on that.
- It is a mandatory requirement for all high-rise buildings to be equipped with sprinklers and recommended for testing and maintenance once a month (inspection maintenance) and once a year (mechanical and electricalmaintenance) respectively.
- According to the ICTAD Fire regulations, each building shall consist with of atleast 2 staircases. It is recommended for more than 2 stairways for the buildings with more height.
- If the building is not sprinklered the max travel distance to the stairways are recommended as apx 30 m and for the sprinklered buildings, it is apx 45 m. The passenger lifts are recommended with at least 1000 kg or more withspecial equipment.
- Fire doors which are self-closing and opening in the direction of escape are recommended each floor for all the high-rise residential buildings.
- Any building that consists of with more apartments will be required to install a centralized gas system.
- If the Individual cylinders are used it is recommended to place in an open area on the in exterior. Cylinders should not be located near exits, stairways or in areas normally used.
- It is recommended to have alarms in each condominium (all out fire alarm) than in common corridors (stay put) as the alarm sound in common corridors can be unnoticed by the apartment occupants.
- According to the mandatory requirements, it is highly recommended to equip all the buildings with portable fire extinguishers in 1m above floor level.
- It is highly recommended for buildings more than 18 m to equip with hydraulic horse reel at least one-horse reel on each floor and the horse reelcabinet should not be locked in emergency use.

❖ Since most of the occupants are un awarded on regulations and safety measures especially with building fire safety facilities it is recommended to have demonstration programs for public awareness for occupants.

This research was carried out about the current practice of ICTAD fire regulations in apartment buildings in SL to uncover unanswered questions by the researchers. Better fire preventive measures related to façade systems in SL, The selection of the most suitable fire safety design for high-rise residential buildings in SL can be recommended for further research

studies.

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Acknowledgment

I would like to express my deepest appreciation to all those who provided me with the possibility to complete this successfully.

I must indebt to the Fire Department who guided me to obtain data from the fire department. Other than that, I would like to thank all the participants who responded to my questionnaire survey.

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Investigating the potential of using an alternative finishing material for counter top construction as a cost-effective solution

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Abstract*: Current economic situation, material price hikes and shortage of materials have directly and indirectly caused an unprecedented price increment in finishing materials and the total cost of construction specially in the finishes stage. Therefore, finding alternative materials that are cost effective without sacrificing quality and appearance has become a vital need. With the popularization of open kitchen and open pantry concepts countertop construction has gained more attention in terms of aesthetics and appearance as well as the function. Thus, a research series was initiated with the aim of investigating the feasibility of the ferrocement as an alternative material for countertop construction while maintaining the intended appearance and functional requirements. The paper presents the findings of the initial stage of the research conducted to assess the cost effectiveness of the proposed alternative material prior to further experimentation on material development. An onsite experiment was carried out to construct a prototype countertop and check the feasibility of construction. Ferrocement panel with a dimensions of 1200mm X 600mm X 20 mm was cast for the study. Epoxy coating was applied on ferrocement body to achieve desired water absorption rate and aesthetic appearance of the final product. Since the prototype construction was successful a cost comparison was conducted. The total production cost was calculated and compared with same size conventional granite countertop construction. Accordingly, sq.ft rate of ferrocement countertop was calculated to be Rs. 1536.08. Results showed that 41.7% cost saving could be achieved while keeping the desired aesthetical qualities and water absorption limits. This could be a feasible alternative for countertop construction in Sri Lanka.*

Keywords: *Countertops, Ferrocement, Cost effective materials*

1. Introduction

Construction is one of the major industries in Sri Lanka which directly accounts for the overall economic development of the country while providing numerous direct and indirect job opportunities. However, due to the current economic crisis and depreciation of currency the construction industry has been heavily disturbed by the price hike as well as shortage of materials. Observations clearly depicts a sharp drop in projects and job opportunities due to the prevailing energy and fuel shortage, rise of raw material price as well. In such a context, it is vital to rethink how to approach the industry and find solutions to deal with such challenging shifts. Finding alternative cost-effective materials can be identified as a remedial action to overcome the material shortage and the price hike.

Opara (1999) defines a material as a blend of processed or un-processed materials or compounds utilized in engineering construction including timber, sand, cement, gravel, graniter etc. In construction, cost of these materials is identified as a major contributor to the total cost (Ayeni, 1986, Wahab, 1996 and Ene, 1997). Cost effectiveness in construction is a concept that is related to budgeting and aims to cut off construction costs by proper utilization of locally available materials, managing skills and technology better without giving up the quality or durability (Tiwari *et al.*, 1999). As Miles

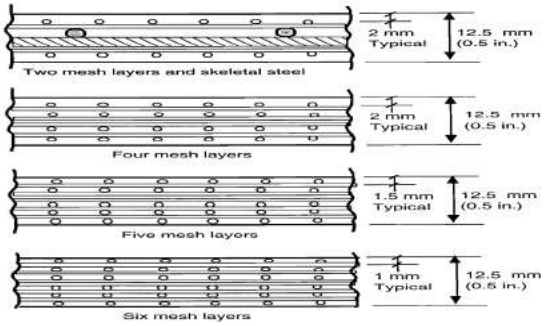

Figure 1: Typical cross section of ferrocement
Source: Naaman (2000)

(2000) states, effective use of locally available materials and techniques which are economical, durable, acceptable and low maintenance leads to achieving cost reduction in construction. Further, research findings highlight that effective budgeting, improved techniques and skills contribute to cost reduction without any damage to the material performance or life time of materials (Kumar, 1999; Civil Engineering Portal, 2008).

The finishes of a construction project costs a considerable percentage of the total costs. However, quality and the appearance of the finishes have a greater contribution to the overall end product. Therefore, designers as well the clients always have a high concern about the finishes of a building project. Finishes of a building ensure the aesthetics, taste and comfort and by utilizing different materials. In current context where construction costs have hiked in greater percentage reducing the costs for finishes while maintaining the quality and appearance is vital. Therefore, experimenting alternative finishes is needed.

Ferrocement construction technology is not a new concept in the industry. Commonly, ferrocement is used as a thin element in construction and also as a repair material. Apart from these common applications as structural and form making, architectural applications such as building elements with attractive and rich surface finishes have been put in to practice in different design applications as observed through magazines, case studies and etc. However, research evidence on such applications and their long term feasibility, cost, application process and development are not available.

With this need an experimental research was initiated with the aim of investigating ferrocement as an alternative material for countertop construction. As the first step, the cost of the proposed alternative material was investigated prior to further investigations. The paper presents the findings of the initial stage conducted to investigate the cost effectiveness of ferrocement as an alternative worktop construction material in the construction industry.

A. Ferrocement as a construction material

With the current need of finding materials that are fit for the purpose and cost effective, ferrocement is identified as such material which is slender and slim while the same time being elegant and strong (Divekar, 2011). Ferrocement is investigated as an alternative building material for prestressed concrete, RCC, stone, steel, brick, , timber and structural components such as slabs,columns, floors, roofs, water and soil retaining wall structures and roofs. Further, ferrocement is also used for applications such as shutters, doors and windows (Divekar, 2011, 2011a,b,c). Moreover, the studies on ferrocement reveal the possibility of the material being formed into different shapes or structural configuration which cannot be achieved with RCC, standard masonry or steel (RoblesAustriaco, 2006; Dongyen et al., 2006; Kondraivendhan & Pradhan, 2009).

There are numerous structures made out of ferrocement such as houses, shell roofs, water tanks, swimming pools, storage units for food, biogas digesters, silo, and etc. Also, in situations such as floating marine structures where RCC is heavy, ferrocement is used as an alternative (Hago et al., 2005; Naaman, 2000; Abasolo et al., 2009). Research conducted on ferrocement applications has proved that when compared to similar constructions using steel, reinforced cement concrete, steel or fiberglass use of ferrocement is cost effective (Sharma et al.

1979; Report JABE-ARC-07, 1976; Ferro 10 Information).

Being a thin construction element ferrocement thickness can be achieved to be 10-25mm. It consists of rich cement mortar with no coarse aggregate. One or several small diameter steel wire or mesh is used as reinforcement in ferrocement construction. As depicted in Ferro 7 (2001), ferrocement does not require high skilled labor for casting and require less or no formwork. Further, as the reinforcement which is below the surface takes over the cracking forces the cement matrix is resistant to cracking (Desai, 2011). Due to these properties and behavior and the uniqueness and versality ferrocement construction has become very popular in many countries like USA, UK, Canada, Australia, Mexico, New Zealand and etc. as well as in developing countries.

B. *Experimenting ferrocement as the worktop material*

Shortage of essential building construction materials such as ceramic tiles, granite, high increase in material cost has made an opportunity for sustainable and economical alternatives. Use of ferrocement for different architectural applications and elements can be experimented. However, countertops are a common feature in almost all the residential and commercial projects which is considered as a vital element in interiors in terms of functional purposes as well as aesthetical appearance. Therefore, the research scope was limited to application of ferrocement as countertop material for this specific study.

Granite, timber, ceramic tiles, timber, cut cement finished concrete are few of common materials used for worktop construction. Based on the current market trends and the opinion of designers as well as clients, granite is the most popular building material used for countertop construction in Sri Lankan residential building. Granite finish has replaced tiled surface of counter tops due to lower maintenance, ease of installation, high strength and durability, lower water absorption (0.05% to 0.40%), and scratch resistance. Resistance to stains and the excellent moisture repellent quality as well as the high heat resistance makes it more appropriate material for the countertop finish. The ability to create seamless counter tops with continuous surface is beneficial in avoiding staining and food seepage compared to tile surface which is hygienic than the tiled surfaces. Due to the rich outlook and the timeless appearance of the granite finish, the attraction towards granite as the finishing material has remained high. Granite can be well polished to achieve a rich surface texture due to its igneous property.

Due to its properties by today, granite has become one of the most preferred countertop finish materials which also depicts an ultimate status and style symbol in the kitchen. Further, granite facilitates creating beveled or bullnose finish on the horizontal edges if required. Among the available surface finish texture of granite countertops, polished finish is the most commonly used granite finish option. However, with the prevailing situation in the country granite has become a highly expensive countertop finishing material.

The research was initiated with the aim of investigating the potential of using ferrocement as the countertop finishing material as an alternative material which has the desired qualities and the aesthetical appearance of the highly preferred granite material. Therefore, the purpose was to find the feasibility of architectural applications of the proposed alternative material.

Since ferrocement technology facilitates the construction of complex curvatures, architects are given the freedom to try out different forms. However, apart from such form making options, the use of ferrocement as a finish material has been rarely explored. Based on the properties of ferrocement and its practical applications it was observed that this could be used as an alternative to replace the expensive granite material as the counter top finish material. The thickness, cracking behavior and specially the

resistance to biological agents such as vermin or fungus makes ferrocement an ideal alternative for countertop finish material.

As discussed earlier the mural joints, rife and grains in granite enables the material to be finished as larger slabs with less thickness. Similarly homogeneous reinforce arrangement of the ferrocement
allows casting of precast slabs with small thicknes in an affordable price. Due to the nature of the mineral comprising of stone, granite is a highly polishable material which makes popular as countertop material with less maintenance requirement as the polished surface resist stain penetration. Eventhough ferrocement doesn't inherit superior polishing quality it can be improved by adding a cement rendering layer on top of the ferrocement body ultimately achieving the desired finish.

Granite naturally inherit variety of colours and patterns due to its hardening process which involves combining of various sources of molten lava.Alternatively, to achieve the
desired architectural appearance when ferrocement is used, colour pigments can be added to the cement rendering layer. Granite has a significantly lower water absorption rate (0.1% - 0.4%). Though compared to granite ferrocement's water repellent quality is lower it is no exception as it is also used for construction of water tanks and boats due to its low water absorption. However, application of an epoxy sealer as the top coat of the finished product can heighten the water repellent quality of ferrocement while at the same time enhancing the glossy finish of the final product.

2. Methodology

The research was designed as an on-site investigation with field and lab testing to develop a worktop with the intended ferrocement finish. Titanium Oxide and Iron Oxide were added as colour pigments for the particular study. As the first step a cost comparison was done to identify the potential cost effectiveness of the proposed ferrocement counter top finish. A prototype model worktop in the size of 600mm X 600mm X 25mm was constructed on site to calculate the unit rates of the construction. The mortar composition was maintained as cement; sand: water proportion

WIRE-MESH REINFORCEMENT	• Wire Diameter: • Type of Mesh: • Size of Mesh Openings: • Number of Mesh Layers: • Volume Fraction of Reinforcement • Specific Surface of Reinforcement	• $0.5 \leq d_w$ 1.5 mm; $(0.020 \leq d_w \leq 0.062$ in.) • Square woven or welded galvanized wore mesh; aviary (chicken) wire mesh; or expanded metal mesh • $6 \leq D \leq 25$mm $(1/4 \leq D \leq 1$ in.) • Up to 6 layers per cm of thickness (Up to 14 layers per in. of thickness) • Up to 8% in both directions corresponding to up to 630 kg/m³ (40 lb. per ft³) of steel mesh reinforcement. • Up to 4 cm²/cm³ in both directions (up to 10 in.²/in.³ in both directions)
INTERMEDIATE SKELETAL REINFORCEMENT	• Type: • Diameter: • Grid Size: Skeletal reinforcement not always present	• Wires; wire fabric, rods; strands • $3 \leq d_b \leq 10$ mm; (1/8 to 3/8 in.) • $5 \leq G \leq 15$ cm; $(2 \leq G \leq 8$ in.)
TYPICAL MORTAR COMPOSITION	• Portland cement: • Sand -to-Cement Ratio: • Water-to-Cement Ratio: • Recommendations:	• Any type depending on application • $1 \leq S/C \leq 2.5$ by weight • $0.35 \leq W/C \leq 0.6$ by weight • Fine sand all passing U.S. sieve No. 16 (1.5 mm) and having 5% by weight passing No. 100 (0.25 mm), with a continuous grading curve in-between. • Additives: (Fly Ash / C) = 0.2 Air entraining agent; Corrosion inhibitor; Water reducing agent, or Superplasticizer, as needed.
COMPOSITE PROPERTIES	• Thickness: • Steel Cover: • Ultimate Tensile Strength: • Allowable Tensile Strength: • Modulus of Rupture: • Ratio	• $6 \leq h \leq 50$ mm; $(1/4 \leq h \leq 2$ in.) [mostly < 30mm] • $1.5 \leq$ cover ≤ 3 mm; $(1/16 \leq$ cover $\leq 1/8$ in.) • Up to 35 MPa (5,000 psi) • Up to 14 MPa (2,000 psi) • Up to 70 MPa (10,000 psi) • From 2 to 2.5

Figure 2: Properties of ferrocement
Source: Naaman (2000)

in 1.5:2.5 ratio. Sand particles less than 2mm was used and a water proofing admixture was added.

Formwork was made with 12.5 mm thick Marein plywood sheets. Portland cement and sand were used as the cement-based Matrix. Sand cement were proportioned by weighting (1.5:2.5) for the dry mix and then it was mixed with water using mechanical mixing. Square type steel mesh with 3mm mesh opening size, was used as reinforce structure. Three layers of mesh reinforcement was placed in the cement matrix. The volume of the reinforcement (volume fraction) is 4- 8 % in both directions ensuring homogeneous reinforcing structure.

Compaction was done by beating the mortar with a trowel. Cement slab was kept for four days for curing prior to removing the formwork. After the curing time, Cement /titanium rendered finish with colour pigments were applied on all the faces and edges of the slab to get the desired architectural finish. Slab was for kept two days for drying after sanding. Finally, a clear epoxy coating was applied using a roller to get the final finish. Based on cost of the prototype countertop slab construction the cost analysis and the cost comparison were conducted considering a countertop finish of 600mm x 3000mm x 20mm counter top slab.

3. Reuslts and Discussion

Based on the costs incurred for the prototype ferrocement countertop slab construction, cost for a typical countertop and sq.ft rate for construction was calculated.Cost calculation is conducted according to the below Table 1. Since cost calculation was conducted to compare the construction cost of ferrocement countertop with the cost of typical granite counter top construction. Since both the material are pre-fabricated and transported the transportation costs were not considered for the comparison.

Based on the cost analysis, approximate cost for the construction of ferrocement countertop with the dimensions of 600x300x 20mm is Rs. 18,433.00. Therefore, the per square foot rate is calculated as Rs. 1536.08. As per the current market rate, granite countertop construction cost per sq. ft rate varies from Rs.3000 – 4000 upwards where local granite countertop cost varies between Rs. 3000 – 3400 and imported granite countertop cost varies from Rs. 3600-4000 upwards.

Accordingly if average cost of granite countertop is taken as Rs. 3500 and ferrocement countertop is taken as Rs. 1540, the cost saving percentage with the alternative material application is calculated as 41.7%. Therefore, based on the calculations it is evident that the developed ferrocement countertop construction cost is significantly lower than granite countertop construction.

Table 1: Ferrocement countertop construction – cost calculation

Concrete 1 1/2:2 1/2 (Cement: Sand)		**12 sq. Ft**			
	Cost type	**Qty**	**Unit of measure**	**Total cost (Rs)**	**Cost per sq. Ft (Rs)**
1.0	**MIXING Cost**				
a	Materials				
b	Cement	0.25	bags	3,200.00	800.00
c	Sand	0.007	Cube	23,000.00	161.00
d	Water	15.00	gal	1.00	15.00
e	Net (2-0" x 6'-0") X 4	36	sq. Ft.	170.00	6,200.00
f	formwork Plywood board (8'x4')	0.50	no	3,500.00	1750.00
					8926.00
2.0	**LABOUR Cost**				

a	Un / skilled Labour	1.00	day	2,500.00	3,000.00
					3000.00
	Cost 12Sqft (mixing only)				**11,926.00**
	Add				
b	3% of Cost for tools				357.00
3.0	**CURING**				
a	Water	100.00	gal.	0.50	50.00
b	Un / skilled Labour	0.04	day	2,500.00	100.00
					12283.00
4.0	**FINISH**				
a	Cement rendered Titanium finish	12.5	sq. Ft	300.00	3,750.00
b	Epoxy Finish	12.5	sq. Ft	200.00	2400.00
	Cost for 12 sq. Ft slab				18433.00
	Sq. Ft rate for finish product				**1536.08**

According to the market observations among the available countertop finishing materials, granite has obtained more popularity as a luxury finishing material in local market due to its appearance and high quality. Based on the observation in practical applications it has been identified that when using local granite, due to the iron contained in the stone, when contact with oxygen and water for longer time it generate iron oxide (rust) which causes scaling and discoloration. Therefore most countertop projects are done with imported granite slabs. In this regard, rather than importing finished products, introduced ferrocement precast slab can be easily manufactured locally with imported raw materials which is more cost effective and a good alternative for material shortage in sri lanka.

However, the imported granite slabs have a variety of color variations and patterns. Therefore, further experiments needed to be conducted with different pigment combinations to achieve colour and variation in the proposed ferrocement pre cast countertop construction. Further, comparatively to other raw materials steel price is high for ferrocement construction. Therefore, introducing natural fiber instead of steel reinforcement can be a good alternative. Further research can be conducted on natural fiber reinforcement as well.

Findings suggests ferrocement as an ideal alternative material to countertop construction in terms of cost effectiveness. However, further research is needed on the properties, structural feasibility and long term application to promote the proposed material as a feasible alternative countertop material. Also, experimental studies need to be conducted to get better aesthetical appearance (eg- Mixing of colour pigment powder and in a liquid form together).

4. Conclusion

At a time when solutions should be found to address the challenging situations in construction industry the research was initiated as an experimental study to find alternative finishing materials for countertop construction. The paper presented the results of the initial step of the research conducted to investigate the economic feasibility and the cost effectiveness of the proposed alternative material compared to the cost of the countertop material most preffered in the market as a luxury and high quality material.

Ferrocement was identified as a potential alternative and therefore an onsite experiment was carried out to construct a prototype countertop and check the feasibility of construction. Since the prototype construction was successful and demonstrated the potetial for further development it was decided to conduct a cost comparison to confirm the cost effectiveness prior to advancing with the research. The paper presented the outcome of the cost comparison which confirmed the cost effectiveness of the proposed material intervention. Therefore, it can be assumed that ferrocement can be used as an alternative material to countertop construction which is a cost effective approach. Further testing should be conducted to identify the properties, structural feasibility and long term application prior to promoting the proposed material as a feasible alternative countertop material.

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The Impact of Urban Morphological Transformation on Legibility of Old Neighbourhoods; with special reference to old Colombo – Kandy Main Road in Mawanella

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Abstract: *Mawanella is a small suburb in Sri Lanka, has been developed as a transitional town since the colonial period. The historical layers of the town were reflected as traditional buildings on either side of old Colombo- Kandy main road. The development of road widening projects was carrying drastic changes to the existing urban form and many of old settlements were erased by uncontrollable development, practiced during the last 20 years. The study explores how the gradual changes in urban morphology impact on legibility of older neighbourhoods, considering Mawanella as a model case. Literature review synthesized the parameters such as pattern of urban morphology, serial vision along the main artery and the façade articulation to study the transformation of the city form. The methodology was adopted to identify the aspects that are contribute to the city's identity, how the urban morphology has been transformed over the last 20 years and how it impacts on city legibility through visual survey and a perception study. The research confirmed that people were strongly attached with the old city elements and the unique morphology of the old neighbourhood which were visually and physically contribute to achieve the city legibility though currently it was unable to gain through the modernized environment. The outcomes of the study were formed as an urban design toolkit, to be used for future developments of the older neighbourhoods.*

Keywords*: Urban transformation, Morphology, Urban grain, Serial vision, Perception, Urban form, old neighborhoods, Legibility*

1. Introduction

A city can be configured in various ways, such as spatially, contextually, visually, perceptually, socially, functionally, and morphologically (Carmona, et al., 2003). Basically, the urban morphology can be referred as the study of 'urban form' (Cowan, 2005) or the study of the form of human settlements, as well as the process of their formation and the transformation. In addition, urban sprawl, growth pattern and rapid developments are heavily influencing issues on the urban form. Urban form is a result of a patchwork in which different features are stitched together and a coexistence of different features, each of which belongs to a clearly identifiable interpretation of city form. Lynch (1981) recorded that, "Urban form comprised of visual images of the cities, experiences, feelings, memories of place, thoughts and intellectual constructs anchored in the realm of art and humanities". An urban form usually comprises with regions, cities, streets, neighbourhoods, or blocks. Neighbourhoods are combined with different social communities and spatially specified to geographical areas (Schuck & Rosenbuam, 2006). The morphological study helps to understand the spatial structure and the character of the metropolitan area, city, town and village by examining the patterns of its components, the process of its development at different scale. In addition, the morphological analysis gives special attention on how the city form changing over time. Usually, cartographic sources such as maps used to study the morphological transformation. On the other hand, as a subfield study, it was helping to understand the social form through the physical

layout of the city which are expressing how the physical forms contribute to produce or reproduce the various social forms. (Carmona, et al., 2003) (Seçmen & Makaklı , 2019).

Mawanella is an older neighbourhood of Sri Lanka, developed as a transitional town since colonial period. Its historical layers were reflected as traditional buildings on either side of old Colombo- Kandy main road. The development of road widening projects were caused drastic changes to the existing urban form and many of old settlements were erased by uncontrollable development which has been taken place during last 20 years. However, it was observed that the lack of focus on fading characters of the traditional urban setting, is leading to negatively effect on particular spatial qualities while unable to fulfilling the essential urban needs. Not only Mawanella, but there are also many old neighbourhoods in Sri Lanka where slowly eroding the identities of the unique urban characters due to current haphazard developments. The unguided development plans were resulted in transformation of urban form caused to change the morphological characters of the cityscape. Thereby it effects on the legibility of the city (Behzadfar & Saneei , 2012). Lynch, (1981) mentioned the same issue in another perspective that whenever the city elements lose or changing their character, the particular setting has been changed and the result is reducing the legibility of the space. Hence, there is a profound need to investigate the impact of morphological transformation on legibility of such older neighbourhoods. Because the vitality of rethinking on how to mitigate such issues to create a legible city and how to develop cities with the minimal impact on its characters are important questions to be resolved in urban planning. Mawanella is a transitional point and the main gateway to the hill country since colonial period. When the British built the Colombo – Kandy main road as a trade path, a mix of commercial, residential, and linear settlements built along the road. Old settlements on either side of the Colombo - Kandy main road (Bazaar Street) brought a unique meaning to the city though current city developments which have been practiced during the last 20-years, impacted on many traditional built structures. Some built masses are newly appeared, and some have disappeared from the city form, by interfering haphazard developments. Thus, there is a question aroused how this morphological transformation affect for the legibility of the Mawanaella town. 'Legibility' is a physical and a spatial quality which making the city as graspable and its important at two different levels; physical form and activity pattern (Alcock, et al., 1985). The combination of these two levels is contributing to provide a clear sense of the environment to its users. Awareness of these two must complement one another. The legibility of the city can be formed as an individual element or as a whole (Lynch, 1960). However, it is urge to understand how the urban morphological transformation occurred in Mawanella during last 20 years to analyse how it affected on legibility of the old neighbourhood.

2. Literature Review

The 'urban morphological transformation" can be studied through urban morphological analysis which used to study present and past conditions of the urban structure, form, land use and pattern. At different scales, including individual buildings, lots, street patterns, and blocks, explains the existing physical form and structure of the urban environment (Environment, 2006). Further, changing patterns of the urban morphology represented by, urban grain, building footprint, building orientation, land use pattern and other special qualities such as serial vision and facade articulation (Seçmen & Makaklı , 2019) (Liombo , 2012). According to Montgomery, (1998) successful cities are in part shaped by the relationship of built form to space, and the range, variety, and characteristics of the spaces. The Urban granularity divided the city into particular sizes of lots. Therefore the 'grain' describes as something made up with smaller particles and being a key element of hierarchy of urban form. Rooney & Houlston, (2017)

stated that the 'grain' represents the arrangement or pattern of the buildings and streets within the built form and forming as fine or course, formal or informal, linear, blocky, planned, structured or unstructured. The concept of urban grain has been applied mainly to understand the aspects of the physical form (Norton , 2016). The urban grain divided into two; fine grain and coarse grain relating to the way they perform the fineness, in the urban grain. The dominance of small plots within an urban block can be describe as a 'fine grain' (Norton , 2016). Fine grains are usually characterized by similar elements and functions are widely dispersed throughout the area without forming any large clusters. Norton, (2016) was summarizing the benefits of well-organized fine grain pattern, providing greater mix of use, greater mix of ownership, greater mix of business, enhanced streetscape, and enhanced street life. Montgomery, (1998) stated that traditional European cities are relatively dense and fine-grained. Coarse grains are given dominance to one or relatively few, medium or large-scale plots in a block. Usually, 'fine grain' indexes a vital physical condition for a good city form (Montgomery , 1998). As explained by Haughton and Hunter, (1994) transformation of urban grain of cities occurred significant changes in urban form in 20th century. In addition, the trend of lump developments caused the damages of the traditional urban grain (Tibbalds, 1992). However, there are traditional cities still remaining as a part of modern urban context; 'Salem' is one of traditional city work in the grain and fine old buildings are preserved and reused (Whyte, n.d.)

Warren & Andrew, (2021) explains that 'building footprint' also a metric that used to understand different spatial scales and spatial representations of a city. Further, 'building orientation' of a city helps to enhance the 'image-ability' of the city ((Lynch, 1960). Well-oriented places and buildings are providing sense of emotional security and well-ordered, organized environments making harmonious relationship between people and the outside. Visual elements are important inputs for the morphological analysis of a city (Black, 2020). Hoosgrahar, (2015) stated that visual elements can be classified as their height, volume, geometry, materials, shape, location, elevation, architectural features, function, roof form, fenestrations, and other features. 'Serial Vision' is a visual approach of a moving person's perspectives. This visual experience can be represented as series of hand drawn sketches. The aim of presenting is to express an informative illustration of spaces and it provides a sequence of revelations throughout the journey (Cullen, 1961). This method contributes to explore the transformation of the space from traditional to modern, pressure to vacuum or public to semi-public (Black, 2020). Further, street façades and elevations are one of the important visual elements helps to study city morphology (Rooney & Houlston, 2017). Hoosgrahar, (2015) has stated that 'street elevations' are kind of visual documentation and representing intervention, restoration, or re-functioning of the buildings. Classification of buildings of a street elevation are based on their language, visual elements, or the typology. These important tools can be forming as; 1) dimensions of the façade (ex: The dimensions are mainly focusing on the width of the façade and number of stories of the building) (Seçmen & Makaklı , 2019) 2) building edge (ex; Identity of the building fronts can be defined by the building edge and sometime it is the most active place.) (Alcock, et al., 1985) and 3) skyline (ex: Profile of built form and land defined against the sky. Sometimes referred to as silhouette.) (Rooney & Houlston, 2017). Distinctive skylines are essential aspects of visual identity of a city and it helps to form an iconic image. On the other hand, the changing skyline act as a dynamic visual artefact, which provide a detail guidance about how the city was evolved, influences at different period of times. Thus, the literature evidenced that all the important morphological features are described above supporting to ensure the legibility of a town or a city (Lynch, 1960).

As explained by Lynch, (1960) the vitality of legibility always offered an ordered environment and serve broad frame of references. It is providing sense of emotional security that can establish a harmonious relationship between human and the outside world, avoiding fear that comes with disorientation. That means a legible environment not only provides security but also heightens the potential depth and intensity of human experience. Further Lynch, (1960) highlighted that legibility is one of visual quality of the cityscape that visually grasped as a related pattern of recognized symbols. As well as they are consisting with easily identifiable, paths, nodes, or districts. The human experience and user perception was based on the environment and physical cues, or elements represented in the mind and the image can be describe as individual personal experience of physical elements of particular urban setting.

Thus, the research focuses on small old neighbourhoods of local context which are influenced by uncontrollable developments. Because the lack of concern may cause erasing historical layers and this attempt is to understand the morphological characters of the traditional city and how current deviations impact on the spatial qualities of the city form. Furthermore, this study identifies how older neighborhoods contribute to create legible environments. Further, the findings of the study can be used as a toolkit of urban design to be applied while doing future developments on old neighboruhoods. Addressing the main issue; the impact of morphological transformation on legibility, especially for small older neighborhoods like Mawanella, will be fulfilled the research lacking on urban design. Therefore, the research objectives are set as follows; 1) To identifying the morphological transformation that take place in case study area (The settlements along old Colombo – Kandy Road in Mawanella), 2) To understand how the city elements were adapted to morphological changes over last 20 years and 3) To identify how morphological changes influencing the legibility of study area (The settlements along old Colombo – Kandy Road in Mawanella).

To achieve the said objectives the research methodology was adopted basically focusing on the patterns of urban form, serial vision, and the facade articulation. The study area is limited to the settlement on either side of the old Colombo- Kandy main road of Mawanella. As a linear city most of traditional built masses tend to densify along the road. Therefore, to simplify the analysis, the whole study area was broken into 03 blocks, a linear stretch along the road. Each block is approximately 500m lengthier and the width of a block extend to 50m from the road edge. Due to Covid-19 pandemic situation, it was limited to interact with the user to get their perceptions.

3. Research Methodology

'Morphology' is a study of change in form and shape overtime. Therefore, the study was focusing on the urban pattern and the composition. Through the literature review, the list of parameters was synthesized to understand the changing urban pattern and composition of Mawanella over last 20 years (2000-2020) and to analyse the user perceptions on the changing city attributes and how it impacts on city.

List of Identified parameters of urban Morphology was studied through the visual survey and the perception study as shown in Figure 2 such as; 1)**Urban patterns** (Urban grain, Building Footprint, Building Orientation), 2) **Serial vision along main artery** (City elements within the studying Boundaries, the relative width of street, horizontal and vertical components, symbolic direction with its image and function), 3) **Façade articulation** (Architectural features, Scale and proportion, Dimensions of the façades, Skyline and Building edge)

1. Justification for the study area

Old Colombo- Kandy main road of Mawanella, was used as the model case study (Figure 1). Here the main focus was given on the

transformation of built patterns and composition of the selected town area. It supports to identify the morphological transformation which represents via buildings, streets and the physical layout of the case study area.

Figure 1. Case study area (old Colombo-Kandy Road)

(Source: Google Earth)

2. Data Collection tool

*1)*Maps: Maps were sourced by Sri Lanka survey department, google earth and the author. The transformation of urban grain, building orientation and building footprint was studied by evaluating figure ground maps of years 2000 and 2020. For the analysis, it was introduced special grading matrix and colour coding system for the urban grain and the building footprint. In respect to the literature review (Carmona, et al., 2003) and the evaluation of maps, it was identified that there are six (06) number of buildings within a 400 sq.m area to become a 'fine grain' setting and if number of buildings are less than three (03), the grain defines as 'coarse' as shown in Table 1 and 2.

Table 1. Grading matrix for the categorization of grain pattern

Type of urban grain	Colour code	No. of buildings belonging to 400 sqm area
Fine		06 buildings
Mix		03 buildings
Coarse		< 03 buildings

(Source: Author)

Table 2. Grading matrix for the categorization of building foot print

Range of building foot print (sqm)	Colour Code (Colour range to show the footprint intensity)
< 40	
40-80	
80-160	
160-280	
>280	

(Source: Author)

2) Photographic Survey: Visual images were sourced by the author, google street view and some old photographs were collected from the old shop owners and residence in Mawanella.

3) On-site observation: On-site observation was conducted to identify the present condition of the context and the city elements within the selected town case study area.

4) Questionnaire: The main target group of the study representing the residents in Mawanella including shop owners and pedestrians. The survey was carried among 100 participants, who was above 18 years old. Purpose of the

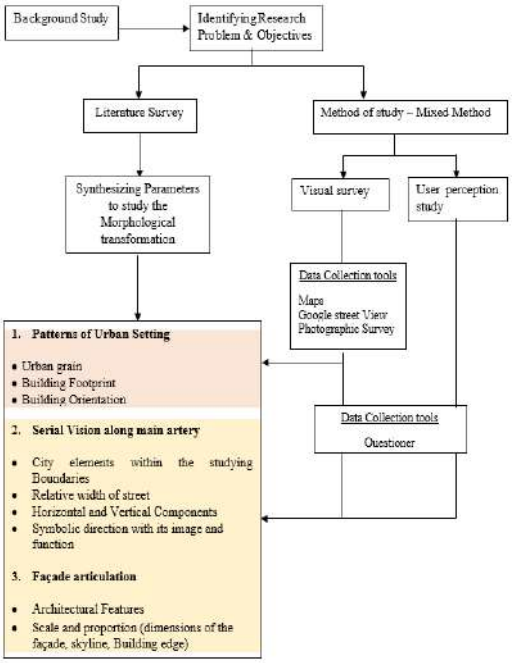


Figure 2. Methodological frame work

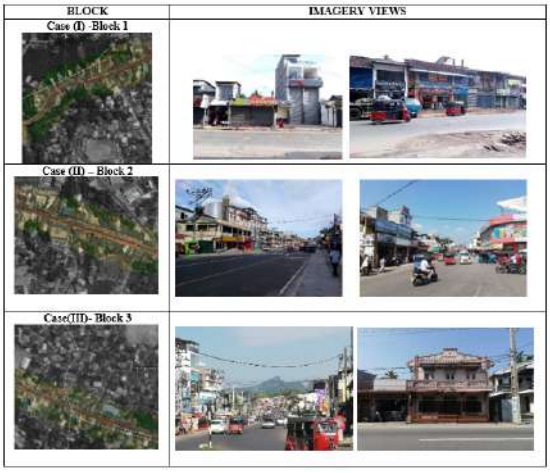
(Source: Author)

questioning is to get a public image of the area and how they felt recent changes and how it affects when reading the city.

4. Case Study

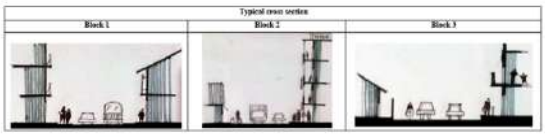
The existing old Colombo-Kandy main road was earlier known as "Bazaar Street" during British colonial period. The route was mainly used for the transportation of goods and passengers. However, the literature says the Mawanella town was used as and transition point by traders while travelling to Kandy or Colombo because they used to get breaks from their long-distanced journey and engaged in commercial activities at Mawanella. This resulted to bloomed in series of colonial structures like 'shop-houses' which were built on either side of the road giving unique character to the main town artery. For the purpose analysing the selected context the selected case study area (ex: Linear artery) was divided to three (03) blocks as shown in Table 3 and Table 4.

Table 3. The selected three (03) case study areas were mainly focused on block 1, 2, and 3.



(Source: Author)

Table 4. Typical cross sections through Block 1,2,3



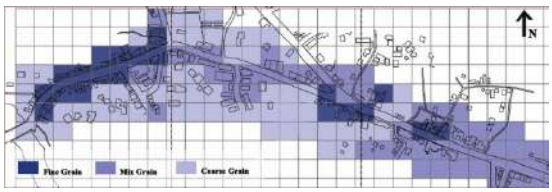
(Source: Author)

The simplified three (03) blocks in the case study area were used to evaluate the transformation of urban morphology serial vision and legibility of Mawanella town.

5. Reuslts and Discussion

1. Changing components of Morphology

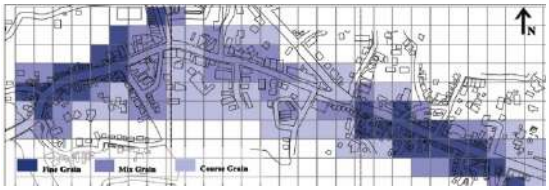
It was founded that the urban grain has been changed over last 20 years of the selected areas. The "fineness" of the grain was differed in each selected block. Considerably, block – 1 and block -3 were largely affected due to road developments and number of old buildings were demolished. The grain has changed from 'fine' to 'coarse' in block – 3 from year 2000 – 2020. In block- 1, more 'fineness' can see in year 2020 than the year 2000 (Figure 3, 4 and 5).



Block 1 Block 2 Block3

Figure 3. Urban grain of the study area 2020

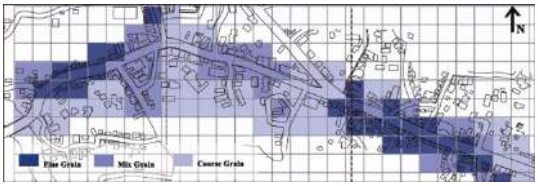
(Source: Author)



Block 1 Block 2 Block3

Figure 4. Urban grain of the study area 2015

(Source: Author)

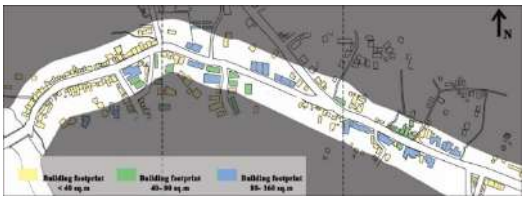


Block 1 Block 2 Block3

Figure 5. Urban grain of the study area 2000

(Source: Author)

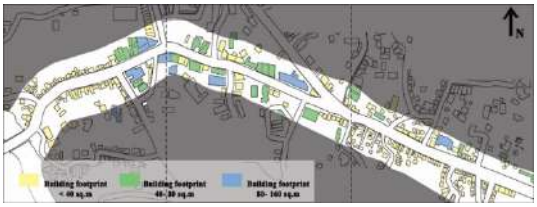
Building footprint has transformed over last 20 years due various developments. Majority of buildings which had small footprint (<80sqm) are residential buildings with colonial architecture. Usually, large footprints founded in public places and large malls only. (Figure 6 and 7)



Block 1 Block 2 Block3

Figure 6. Building Footprint of the study area-2000

(Source- Author)



Block 1 Block 2 Block3

Figure 7. Building Footprint of the study area-2020

(Source- Author)

Building orientation did not show a drastic change in the study area. Compared to urban grain, the building footprint was highly affected due to the morphological changes happened from 2000 to 2020. Therefore, from the components of morphology, building footprint was provide greater contribution to change the patten of the physical setting.

2. Serial vision

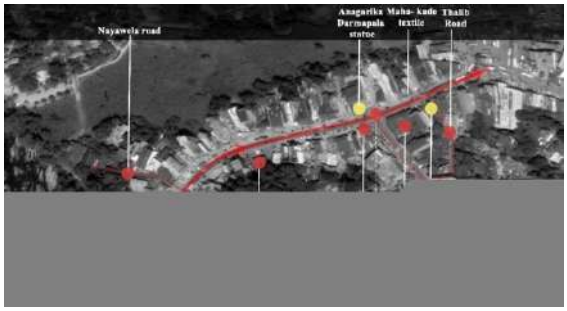


Figure 8. Identifying city elements within Block - 1

(Source: Author)

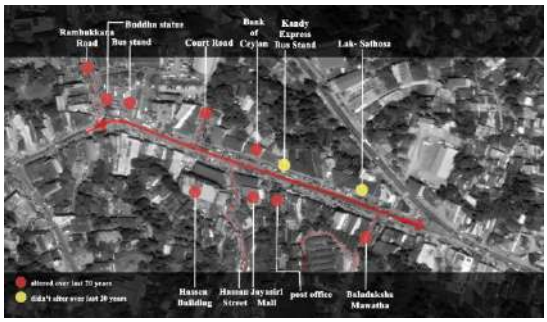


Figure 9. Identifying City elements within Block - 2 (Source: Author)

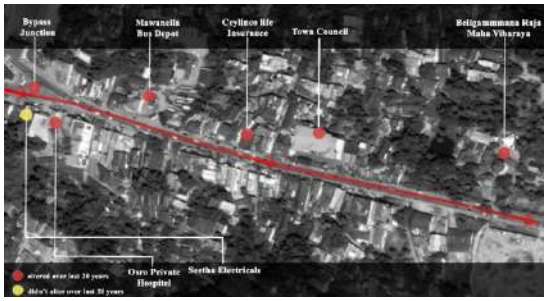


Figure 10. Identifying City elements within Block - 3 (Source: Author)

80% of city elements were altered over last 20 years according to visual survey as shown in Figure 8, 9 and 10. According to user perception analysis it was found that old elements (20 years old or above) are involving to create the overall city image rather than new ones (Figure. 11).

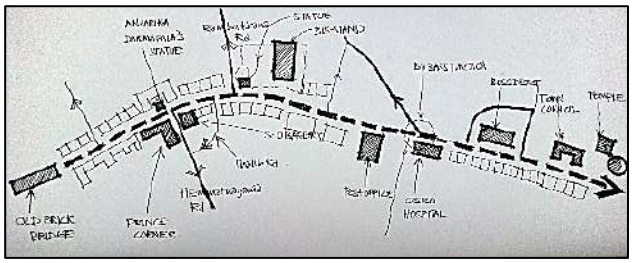


Figure 11. Typical cognitive map of overall city, produced using the user perception analysis

(Source: Author)

The road width of the main artery of blocks 1 and 2 were expended in twice the original size due to road widening project. Thus, the perception study was revealed that expanding road width was affected on respondents' comfortability and they have lost the sense of place. They highlighted that the current condition of the road is majorly responding to the vehicular movements only.

According to the visual survey the rhythm of the space was created by both horizontal and vertical components of the façade. However, it was gradually fading over the time, with the absence of delicate components. Perception study revealed that the visual harmony which was offered by traditional facades were unable to perceived through the modern facades. Old shop-houses were expressing the symbolic meaning that the rich socio-economic background of the old neighbourhood of Mawanella. In addition, *'Uthuwankanda'* mountain is one of the significant landmarks which providing sense of direction through the old neighbourhood though it is not much highlighted now with the modern town setup (Figure 12).

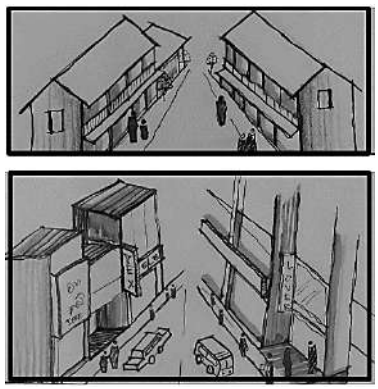


Figure 12. Serial vision then and now (Source: Author)

3. Facade articulation

Architectural features: The spectrum of different aged façades (ex: colonial, post-colonial and contemporary) have been transformed over long period of time. Visual obstacles are overwhelming the detailed appearance of the façade and that unique contrast was unable to perceive through the monochromatic facades of new buildings (Figure 13).

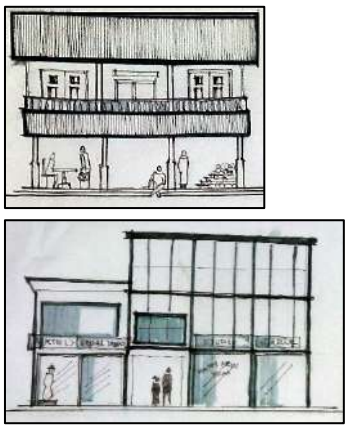


Figure 13. Typical facades of then and now (Source: Author)

Scale and proportion of the façade: The average facade width of colonial or post-colonial buildings is about less than 15 meters (<15m) and predominantly they are built in single or two storied. Contemporary building's façade width is about 03 meters (narrow facades) or 25 meters (wider facades) and can be reached up to five or more stories. Respondents were enjoying with more welcoming wide entrances

including with single or double storied heights of traditional buildings. Unlike uniformly distributed traditional building profiles, the new trends of varying heights creating undefine skyline and cause to made confusion to configure the dominant traditional silhouette. Extended shopfronts are more visually and physically permeable and creating active building edges (Figure 14).

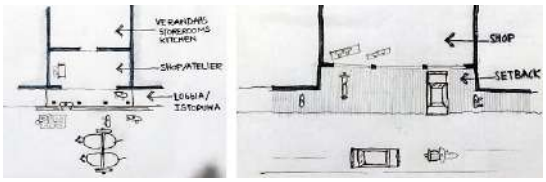


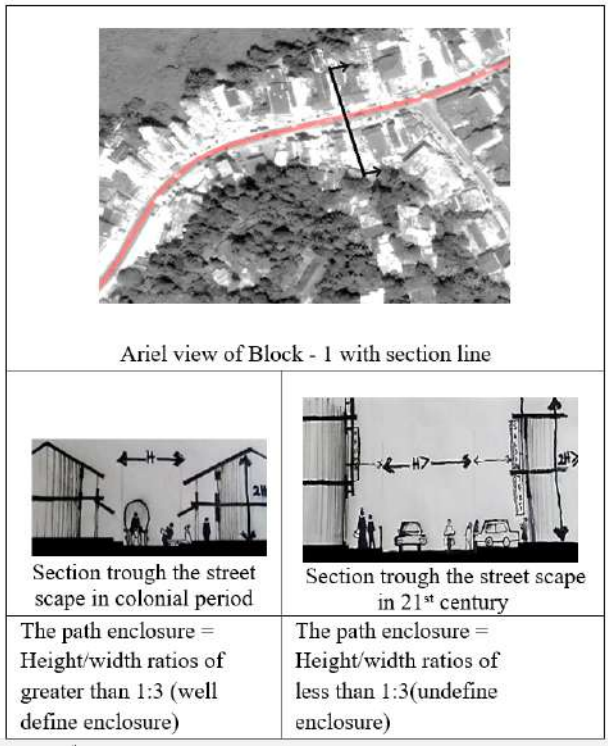
Figure 14. Shop fronts then and now (Source: Author)

4. The impact of morphological transformation on legibility of Mawanella

Montgomery, (1998) has defined the city image as a combination of identity of the place and set of feelings, impressions about the place of user perception. To describe the overall public image of the old Colombo- Kandy main road in Mawanella, it was considered the user preference on city elements. 80% were given their preference to old city elements and 15% were chosen new elements. Thus, it was confirmed that the memorability of the building setting should stronger enough to enhance the image of the city and its uniqueness (Lynch, 1960). Accordingly, the traditional elements of the city were providing a strong identity to the city, but haphazard development and misconceived modernization cause to diminish the unique character of the old neighbourhoods like Mawanella.

According to Seçmen & Makaklı, (2019) changing patterns of urban morphology reflected through its urban grain, building orientation, and building footprint. The map analysis showing that urban grain and the building footprint were drastically transformed and comparatively the building orientation was not much effect on the morphological transformation. The mapping was clearly figure out buildings which had small footprint (<80sq.m) were belonging to the fine grain, and large-scale buildings were belongs to the mix or coarse grain. Therefore, all the colonial shop houses were belonging to the fine grain and this unique character contribute to creating a stark contrast by repeating similar elements until year 2000. Coarse grains are usually large-scale buildings, tend to segregate from each other and scattered over larger areas dis-orderly. Fine grained, orderly organized built fabric are providing multiple choices available in the town setting (Carmona , et al., 2010). However, currently it was almost left the finer grain pattern and introducing coarse and mixed grain to the urban setting in Mawanella.

Alcock, et al., (1985) stated that the 'path enclosure' is a crucial factor that effect on legibility. He described that this quality helps to improve strong character while bringing functional importance to the streetscape and helping to distinguished to the user as well. Also, the path enclosure should be (Height/width ratios) less than 1:3 seem Figure



15. Path enclosure then and now (Source: Author)

weakly enclosed (Alcock, et al., 1985). It was identified through the visual survey; the heights of the traditional building layer were almost existed and the road width also comparatively doubling in the present condition (Figure 15).

It was clear that varying road widths and heights of the buildings were leading to undefine enclosure result in lack of legibility of the road. Before year 2000, the uniformly distributed heights creating homely enclosure throughout the journey. While comparing to the user perception on recent road widening project, the majority of 76% were agreed that the current image of the old road is lack of comfortability.

According to Alcock, et al., (1985) people used to interpret the context using visual cues, and it supports express the right meaning of the place. People more likely to attract horizontal and vertical components on old facades, because traditional elements of the buildings providing visual harmony for their journey. It seems to be the interplay of horizontal and vertical rhythm of elements contribute to made visual cues. Alcock, et al., (1985) mentioned that the horizontal and vertical interplay of components are involved to create the rhythm of the journey. Relatively the horizontal rhythm was contributed on visual harmony. 68% of people were interest on repeating balconies, overhanging and even the handrails that provided by the traditional facades.

Since year 2000 there was a spectrum of different ages of buildings built during colonial, post-colonial and contemporary eras could found in Mawanella area. However, it has been drastically changed over last 20 years and remain only handful of colonials, post-colonial buildings where majority of the buildings were replaced by contemporary structures. According to the architectural features identified through the visual survey, and the result from the questionnaire, it was identified that majority (78%) were agreed that the detail appearance of the aged facades was overwhelming by the large sign boards and cladding facades while obstructing the visual cues of the users.

40% user preference was showing that buildings which merge with the street edge are more functionable rather than set-back shop fronts (Figure 16). Further, it was identified that traditional buildings having active and more welcoming entrances rather than set-back buildings. Wide openings that are extensively exposed to public, are more visually and physically permeable and accommodate to public activities while creating an active building edge (Mehta , 2013). 42% of participants were agreed that old traditional buildings are supported to create an active functional building edge in selected case study area.

Figure 16. Largely affected shopfronts (Source: Author)

Nevertheless, it was largely affected on active shop fronts along the old main road (Bazaar Street) due to recent road widening project implemented since 2019. The town lost number of active shop fronts of the old neighbourhoods. That was clearly identified through the footages of a colonial building located at the Hemmathagama junction and how its envelope was changed over last 10 years. On the other hand, old shop houses and *'Uthuwankanda'* mountain are providing evidence for the rich identity of the city. Therefore, the symbolic direction of the main artery providing a greater contribution to create the city image. However, over the time, despite the fact of changing the unique pattern and composition of the urban

setting caused to made confusion (Lynch, 1960).

According to the results from visual survey, it was almost vanished the usual skylines as well and varying heights were caused for undefined skylines. Large scale masses reaching up to 03 to 05 stories and some of facades were defined by flats capes. The questioner survey showed that the silhouette of massive scale buildings was unable to easily perceive by pedestrians due to the height of the buildings and the uniformly distributed skylines with traditional layer promoting the path enclosure. Further, current undefined skyline was giving lack of contribute on vertical rhythm and visual cues of urban setting. When, the morphology of the old neighbourhood was transformed over long period of time, several spatial characters that inter-linked and impacted with the 'Legibility' of the town and it was unable to perceived through the current environment as follows (Figure 17);

5. The city image of Mawanella, is strongly associated with its unique pattern and composition of traditional built form on either side and main artery. Therefore, the contribution for the legibility has much provided by visual and physical qualities of these composition.

6. Decaying traditional elements and replacing into large clusters have caused to change the fine grains into coarse grain. Different sizes of building footprints made coarse patterns of the grain.

7. Relative to other key parameters, changing morphological patterns such as grain, footprint and orientation are majorly impacted on the legibility of the physical setting, but less effect on user.

8. Old neighbourhoods were comprised with different symbolic meanings. The entire image of the city was based on collective images of the main artery and the built forms. Earlier, the symbolic meaning of the place was enhanced by the traditional buildings and the axial view of the main artery. But currently, the transformation of symbolic meaning of the city does not reflect through the city elements.

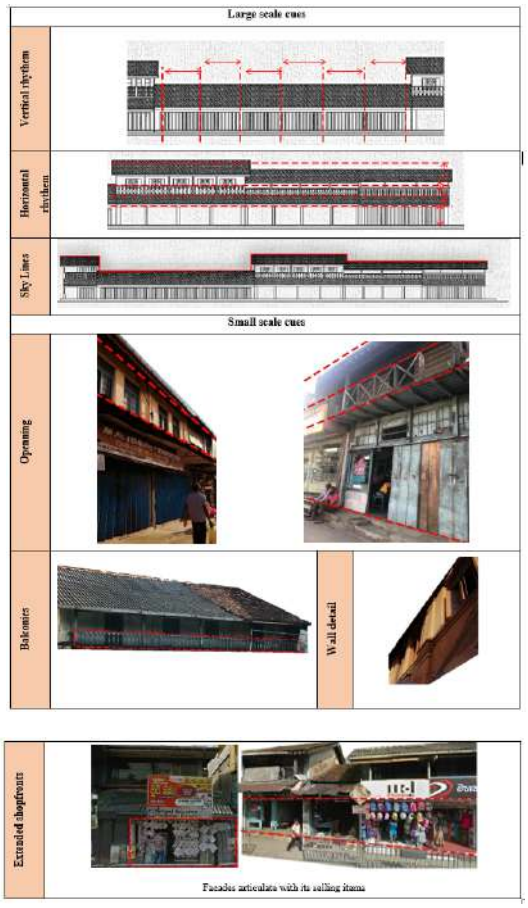


Figure 17. Identified small scale and large-scale contextual cues which promote the legibility of old neighbourhood

(Source: Author)

9. Expanding road width, undefined skylines offer less path enclosure and lack of contribution on path legibility. Recurring visual features along the road including horizontal/ vertical components, detail appearance of the façade, skyline that most people likely to experienced, have been unable to fulfil through the existing context. Therefore, it causes to reduce the large scale and small-scale visual cues of the environment. The collective contribution of façade width, skyline, horizontal, vertical components were important for the visual cues.

Ultimately, the findings that obtain through the survey can be include to a framework as shown in Figure 18.

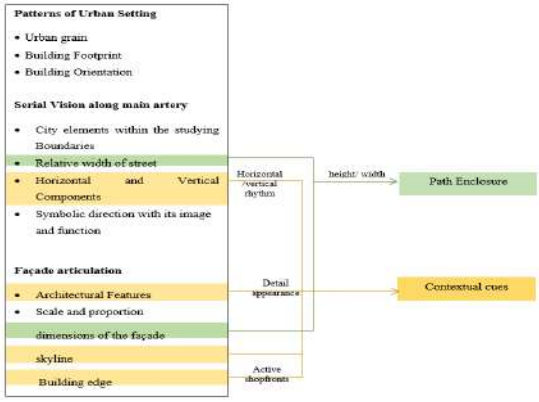


Figure 18. Framework of the research findings

(Source: Author)

6. Conclusion

Old Neighbourhoods and its elements are the roots of city image, tightly bound with its unique morphology. Therefore, it should have a deep need for taking into account about transforming older neighbourhoods due to haphazard developments. As mentioned before, Mawanella is one of the model case studies which representing linear and old neighbourhoods in Sri Lanka. The research design was created to identify how a traditional neighbourhood can sustain the legibility of a town. According to the discussion, the overall findings relating to the transformation of urban morphology and its impact on legibility can be summarized as follows;

1. From the questionnaire, 80% of respondents have chosen old elements associate with some important public activity to describe their journey. 20% of respondents are tend to select newly appeared elements. It was found that the city image of Mawanella strongly attached with its unique traditional elements.

2. The mapping shows that, there has a considerable change of the urban grain and the footprint during last 20 years. Traditional buildings were helped to create finer grain patterns and it was visible in the maps extracted in year 2000. In year 2020, it was gradually transformed to a coarse grain pattern included with large clusters due to rapid commercial development. In addition, individual buildings with larger footprints contribute to reduce the "fineness" of urban grain of Mawanella. Building orientation was almost perpendicular to the main road and did not change over last 20 years. Ultimately it was identified that, the formation of old Colombo-Kandy Road during last 20 years, was the main reason for the transformation of urban grain and the building footprint. Although there is considerable impact of morphological patterns (such as urban grain and building footprint) for the legibility of physical setting from year 2000 to 2020, though it has less effect on the user perception.

3. It was identified that the ribbon development of the main artery was catalysing the transformation of the urban morphology of the Mawanella. While changing the road width and the varying heights of buildings made confusion on street enclosure.

4. Majority of old elements of traditional façade are more contributing to create visual cues rather than new cladding facades. As well as it was clear that, over the time, building envelops tend to adhere cladding facades and made monochromatic building interface along the road.

5. In the past, shop-houses by the road providing symbolic meaning of the rich socio – economic background of Mawanella. The unique character itself almost left and unable to fulfil through the modernized built environment. Therefore, Mawanella city does not provide any sense of transition to

passengers when passing through the main artery from Colombo to Kandy.

From the results obtained through the perception study and the visual survey, it was observed that, changing factors highly influenced the legibility of Mawanella, and the greater contribution was offered by the path enclosure and the contextual cues that was created by, façade articulation and serial vision rather than morphological patterns. Ultimately it was clear that, old neighbourhoods are very sensitive potions of large-scale urban settings and should highly concern about its physical composition and building interfaces on either side of the road when proposing city development projects.

7. Recommendations

Old linear neighbourhoods like Mawanella, threaten by uncontrollable ribbon developments. Therefore, the identity of the city does not clearly appear from the physical environment. In proportion to the research outcomes, the determinant factors of visual cues and the path enclosures are the major concerns of an old neighbourhood when preserving its legibility. Thus, the developed research design can be used as a reference in designing older neighbourhoods. Further, the research outcomes are able to use in developing different levels of planning policies relating to the urban rejuvenating projects of old neighbourhoods in Sri Lanka.

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An investigation of the resource finding issues in highway construction projects in Sri Lanka with COVID-19 pandemic situation

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Abstract *: The construction resources are most necessary for running the construction projects consistently up to their finishing stage and construction resource planning and management compulsory to ensure project goal in any project that the on time handover within budget. The whole construction industry of Sri Lanka was affected by advent of COVID-19 pandemic outbreak and the most construction projects had to face the difficulties of effective resources management. The research approach has been taken in to investigate the resource finding issues that arisen with COVID-19 pandemic in four highway construction projects which selected from four provinces in Sri Lanka. The study also focused to identify the effects to projects' delay, cost and quality. Through the literature review around topic background, seventeen resource finding issues related factors were identified under three categories that human, material and financial. Then, the importance level of identified factors were justified to this particular study through the responses gathered using questionnaire survey. The responses were taken from construction professionals (project managers, planning engineers, construction managers, QA/QC engineers, quantity surveyors and site engineers) who selected according to the researcher judgement from four contractor firms. Then factors were analyzed and ranked using Relative Importance Index (RII) and descriptive statistics, utilizing Excel and SPSS software. The results presented that the whole factors perfectly affected to resource finding issues and were discussed with qualitative findings to show their effects on projects' delay, cost and quality. Finally, concluded the identified effective solutions for continuing highway construction projects during COVID-19 pandemic period.*

Keywords :*Resources, Project objectives, COVID-19*

1. Introduction

The human resource, financial resource and material resource are the key construction resources which are consumed frequently by the construction projects and the construction management teams (client, consultant & contractor) normally confronted some challenges while resource management at the preliminaries or during construction period and they may probably come as one of environmental, social and health challenges, etc., or whole which cannot exactly be guaranteed.

At end of the year 2019, global people started to face the COVID-19 (Coronavirus) pandemic which was an immense health challenge highly affected the construction industry in recent times in Sri Lanka and other countries in the world. "The construction industry was one of the first industries that were impacted by COVID-19, and the workers have been subjected to an increased risk of unsafe" (Koh, 2020). The pandemic created a new unsafe and uncertain environment in construction industry in Sri Lanka and the normal construction works of many projects were disruptive to continuing energetically as previous.

Road construction projects are in a high-risk environment with their associated parties compared to the other construction projects running during the COVID-19 period (Julian Bailey, Nicolas Bouchardie, and Ignacio

Madalena, 2020). In Sri Lanka, highway construction projects faced a critical situation due to the raised barriers from the spread of the COVID-19 and the pandemic made an environment which having many resource related issues (shortages of existing resources or trouble in finding new resources required) against the completion or continuation of projects as planned. Enacting the regional lockdown, country lockdown, travel restrictions, social distancing and other isolation safety measures significantly affected handling the resources in the ongoing construction projects properly in Sri Lanka. So, this research approach taken into the highway construction projects considering its existing nature to investigate resource finding issues that generated with the COVID-19 pandemic. The study aim was to investigate the resource finding issues in four highway construction projects which were selected by covering four provinces during the COVID-19 pandemic situation in Sri Lanka and to discuss how those affect the delay, cost and quality of the project.

2. Literature Review

The continuing COVID-19 pandemic, which began in the Chinese city of Wuhan, has caused tremendous harm to the worldwide population and economy. The first incidence of COVID-19 in Sri Lanka was reported in late January 2020, involving a Chinese migrant, and the initial local case was detected at the second quarter of March. Since then, the Sri Lankan government has implemented a series of measures to decrease social distancing, including the closing institutes, the implementation of a work-from-home model to reduce crowds and, most recently, the regulation of an island-wide curfew in order to help reduce the risk of the pandemic on the Sri Lankan population (T.M.Wickramaarachchi et al., 2020). The COVID-19 outbreak has had a significant negative impact on key income-generating sectors. Because of its rapid growth, the COVID-19 outbreak could not be predicted or controlled. However, the COVID-19 pandemic significantly altered community lifestyle in Sri Lanka (Jayasingha, 2021).

A. Construction Projects Background with COVID-19

Michael A. Stover, Cynthia E. Rodgers-Waire and Thomas J. Moran (2020) even in the COVID-19 pandemic, contractors and other project-related parties are dealing with close problems like lack of raw materials and labour shortages, but it happened at unprecedented size and duration. The new existing situation like stay-at-home and government shutdowns/country lockdowns started considering the construction projects as "non-essential". Olanrewaju et al., (2021) state site productivity would be lowered by up to 50%, and the epidemic will cause a 40% increase in skilled labourers' shortages. Richard savino (2021) epidemic brought many construction projects to a halt for a brief period and it was a difficult stop that cost many jobs, revenue, and growth. While other industries are returning to work, the pandemic has presented additional barriers to some sectors, especially those in the construction industry.

Delay of completion, breakdown of supply chain and materials, change public attitude about the construction site, economic uncertainty locally and globally, job turnover of professionals, less productivity of projects, labor shortage, uncertainty of continuing site works, less funding for the future and demand reduction identified as challenges to the construction industry in Sri Lanka during COVID-19 pandemic (WN Kawmudi et al., 2021).

B. Construction Resource Background with COVID-19

1) Human Resource: The construction sector was experiencing a record scarcity of trained workers in prior to the epidemic, and that problem was increased because COVID-19 has halted some projects and slowed others. Although companies have begun calling back workers who were let off but some have declined, claiming a desire for unemployment benefits, virus fears, or family obligations (Shelley D. Hutchins, LEED-AP, 2020).

2) Material Resource: The ongoing coronavirus pandemic has caused considerable disruptions

in supply chain and material shortages in the construction sector, resulting in both lengthy delays and higher costs for numerous projects. Series of COVID-19-related influences, such as lockdowns, workplace restrictions, and border closures, caused significant disruptions in the manufacturing and distribution of construction materials, as well as both domestic and international supply chains (Ben Cotter and Katie Zhang, 2021).

3) Financial resource: During the COVID-19 epidemic period, one of the key issues for principal contractors, subcontractors, and suppliers in the construction business has always been project cost and cash flow maintenance. Construction projects' shutdown during COVID-19 prevents the projects from collecting income, but the projects must still account for many of its overheads (Thorpe, M, 2020). The cost of the projects was severely impacted after installing the on-site health and safety facilities and other safety measures. It has been critical to have access to cash that was the key challenge for construction parties during the COVID-19 pandemic period (Sierra, 2021). The developing countries face significant construction financial challenges, which complicate the impact of COVID-19, such as fluctuations in foreign exchange rates, inflation, interest rate changes, and material price fluctuations (Ben Cotter and Katie Zhang, 2021).

C. Construction Projects' Delay with the COVID-19

The human resource management in construction sites, is highly joined together with the working condition and it always affects the output. The better working condition means that the employees working safely. COVID-19 epidemic changes the proper working condition needed for effective resource arrangement in the construction sites. Due to the hazardous conditions that existed throughout the COVID-19 period, employees frequently failed to report to work and absenteeism was increased (All Answers Ltd, 2018). Labourers and other staff members are infected by COVID-19 and quarantined frequently. So, the increase in labour shortage highly caused to delaying the construction works of many projects in Sri Lanka. Some construction sites have been stopped purposing to resume again later (Sampath Udayanga E.A.D , 2022).

ILO (2021) with the shortages of raw materials and other inputs, contractors, subcontractors and employees, the pandemic and its disruption of global supply lines have increasingly impacted construction activity. The manufacturing and distribution of some materials have been halted and construction projects were closed for extended periods. Project handover dates have been tentatively postponed.

D. Construction Projects' Cost with the COVID-19

Andy Choi (2021) states the many organizations faced and are still facing major financial difficulties. Contractors lacked the financial resources even though they were required to cover staff wages and keep their firms running during the COVID-19 pandemic period. The construction industry's profit margins were severely impacted by an unforeseen rise in material costs, with some businesses even losing money. Delay is one of the most critical factors that affect the cost of construction project during the COVID-19 and the price of construction materials frequently rise with time delay, while the supply of construction materials declined. Dealing with unexpected extra expenditures has always been a difficulty for contractors. The onset of the COVID-19 pandemic had a detrimental impact on many contractors' financial background since it was unexpected.

John G. McConville CCP (2020) mentioned due to the social distancing maintenance, small groups of workers available, and endless safety measures, caused to loss of productivity in construction projects that will result in more cost and the COVID-19's influence will result in increased indirect cost for the safe COVID-19 conformity and employing additional site safety

employees to monitor worker social distance and daily temperature checks at the site's entrance, masks, gloves, face masks, hand sanitizing dispensers, additional worker changing room facilities and isolated dining facilities are required to enable social distancing techniques, more buses and vans or trucks need to facilitate isolated worker group transportation from residencies or accommodations to the worksite. Olanrewaju et

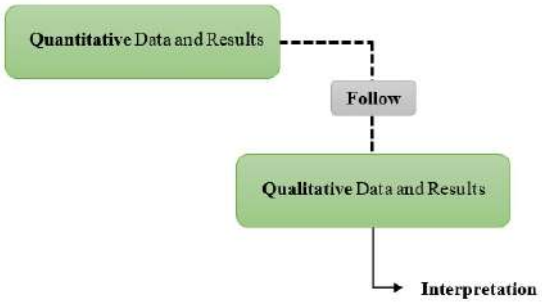

Figure 1. Explanatory process of research design

al., (2021) the costs of COVID-19 prevention health and safety requirements will increase project costs by more than 20%.

E. Construction projects' quality with the COVID-19

Ryan Buma (2021) Shortage of material receiving and shortage of labourers' attendance to the construction site, effect decreasing the output on time. Low productivity of jobs in projects directly affected delaying the constructions during the COVID-19 pandemic period is one of the challenges to quality satisfaction. Standard materials help to gain the strength of work done and keep the work decent. The local and foreign materials for the quality construction achievement but the direction was going away due to the COVID-19 disease. Material suppliers and other parties related to the supply chain got many problems from the pandemic situation and essential materials handling were difficult in the construction sites. Shutting down of the material production and running supply chain was the problem encountered to continue the quality construction works in the construction projects (Richard savino, 2021).

3. Methodology

The research was designed by mixed method (both qualitative and quantitative) to address the research qestions of this study. The mixed method approach was followed by an explanatory process which initially conducted quantitative data collection and analysis and then, discussed with qualitative findings in second phase as a follow-up to the quantitative results.

A. Research Area

The study was carried covering four (04) provinces (Western, North-western, Central and Eastern) where the large scale highway construction projects under construction during COVID-19 pandemic period in Sri Lanka and one construction project was identified and selected from each province.

B. Target population

Professionals of construction management teams of selected contractors in each selected highway construction projects from specified four provinces in Sri Lanka were targeted.

1) Sampling Frame: Registered and graded (CS2) main contractor firms which possess the qualified professional teams of road construction industry in Sri Lanka under the Construction Industry Development Authority (CIDA) were considered to this study. Specifically, highway construction projects were selected considering two criteria due to prevailing COVID-19 pandemic situation in Sri Lanka.

Table 1. Criterion background used to select the projects

Availability	Ongoing highway construction projects during COVID-19 pandemic period
Size	Large scale highway construction projects

2) Sample Size: The fifty (50) of individuals were expected to cover from the selective professional (project managers, planning engineers, construction managers, QA/QC engineers, quantity surveyors, site engineers) job roles through the selected projects.

3) Sampling Method: Purposive sampling method was used to select the suitable individuals according to the researcher judgement which under the non-probability technique.

Table 2. Responses rate of questionnaire

Respondents	**Responses**
Project Manager	03
QA/QC Engineer	03
Quantity Surveyor	06
Construction Manager	06
Site Engineer	18
Total	**36**
Expected responses	**50**
Responses (%)	**72**

C. Data Collection

Both quantitative and qualitative data were gathered by questionnaire survey and interviews respectively from the sample selected through the data source. The 05 scale "Likert format", close-ended type questionnaire was dispatched through online media (email and Whatsapp) focusing the construction management teams selected from the highway construction projects running during COVID-19 situation and thirty-six (36) resposes were received. Then, focused, Open-ended type semi-structured interviews were conducted through the telephone calls with selective four (04) professionals from each projects.

D. Data Analysis

Analyzed both quantitative and qualitative data for getting clear view to the research questions as well as objectives of the research. Relative Importance Index (RII) analysis and descriptive statistics were used to analyze and interpret the collected quantitative data and then, the statistical analysis were followed by qualitative analysis. Two software applications (Excel and SPSS) were used to analyze the responded data statistically.

1) RII Method in Data Analysis:

$$\mathbf{RII} = \frac{\sum \mathbf{Wn}}{\mathbf{A}*\mathbf{N}}$$

W - Constant that weighted each response

A - Highest weighting

n - Frequency of responses

N - Total number of the respondents

4. Results

A. Data Analysis of Questionnaire

Fifty (50) responses from construction professionals' were expected to cover by questionnaire survey and thirty-six (36) responses were received. It was 72% to the expected responses of the study. Gathered data through the questionnaire survey regarding seventeen (17) factors that negatively affected finding the resource under the three (human resource, materials resource and financial resource) categories during COVID-19 pandemic period were analyzed using RII analysis and descriptive statistics by utilizing Excel and SPSS softwares.

Human resource related factors were labled as; **(HR1)** Prophylactic absenteeism of professional staff and labourers are greater than the normal situation, **(HR2)** Job turnover of professional staff is higher comparing to the normal situation, **(HR3)** Job turnover of skilled, non - skilled labourers' and other related parties (drivers, store keepers etc.) are higher than normal situation, **(HR4)** Amount of hiring skilled and non-skill labourers are greater comparing with previous and **(HR5)** Amount of hiring professional staff is greater comparing with previous.

Table 3. RII values of human resource related factors

Factor ID	5	4	3	2	1	RII	Rank
HR1	24	12	0	0	0	0.933	1
HR2	6	26	4	0	0	0.811	4
HR3	7	29	0	0	0	0.839	3
HR4	24	12	0	0	0	0.933	1
HR5	8	28	0	0	0	0.844	2

According to the Table 3 based on RII values of factors of human resource related category, there are two most significant factors of human resource related factors that parellely affected the resource finding issues are (HR1) and (HR4) and (HR2) is the least significant factor.

Table 4. Descriptive statistics of human resource related factors

Descriptive Statistics

	N	Mean	Std. Deviation
HR1	36	4.58	.500
HR2	36	4.06	.532
HR3	36	4.19	.401
HR4	36	4.67	.478
HR5	36	4.22	.422
Valid N (listwise)	36		

Table 4 shows all of the responses are in between strongly agree and agree in the category of human resource related factors. (HR4) factor got the highest mean value and it is the most negative factor affected the human resource handling during COVID-19 pandemic period. The standard deviation of the (HR4) factor is (0.478) and it means that the responses of (HR4) factor were not highly spread. The factor (HR2) has taken the comparatively lowest mean value and it is least affected negative factor that human resource handling during COVID-19 pandemic period. The standard deviation of the (HR2) factor is (0.532) and it means that the responses of (HR2) factor were not highly spread.

B. Data Analysis of Interviews

Table 5. Responses rate of interviews

Respondents	Responses
Project Manager	01
Planning Engineer	01
Quantity Surveyor	01
Site Engineer	01
Total	**04**
Expected responses of interview	**04**
Responses (%)	**100**

Interviewees stated that project time has been delayed during the COVID-19 pandemic period as never happened in the previous time on highway construction industry in Sri Lanka. The absenteeism of the staff members and labourers were highly increased during the pandemic period due to the travel restrictions, COVID-19 infection, group quarantine of infected parties, fear of the next wave and other social influences regarding the pandemic. They mentioned also that some quarantined people were not reported to the work again after finishing the quarantine period. Additionally, some interviewees mentioned some staff member and labourers have left their job in the projects and shifted to the different jobs because well caring about family members and relations during spread intensity of the COVID-19 pandemic period. So, finding new labourers and staff members to the site again were quite hard

and more time consuming work during prevailed pandemic period.

Prticipants stated that unexpected cost of project has been increased during the COVID-19 pandemic period as they never experienced in the previous time on highway construction industry in Sri Lanka. Health issues on manpower were increased in highway construction projects with COVID-19 virus outbreak and sufficient staff members and labourers have not been reported continuously to the construction project. So, tried to hire additional staff and labourers to the project as a solution for continuing the construction works even the virus outbreak. The new hired people were tested for COVID-19 by Rapid Antigen Test (RAT) frequently by transporting to the medical centre as the order of come to the site and they were provided all sanitary facilities (masks, sanitation liquids, hand wash, isolated accommodation and transportation etc.) to maintain healthy and safe environment in the worksite. They stated that the daily, weekly and monthly expenses of the projects were gradually increased when hiring the more manpower and facilitating safety precautions them during COVID-19 pandemic period. Planning the cost of safety measures and daily expenses were more difficult in the COVID-19 pandemic period and cost of medical and sanitary facilities raised with frequency of doing Polymerase Chain Reaction (PCR) test and RAT.

5. Discussion and Conclusion

The (HR1) and (HR4) factors were identified by both analysis as the most negatively affected two factors parellely to handling the human resource to the highway construction projects during the COVID-19 pandemic and qualitative findings shown that the above factors were highly affected the projects' cost and time delay. Other two categories also analyzed same way and the results presented clearly that the whole factors highly affected resource finding issues in highway construction projects in Sri Lanka with COVID-19 pandemic situation. The most affected factors of other two categories were also discussed with qualitative findings which gathered from the four interviewees of selected projects to show the effect on the time delay, cost and quality of the project. After evaluation the quantitative results with qualitative findings, the aim of the research has been achieved successfully.

The effect of (HR1) factor upon projects' delay can be decreased in some considerable degree, if the all labourers can be retained to the full by providing high level of safe working environment within the premises ensuring their sanitary facilities intensively. For that, isolated accommodation facilities with entertaining background to gain their mind happy from stress afar COVID-19 and essential goods and meals need to be supplied. Then they will stay safe and work happy even the out-side situation is worst. The continuous additional indirect costs of projects can be controlled by that pracitice because of providing additional transportation is limited and COVID-19 testing requirements are less. The effect of (HR4) has raised when the labour shortages happen, so that can also be minimized on project cost if the (HR1) is controlled. Then the cost overrun can be controlled on safety measures that need to be taken on frequent labour hiring. The minimization of human related issues will be beneficial to decrease the additional cost and continue the highway construction projects as much as possible without longest delaying effectively with COVID-19 situation in Sri Lanka.

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Acknowledgment

Foremost, I express my sincere gratitude to the internal academic coordinator Dr. A.H.M.D.R Dassanayake and external supervisor Dr. K.A.S.G. Suneth Karunanayake who guided me by giving utmost support to successfully finalize this research.

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The Existing Sustainable Features in the Sri Lankan Road Construction

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Abstract*: One of the world's greatest natural resource exploiters relies on the building and materials sectors for physical and biological support. The concept of sustainable development has been around for more than 30 years, and it connects development and the environment. The road industry emits the most greenhouse gases, both directly and indirectly, due to the usage of fossil energy in mining, transporting, and paving operations. As a result, road development contributes significantly to pollution in Sri Lanka's environment. However, the success of environment-friendly road construction is not at a sufficient level in Sri Lanka mainly a low level of attention given to sustainable development. Hence, this research focused on enhancing road construction success through a better understanding of sustainable development.*

An extensive literature synthesis was carried out to review the concept and key features of sustainable road construction globally and with reference to Sri Lanka. Following that, an expert interview and a survey were used to continue the study using a mixed research approach. Expert interviews and questionnaire surveys were conducted as the data collection method. The data analysis was done through manual content analysis and Relative Important Index (RII) techniques.

The findings revealed what are the existing sustainable features in Sri Lankan Road construction and its advantages and disadvantages. Then identify challenges and opportunities of Sri Lankan Road construction for sustainable development. Thus, the applicability of existing sustainable features to Sri Lankan Road construction shall be reviewed further in empirical research.

Keywords*: Road construction, Sustainable features, Sri Lankan Road construction*

1. Introduction

The construction sector is frequently considered the engine that causes economic growth due to its strong backward and forward connections with other sectors. Increased construction activity on the other hand is thought to have negative economic, social, and environmental consequences (Balaban, 2012). According to Horvath (2004), environmental assessment is complicated because it covers a wide range of societal infrastructure components and facilities, including residences, commercial buildings, transportation, government, and military installations, roads, bridges, utilities, ports, and all public and private sector projects. Infrastructure and road construction projects, in general, are connected with a large number of emissions that vary from the commencement of project execution until the demolition stage (Marzouk et al., 2017). However, road infrastructure projects are difficult and vital measures for a country's social and economic development (Pilger et al., 2020). All sorts of roads, facilities, structures, signage and markings, and electrical systems are part of the road infrastructure, and they are all required for safe, trouble-free, and effective traffic flow (Ivenova & Masarova, 2013). Furthermore, when considering the life cycle of roads, primary energy consumption is linked to the use of electricity for road lighting and the usage of natural gas, diesel, and gasoline for construction equipment. The implementation of numerous construction operations such as earthmoving, truck transit on unpaved roads, crushing, material manufacture, and the operation of diesel-powered equipment has

significant effects on the environment and human health through air pollution (Giunta, 2020). Furthermore, dust emissions of road construction depend on the construction processes, duration, equipment, plants, and quantity of material employed and transporting and handling methods. Therefore, to protect the global nature, significant changes are necessary to do further with fewer impacts.

Different advantages can be achieved through sustainable construction. Luther (as cited in Shurrab, Hussain & Khan, 2018) states the benefits of sustainable development as environmental, economic, and social. Furthermore, increased air and water quality, reduced energy usage, and reduced water consumption are all environmental benefits. Reduced operating and maintenance expenses, greater sales price, and improved health and comfort are all economic benefits. Typically, road design is based on technical and economic factors, with other factors such as social and environmental implications being overlooked (Machi et al., 2017). To achieve long-term sustainability in road building, measures such as environmental management, water-sensitive urban planning, advanced and recycled materials, and environmentally responsible project management and construction are required (Thorpe, 2012). Moreover, when consider economic sustainability of roads it is required to be built and managed within the budget and provide economic profit.

In Sri Lanka, rapid industrialisation in both the public and private sectors has resulted in pollution (Zubair, 2001). International Conference on Real Estate Management and Valuation (ICREMV, 2017) states government infrastructure projects are another trend in the Sri Lankan construction industry. The value of work done on roads and railroads is higher than all other types of construction, according to the final report of the Survey of Construction Industries in Sri Lanka 2017/2018 (2020). As a result, road construction represents a large portion of the Sri Lankan construction industry. Thus, investigation of the existing sustainable features introducing sustainable development for road construction is very important to avoid environmental, economic, and social issues relating to the construction industry. To attain this aim, the study had to address the following objectives:

1. Review the sustainable features normally used in the world for road construction
2. Review the advantages and disadvantages of sustainable road construction and identify challenges and opportunities globally and with reference to Sri Lanka
3. Investigate the existing sustainable features in the Sri Lankan Road construction.

2. Literature Review

A. Why need sustainable development

Pollution of the environment is a major problem all over the world, and it has a significant impact on human health. Pollution can be caused by both human and natural sources (Fereidoun et al., 2007). The construction and materials industries provide physical and biological support to one of the world's largest natural resource exploiters (Spence & Mulligan, 1995). McGeehin, Qualters, & Niskar, (2004) reported that Cancer, birth abnormalities, and asthma affect a significant portion of the population in the United States, and many of these disorders are linked to environmental exposures. According to estimates of global pollution, building and construction activities are responsible for 23% of air pollution in cities, 50% of climate change through gases, 40% of drinking water pollution, 50% of landfill pollution due to construction activities, and 50% of ozone depletion pollution (Brown & Bardi, 2001). Construction activities can harm the environment by destroying natural flora, water bodies, natural sand hills, gardens, and parking places, as well as causing damage to plant roots, root destruction, and dam damage. As a result, construction pollution has an impact on all humans, animals, the environment, and the natural ecosystem (Jain, Gupta, & Pandey, 2016). When it comes to water pollution, heavy diesel vehicles, paints, and solvents are left on site, and garbage is dumped illegally and mixed with rainwater, and waste is washed away by

rain and mixes with water bodies, increasing water ecotoxicity (Cole, 2000). Construction waste is not properly treated and managed; one of the results is water pollution (Jain, Gupta, & Pandey, 2016). Water contamination is the main cause of death in humans all over the world. Water pollution also has an impact on our oceans, lakes, rivers, and drinking water (Scipeeps, 2009). Water contamination has an impact on soil and vegetation health and quality (Carter, 1985). Some water pollution impacts can be seen right away, while some of the water pollution effects couldn't be demonstrated immediately (Ashraf et al., 2010).

Traffic is the most significant source of air pollution. Pollution caused by traffic is becoming widely available in urban areas. CO, NO2, and PM are examples of such pollutants (Jung, Mehta, and Tong, 2018). Polluted air contains fewer or more hazardous materials, pollutants, or contaminants and that create a hazard to public health (Smith, 2007). Heavy dust production during construction has a significant influence on human health since it causes illnesses such as silicosis and lung cancer in those who work in this environment (Jain, Gupta, & Pandey, 2016).

The noise generated by heavy machine activities during the construction process is also a significant problem that has a negative influence on workers and nearby communities. It also raises the likelihood of sleeplessness, eye discomfort, high blood pressure, and stress issues. However, noise pollution increases due to increases of transportation vehicles in the development of urbanisation and industrialisation (Jain, Gupta, & Pandey, 2016). Cities with significant levels of pollution are placed on red alert in these countries, and they must focus on the impact of construction and find a solution. Construction pollution can be mitigated at this time if construction practices are changed (Jain, Gupta, & Pandey, 2016).

B. Road construction

Road infrastructure projects are time-consuming and essential to a country's social and economic development (Pilger et al., 2020). Soil sub-grade strength and traffic load are the two most significant parameters that influence pavement design (Bezabih & Chandra, 2009). In the past, roads were built entirely of stone, gravel, and sand, with water acting as a binding agent to level the surface and give it a polished appearance. Flexible and rigid pavements are the two types of pavements that are commonly known (Jain, Joshi, & Goliya, 2013; Mohod & Kadam, 2016). The following Table: 2, describes the difference between rigid pavement and flexible pavement.

Table 1: Difference between rigid pavement and flexible pavement

Flexible Pavement	**Rigid Pavement**
1. Subgrade deformation is transferred to the upper layers	1. The deformation of the subgrade is transferred to the top layers.
2. Design based on the component layers' load-distribution properties	2. Create a design based on the load-distribution properties of the component layers.
3. The flexural strength of flexible pavement is poor.	3. Flexible pavement has a low flexural strength.
4. The load is passed from one grain to the next via grain-to-grain contact.	4. The weight is transferred from one grain to the next by making contact with it.
5. Have a low completion cost but a high repair cost	5. Have a cheap cost of completion but a high cost of repair
6. Have a short lifespan (High Maintenance Cost)	6. Have a limited life expectancy (High Maintenance Cost)
7. Surfacing cannot be installed directly on the subgrade; therefore, a subbase is required.	7. Surfacing should never be applied to the subgrade directly.
8. There are no thermal stresses created since the pavement can contract and expand freely.	8. Thermal stresses are more difficult to create because concrete has a limited ability to contract and expand.
9. There is no requirement for expansion joints.	9. An expansion joints are needed.
10. The road's strength is mainly dependent on the subgrade's strength.	10. The road's strength is less dependent on the subgrade's strength.

11. The surfacing must be rolled. 12. Within 24 hours, the road can be used for traffic. 13. Frictional force is reduced in the subgrade and is not transferred to the top layers. 14. Oils and some chemicals cause damages	11. There is no need to roll the surfacing. 12. The road cannot be used until it has been cured for 14 days. 13. There is a lot of friction. 14. Oils and greases do not cause any damage.

C. Sustainable Road construction in Sri Lanka

Sustainable features normally used in Sri Lanka for road construction materials used

- Alternative materials

Soil stabilisation is currently used in road construction in Sri Lanka. A number of studies have developed new biological materials and methods to improve the strength of soils without the use of chemical binders like cement. Furthermore, industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures or soil stabilisation operations (Lee et al., 2019). Cement stabilised Rammed Earth is one such alternative construction material with a better probability of long-term sustainability. CSRE has been successfully used in Sri Lanka and many other nations for a number of uses and another problematic application of CSRE is in the construction of road pavements (Kariyawasam & Jayasinghe, 2016). Because of their great strengthening efficiency and low environmental impact, xanthan gum biopolymer is used as an alternative material for road construction (mostly shoulders and subbases) in Sri Lanka and other countries with similar climates and socioeconomic situations (Lee et al., 2019).

The most environmentally friendly road paving material is cement blocks. Although the initial cost is higher than other types of paving materials, the overall cost is lower. A pavement material that requires fewer maintenance tasks would be preferred (Mampearachchi & Gunatilake, 2013). Embankment filling can be done with coal ash. The use of coal ash in the road sector will improve not only the material shortage for road building but will also decrease the environmental impact caused by ash disposal issues. When compared to most European countries, where coal ash has been successfully used the use of coal ash for road construction in Sri Lanka is negligible (Ariyarathne, 2016).

- Recycled materials

Road construction materials such as reclaimed concrete and demolition waste are currently not widely available in Sri Lanka (Gobieanandh & Jayakody, 2016). To improve their performance in pavement sub-base applications, some recycled concrete and demolition materials, such as crushed bricks, may need to be combined with other durable aggregates (Arulrajah et al.,2011). The use of various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) in the base and sub-base layers of roadways has proven to be a great alternative to natural aggregates without sacrificing infrastructure performance (Vieira & Pereira, 2015).

COWAN center, a major recycling company in Galle, provided recycled concrete and demolition materials. The COWAM Center is Sri Lanka's first venue for sustainable construction waste management. Crushing demolished building trash, screening, and subsequent removal of pollutants such as reinforcement, paper, and other materials provide recycled concrete and demolition waste (Gobieanandh & Jayakody, 2016). In general, the use of recycled concrete and demolition materials in the construction industry is progressing quickly in some nations, but more slowly in others. Recent studies have demonstrated the feasibility of using concrete and demolition materials as recycled aggregate and its acceptable performance. Demolition concrete is a low-cost, ecologically friendly alternative that promotes long-term sustainability (Katkar, 2017).

D. Advantages and disadvantages of sustainable road construction in Sri Lanka

- Advantages of sustainable road construction in Sri Lanka

The most common technique of dealing with concrete and demolition waste is to dump it in landfills, which is posing an environmental risk. As a result, using recycled material in road construction will provide significant environmental and economic benefits. When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant, and it would also benefit the environment significantly by reducing quarry mining (Gobieanandh & Jayakody, 2016). The reuse of these materials helps to alleviate some of the current concerns with waste generation and natural resource extraction. Waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance could all provide further benefits (Jayakody, Gallage, & Ramanujam, 2019). Coal ash has a low unit weight, which helps to reduce the settlement of embankments constructed on poor-bearing-capacity soil. Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money (Ariyarathne, 2016). These advantages include a reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal (Gidley & William, 1984).

- Disadvantages of sustainable road construction in Sri Lanka

Sustainable technologies are more expensive than traditional technologies (Athapaththu & Karunasena, 2018).

E. Challenges and opportunities of sustainable road construction in Sri Lanka

In 2007, the Sri Lankan Ministry of Environment and Natural Resources (MENR) introduced National Sustainable Development Strategies as a country-based and country-owned system for sustainable development (as cited in Athapaththu & Karunasena). Two socially responsible organisations that promote sustainable construction are the Green Building Council and the Sustainable Energy Authority. The current Acts fail to achieve true objectives of sustainable construction. While there are some provisions for environmental sustainability in construction, there are insufficient provisions for social and economic sustainability. The real roadblocks are political or external factors that prevent such laws and regulations from being updated (Athapaththu & Karunasena, 2018).

Contractors play a critical role in supporting sustainable construction by reducing negative consequences on the environment and society while increasing economic gains (Tan, Shen, & Yao, 2011). Contractors, on the other hand, face difficulties due to a lack of resources, technical skills, difficulty in achieving quality and profitability, a lack of understanding of sustainable features, a lack of appropriate building rules, and expensive capital expenses (Pitt et al., 2009). With rates that include expenditures for sustainability, a contractor cannot compete in competitive bidding. Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition (Athapaththu & Karunasena, 2018).

3. Methodology

The research methodology is a set of guidelines for achieving the study's goals by structuring the activities as they are outlined during the research process (Smith, Lowe, & Thorpe, 2002). However, for this study, a quantitative approach was adopted in order to identify the existing sustainable features of Sri Lankan Road construction. Closed-ended questions were used to validate the sustainable features of road construction, challenges, and opportunities identified through the literature review. Therefore, the purpose of having a questionnaire survey was to identify existing sustainable features for road construction in Sri Lanka.

The questionnaire survey was aimed at construction industry professionals with experience in both Sri Lankan Road construction and sustainable construction. As a result, non-random convenient sampling was chosen as the sampling method. At the end of

the survey period, data were obtained from 35 of the 50 questionnaires given, yielding a response rate of 70%. This survey was performed to achieve the 3rd and 4th objectives, which aimed to identify the existing sustainable features in the Sri Lankan Road construction. The distribution of ages of the respondents, academic qualifications and the year of experience they engage in the construction industry was demonstrated in Table 2. Accordingly, 94.3% of respondents had B.Sc. Degree and 5.7% of respondents had master's degrees. Among the respondents, 54.3% were in age Between 25 -35 years and 25.7% of respondents were in age less than 25 years. When considering the years of experience, most of the respondents had 1 -5 years of experience. All of these respondents were construction industry professionals such as engineers, quantity surveyors, architects, and project managers like that. The demographic distribution of the respondents is shown in Table: 2.

Table 2: Demographic distribution of the respondents

Variable	**Category**	**Frequency**	**Percentage**
Ages	Less than 25 years	9	25.7%
	Between 25 -35 years	19	54.3%
	Between 35 – 45 years	7	20%
	Above 45 years	0	0%
Year of experience	Less than 01 year	10	28.6%
	Between 01 – 05 years	12	34.3%
	Between 05 – 10 years	6	17.1%
	More than 10 years	7	20%
Academic qualification	Diploma	0	0%
	B.Sc. Degree	33	94.3%
	Master's Degree	2	5.7%
	Above Master's Degree	0	0%

The applicability of existing sustainable features in Sri Lankan Road construction was examined through the views of 35 experienced and qualified respondents in the Sri Lankan construction sector.

The level of applicability was determined using a five-point Likert scale: **1**-Strongly Disagree; **2**-Disagree, 3-Neutral; **4**-Agree; **5**-Strongly Agree. And a five-point Likert scale was employed, with **1**- Not applicable; **2**- Rarely applicable; **3**- Applicable in moderate level; **4**- highly applicable and **5**- Applicable in all times

The responses were used to score the discovered sustainable features, as well as their advantages, disadvantages, challenges, and opportunities, according to their level of applicability. In his study, Shash (1993) discovered that the Relative Importance Index (RII) is better for interpreting ranking data than indicators like mean and standard deviation. Furthermore, he defined RII as the weighted average of each factor divided by the dimensions' upper scale. The following equation is used to calculate the RII value of a certain collection of data.

$RII = \Sigma PiUi/n\ (N)$

Where;

[**n**- Number of participants; **Pi** -Participant's rank; **Ui**- Number of participants ranking project factor; **N**- Highest rank]

Table: 3 was used to identify the existing sustainable features in the Sri Lankan Road construction.

Table 3: Interpretation of RII values I

RII VALUE	**INTERPRETATION**
0-0.200	Strongly Disagree
0.200-0.400	Disagree
0.400-0.600	Neutral
0.600-0.800	Agree
0.800-1.000	Strongly Agree

4. Research Finding

A. Analysis of the Sustainable features normally used in Sri Lanka for road construction

The RII values for each sustainable feature normally used in road construction in Sri Lanka were calculated and ranked. The results of the analysis are shown in Table 4.

Table 4: Ranking of the existing sustainable features according to the RII values

Sustainable features normally used in Sri Lanka for road construction	RII	Rank
In Sri Lanka, various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) are used in the base and sub-base layers of roadways.	0.806	1
Sri Lankan construction industry has developed new biological materials and methods to improve the strength of soils without the use of chemical binders like cement	0.794	2
Cement blocks are most environmentally friendly road paving material used in Sri Lanka.	0.766	3
Industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures in Sri Lanka	0.754	4
Embankment filling can be done with coal ash. Sri Lanka uses coal ash for road construction embankment filling	0.720	5
Sri Lanka is having a significant process to waste management, including recycling construction waste	0.663	6
Cement Stabilised Rammed Earth is one such alternative construction material with a better probability of long-term sustainability in Sri Lanka	0.629	7
Locally accessible materials are clearly chosen for road construction in Sri Lanka	0.617	8
Sri Lanka use dust controlling methods for road construction	0.617	8
Sun energy harvesting, thermoelectric energy harvesting, geothermal energy harvesting, and composite energy harvesting can all be used to convert solar radiation, thermal gradients in pavement layers, and geothermal heat into useable energies. These methods are used in Sri Lanka	0.520	9
Xanthan gum biopolymer is used as an alternative material for road construction (mostly shoulders and subbases) in Sri Lanka because of their great strengthening efficiency and low environmental impact	0.451	10
Piezoelectric energy harvesters gather traffic-induced vibrations on pavements. This method is used in Sri Lanka	0.423	11

According to the ranking as shown in above Table:4, 'various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement)' 'new biological materials and methods to improve the strength of soils without the use of chemical binders like cement' can be considered as most used sustainable features to Sri Lankan Road construction. Moreover, 'Cement blocks, Industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement in concrete mixtures, Embankment filling done with coal ash, waste management, Cement Stabilised Rammed Earth, locally accessible materials and use dust controlling methods for road

construction presented nearly similar RII values, which had the high usage of Sri Lankan Road construction. 'Sun energy harvesting, thermoelectric energy harvesting, geothermal energy harvesting, and composite energy harvesting can all be used to convert solar radiation, thermal gradients in pavement layers, and geothermal heat into useable energies, 'Xanthan gum biopolymer is used as an alternative material for road construction and 'Piezoelectric energy harvesters gather traffic-induced vibrations on pavements' had the lowest RII values compare to others.

B. Analysis of the advantages of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each advantage of sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 5.

Table 5: Ranking of the advantages according to the RII values

Advantages of sustainable road construction in Sri Lanka	**RII**	**Rank**
The reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance	0.863	1
Sustainable road construction includes a reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal	0.834	2
The use of recycled material in road construction will provide significant environmental and economic benefits	0.823	3
When compared to natural aggregates, using concrete and demolition waste would also benefit the environment significantly by reducing quarry mining	0.800	4
When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant	0.783	5
Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money	0.754	6
Coal ash has a low unit weight, which helps to reduce settlement of embankments constructed on poor-bearing-capacity soil	0.743	7

According to the ranking as shown in above Table: 5, the 'reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance', 'reduction in the usage of virgin resources and a reduction in the environmental effect of waste disposal', 'Use of recycled material in road construction will provide significant environmental and economic benefits, 'when compared to natural aggregates, using concrete and demolition waste would also benefit the environment significantly by reducing quarry mining' can be considered as most common advantages of sustainable road construction. 'When compared to natural aggregates, using concrete and demolition waste would significantly lower costs because it is readily available and abundant', 'Construction of a road embankment using coal ash is less difficult than utilising natural soil and it saves both time and money and 'Coal ash has a low unit weight, which helps to reduce settlement of embankments constructed on poor-bearing-capacity soil showed almost similar RII values, which also can be considered as advantages of sustainable road construction.

C. Analysis of the disadvantages of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each disadvantage of sustainable road construction in Sri Lanka. The results of the analysis are shown in Table 6.

Table 6: Ranking of the disadvantages according to the RII values

Disadvantages of sustainable road construction in Sri Lanka	**RII**	**Rank**
High levels of investment are required to implement sustainable development	0.777	1
Sustainable technologies are more expensive than traditional technologies	0.754	2

According to the ranking as shown in above Table: 6, 'high levels of investment are required to implement sustainable development' and 'sustainable technologies are more expensive than traditional technologies' can be considered as disadvantages of sustainable road construction in Sri Lanka.

D. Analysis of the opportunities of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each opportunity for sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 7.

Table 7: Ranking of opportunities according to the RII values

Opportunities of sustainable road construction in Sri Lanka	**RII**	**Rank**
Green Building Council and the Sustainable Energy Authority help to promote sustainable development	0.794	1
The National Sustainable Development Strategies introduce by Sri Lankan Ministry of Environment and Natural Resources (MENR) as a country-based and country-owned system for sustainable development helps to promote sustainable development	0.669	2

According to the ranking as shown in above Table: 7, 'Green Building Council and the Sustainable Energy Authority help to promote sustainable development' and 'The National Sustainable Development Strategies introduce by Sri Lankan Ministry of Environment and Natural Resources (MENR) as a country-based and country-owned system for sustainable development helps to promote sustainable development' can be considered as opportunities of sustainable road construction in the Sri Lankan context.

E. Analysis of the Challenges of sustainable road construction in Sri Lanka

The RII values were calculated and ranked for each challenge of sustainable road construction in Sri Lanka. The findings of the analysis are shown in Table: 8.

Table 8: Ranking of challenges according to the RII values

Challenges of sustainable road construction in Sri Lanka	**RII**	**Rank**
A lack of understanding of sustainable features	0.891	1

Challenges of sustainable road construction in Sri Lanka	RII	Rank
Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition	0.874	2
Sri Lanka lacks a type-specific environmental rating system for road construction	0.869	3
A lack of technical skills	0.851	4
Difficulty in achieving quality and profitability	0.794	5
A lack of resources	0.789	6
Expensive capital expenses	0.789	7
The current Acts fail to achieve true objectives of sustainable construction.	0.783	8
The real roadblocks are political or external factors that prevent such laws and regulations from being updated	0.760	9
A lack of appropriate building rules	0.743	10

According to the ranking as shown in above Table: 8, 'A lack of understanding of sustainable features', 'Contractors are unwilling to provide projects in a sustainable manner if clients do not require it since they would lose bidding competition', 'Sri Lanka lacks a type-specific environmental rating system for road construction', and 'A lack of technical skills' can be considered as main challenges of sustainable road construction in Sri Lanka. Moreover, 'difficulty in achieving quality and profitability', 'A lack of resources', 'Expensive capital expenses', 'The current Acts fail to achieve true objectives of sustainable construction', 'The real roadblocks are political or external factors that prevent such laws and regulations from being updated' and 'A lack of appropriate building rules' showed almost similar RII values, which were challengers of Sri Lankan sustainable road construction.

F. Analysis of the applicability of existing sustainable features to Sri Lankan Road construction

The RII values for existing sustainable features' applicability to Sri Lankan Road construction were calculated and ranked. The findings of the analysis are shown in Table: 9.

Table 9: Ranking of the applicability of existing sustainable features

The applicability of sustainable features to Sri Lankan Road construction	RII	Rank
New biological materials and methods to improve the strength of soils	0.766	1
Cement blocks	0.766	2
Concrete and demolition materials as an alternative material	0.754	3
Industrial wastes like fly and bottom ashes as an alternative material	0.737	4
Dust controlling methods	0.714	5

The applicability of sustainable features to Sri Lankan Road construction	RII	Rank
Embankment filling can be done with coal ash	0.651	6
Cement Stabilised Rammed Earth	0.600	7
Used local materials (materials which are available in construction area)	0.600	8
Energy harvesters (Sun energy, thermoelectric energy, geothermal energy, Piezoelectric energy and composite energy)	0.594	9
Xanthan gum biopolymer as an alternative material	0.463	10

According to the ranking as shown in above Table: 9,' New biological materials and methods to improve the strength of soils', 'Cement blocks', 'Concrete and demolition materials as an alternative material', 'Industrial wastes like fly and bottom ashes as an alternative material' and 'Dust controlling methods' can be considered as most practicable sustainable features to Sri Lankan Road construction. Moreover, 'Embankment filling can be done with coal ash' and 'Cement Stabilised Rammed Earth', and 'Used local materials', presented nearly similar RII values, which had high applicability of Sri Lankan Road construction. 'Energy harvesters (Sun energy, thermoelectric energy, geothermal energy, piezoelectric energy, and composite energy)' and 'Xanthan gum biopolymer as an alternative material' had the lowest RII values compared to others.

5. Discussion

The intention of the questionnaire was to identify the existing sustainable features in the Sri Lankan Road construction. According to the findings, the level of usage was considered to rank the sustainable features. When considering the RII values, it is perfect that all the sustainable features have an average level of usage having RII value more than 0.5 excluding Xanthan gum biopolymer and piezoelectric energy harvesters gather traffic-induced vibrations on pavements. This suggested that all the identified sustainable features excluding those two sustainable features available in the Sri Lankan Road construction. Furthermore, according to the findings, the advantages of sustainable road construction were ranked according to the level of applicability. When considering the RII values, it becomes evident that all of the advantages have an average level of applicability of higher than 0.7. As per the results, the disadvantages of sustainable road construction were ranked with the level of applicability. When the RII values are analysed, it becomes evident that all of the disadvantages have an average level of applicability of higher than 0.7.

According to the findings, the opportunities for sustainable road construction were ranked according to their level of applicability. When considering the RII values, it's evident that all of the opportunities have a high level of applicability, with an RII value greater than 0.7. The level of applicability of the sustainable features was ranked based on the findings. When considering the RII values, it's evident that all of the sustainable features, with the exception of Xanthan gum biopolymer as an alternative material, have an average level of applicability of more than 0.5. This indicates that, with the exception of these sustainable features, all of the identified sustainable features can be implemented in the Sri Lankan context without any doubt.

6. Conclusion

Environmental pollution is a huge issue around the world, and it has a substantial impact on human health. The concept of sustainable development connects development and the

environment. Sustainable construction can provide a number of advantages and have three components such as social, economic, and environmental. Furthermore, improved air and water quality, lower energy consumption, and lower water consumption are environmental advantages. Economic benefits include lower operating and maintenance costs, higher sales prices, and increased health and comfort. Road design is typically based on technical and commercial considerations, with social and environmental consequences being disregarded. Therefore, this paper's aim of introducing sustainable development for road construction in Sri Lanka was achieved through accomplishing three main objectives.

A comprehensive study of the sustainable features normally used in the world for road construction was reviewed through the literature. Sustainable features normally used in the world for road construction were identified over two main categories such as the material used and the construction process. Furthermore, under material used category identified three main sustainable features such as recycled material, alternative materials, and used local materials (materials that are available in the construction area). Identification of these key features provided the foundation for this paper. Advantages and disadvantages of sustainable road construction were identified according to the identified sustainable features used in the world for road construction. The reuse of these materials helps to waste prevention, energy conservation, natural mineral resource conservation, and landfilling avoidance, reclaimed roadways lower material transportation distances then further savings in the transportation industry, and when compared to natural aggregates, using concrete and demolition waste would significantly lower costs are some of the identified advantages globally and with reference to Sri Lanka. Identified disadvantages are a significant amount of money is required and High levels of investment are required to implement sustainable development.

When considering the opportunities for sustainable road construction, as per the analysis, the green Building Council and the Sustainable Energy Authority help to promote sustainable development, and The National Sustainable Development Strategies introduced by the Sri Lankan Ministry of Environment and Natural Resources were identified as opportunities of sustainable road construction. However, in expert interviews, respondents mentioned that still no contribution or procedure from the government and other relevant authorities to sustainable development for road construction in Sri Lanka. Various types of concrete and demolition materials (recycled concrete aggregates, crushed bricks, and reclaimed asphalt pavement) used for road construction, cement blocks pavement, and industrial wastes like fly and bottom ashes are frequently used to reduce the amount of cement, embankment filling can be done with coal ash, waste management, cement Stabilised Rammed Earth, use dust controlling methods, xanthan gum biopolymer, used local materials and renewable energy were identified through literature review. As per the questionnaire analysis, xanthan gum biopolymer and piezoelectric energy harvesters gather traffic-induced vibrations on pavements were not used in Sri Lanka.

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Challenges Encountered in Teaching English in Rural Sri Lankan Secondary Schools: A Case Study of Bandaranayake Secondary School in Kiriibbanwewa, Moneragala District

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Abstract*: English language competency is a necessary skill in Sri Lanka. With this in mind, successive governments have implemented various approaches to strengthen English Language Education in the rural outskirts of the country. These initiatives include projects like 'speak English our own way' and attempts to recruit candidates as teachers with higher diplomas in English in order to address the dearth of qualified English teachers. However, it is unclear to what extent these efforts have been successful. This study sets out to examine the challenges encountered in English teaching and learning in rural Sri Lanka today, taking Bandaranayake Secondary School in Kiriibbanwewa, Moneragala District as a case study. Data was collected through ethnographic research methods utilizing qualitative observational data and semi-structured interviews, and was then analyzed using thematic analysis. Findings demonstrate that students at Bandaranayake Secondary School, regardless of their grade-level, lack of basic English proficiency beyond an A1 level. This language outcome is a result of teaching methods that prioritize textbook-based reading and writing over speaking and listening skills, while emphasizing accuracy over fluency. In order to address this gap between ELT methods and outcomes, researchers recommend conducting ELT training with English teachers in rural secondary schools through tertiary educational institutes local to the area.*

Keywords:*English, Language, Education, Rural, Secondary, Schools, Sri Lanka*

1. Introduction

After the British brought English to Sri Lanka in 1815, the language began to function as a new criterion for stratifying society, providing status, wealth, and power to rich, upper-caste, urban males (Canagarajah 1995, p.193). Today, English language fluency is still a privilege of a handful of people in Sri Lanka, while at the same time serving as a gatekeeping process in accessing jobs and higher education as English cannot be separated from Sri Lanka's economy or communication and technology systems. As stated by Attanayake, English "has marked its unchallengeable status with its expanding and accommodating nature in the education and employment sectors, inviting policy changes at the national level" (2017, p. 08). Although Sri Lankan students learn English starting in grade 3, most students lack the language competency required for social, economic, and political mobility by the time that they graduate from secondary school or university. The Sri Lankan Ministry of Education notes that "English has been taught for almost over 11 years as a core subject [in the Sri Lankan education system], but the student performance is not at a very satisfactory level" (Ministry of Education, Sri Lanka, 2018). Attanayake locates this dissonance in English teaching methods: "The answers to the how and why questions behind this phenomenon are generally known, scientifically and empirically proven: the problems are found in the teaching methods, the materials in use or both" (Attanayake, 2017, p. 02).

There is a clear gap between the need for English skills and the actual English teaching methods and outcomes in Sri Lanka. This gap is particularly wide in the rural context. As Indrarathne and McCulloch note, "schools in rural areas and in certain provinces tend to fare worse [when it comes to the status of English language acquisition] than those in the urban areas and in the south and west of the island." (2022, p. 38). Furthermore, while more teachers at rural schools achieve below a B2 CEFR level than those in urban schools, rural school teachers still have less access to teacher trainings than those in urban areas. (Indrarathne and McCulloch, 2022, p. 31, 34). These realities demonstrate that there are both significant challenges and opportunities in improving ELT in rural Sri Lanka.

Understanding the existence of this problem, this case study sets out to examine the extent to which current English Language Teaching (ELT) methods at Bandaranayake Secondary School in Kiriibbanwewa, Moneragala result in successful learning outcomes for students' English reading, writing, listening and speaking skills. In assessing these methods and outcomes, this study also seeks to provide recommendations for improving ELT in rural Sri Lanka.

2. Literature Review

Since the 19th Century, a myriad of different language learning approaches have been adopted in Sri Lanka and around the world. These approaches have later been critically questioned to determine whether more emphasis should be given to traditional methods – accuracy-based – or non-traditional methods – fluency-based. This paper will define these approaches and terms in the paragraphs that follow, also elaborating upon their respective pros and cons.

Language acquisition is a process in which people utilize their own intellect and thinking processes to find the rules of the languages that they are learning. Constructivist theory underscores that learners must be active participants in their learning journeys and that knowledge is built through experiences. In keeping with this understanding, non-traditional approaches to language teaching are guided by affect, activation of schema, discussions, real-world examples, stimulation of kinesthetic senses, negotiation of meaning, etc. In non-traditional approaches, learning activities are designed to ignite fluency through comfort, enjoyment, and stimuli (functional reactions), while accuracy (no grammatical errors allowed) is given less prominence.

'Gattengno's silent way' is one such non-traditional, fluency based language learning approach in which the teacher either speaks very little or remains silent while eliciting and subtly reinforcing verbal output from learners. The teacher emphasizes progress, not perfection. Student errors are considered to be natural and indispensable in this process. At the same time, students are encouraged to explore the language with the option to self-correct their errors; the teacher would intervene to correct these errors only as a last resort. As Freeman explains, "students make errors when they first begin speaking and teachers are expected to be tolerant and only correct major errors. Even these should be corrected unobtrusively" (2000, p.115).

In non-traditional methods, such as total physical response, students learn by observing actions as well as by performing the actions themselves. This approach corresponds to the constructivist emphasis on memory stimulation and motor activity, allowing students to act in response to their listening skills without yet having to actually speak. In other approaches, such as in communicative language teaching, authentic communication is encouraged amongst students. Students are urged to work in groups so that they begin to feel affinity towards learning from each other through cooperation. In this process, errors are allowed and considered to be a natural result of the development of communication abilities, especially where students with low linguistic knowledge can nonetheless communicate effectively (Freeman 2000). During these fluency activities, the teacher may make a note

of common errors and return to them later with an accuracy-based activity. This testifies to the fact that fluency can be fostered amongst students without focusing on students' errors.

Community language learning is a non-traditional method that is consistent with the notions of constructivist and cognitive theories, which builds relationships, student confidence, community, self-reflection, independence, decision making, etc. Per Curan (as cited in Freeman 2000), who advocated for this method, notes that the strategy does not require any textbooks. Instead, there is a group of learners sitting in a circle who themselves initiate a conversation in the target language. They are aided by the teacher who acts as a counselor while language data is recorded. The most particular aspect of this method is that, as Freeman (2000) puts it, teachers work in a non-threatening way. One option is for teachers to correctly repeat what the student stated incorrectly and to not focus on mistakes in order to maintain a polite and non-defensive connection between students and teachers. For example, if a student says, "I did not go school yesterday," then the teacher can respond to the student and say, "Ah you did not go *to* school yesterday?". In this situation, the learner's mistake is rectified by repeating what the learner uttered without drawing undue attention to their error, since the primary concern is to foster fluency, not accuracy.

'Desuggestopedia' (Lozanov, 1991) is another prominent non-traditional teaching method. This strategy pays close attention to pupils' feelings and psychological barriers. Indirect positive comments are given to boost students' self-esteem and help them believe that they can succeed. The usage of fine arts in turn heightens their mental faculties. Most importantly, learners' errors are corrected with tolerance and a 'soft' voice for "the activities are varied and do not allow the students to focus on the form of the linguistic message, just the communicative intent" (Freeman, 2000, p.85). This clearly elucidates the fact that the foremost importance is given to fluency while overlooking accuracy.

Okazaki (2005) succinctly summarizes another non-traditional ELT approach: problem-posing within Paulo Freire's theory of critical pedagogy. "[Freire] proposed that when literacy is taught as a collection of decontextualized, meaningless skills…the learners cannot be reflective or bring their own experiences to the learning process…Freire calls this the 'banking model' of education. He suggests instead that a 'problem-posing' process makes literacy immediately relevant and engaging by focusing on problematic issues in learner lives" (2005, p. 177). In problem-posing, teachers choose class content that is directly linked to students' lives and experiences. This approach necessarily makes class more engaging and motivating to learners – because they can relate to it. Ira Shor explains, "We are what we say and do. The way we speak and are spoken to help shape us into the people we become. Through words and other actions, we build ourselves in a world that is building us" (1999, p. 1). Shor argues that helping students to understand the power of language in building their own, their communities', and their societies' futures is an integral part of the ELT task because it connects language learning to students' lives, increasing students' motivation to learn.

Thus, it could be postulated that non-traditional approaches and methods leading to a generation of students who focus more on fluency than on accuracy would positively impact learners in multiple ways. It has been empirically found that most South Asian Learners today suffer from Foreign Language Anxiety (FLA) and Language Attitude Anxiety (LAA) as a result of teachers pointing out individual and group errors constantly (Attanayake, 2020). In fact, in Sri Lanka, "a large majority of students [86.8%] are reluctant to speak English as they are either afraid or shy or both that others will laugh at their mistakes" (Attanayake, 2020, p. 03). Thus, it is of "it is of paramount importance to build learner confidence to speak English as part of our teaching methodology" (Attanayake, 2020, p. 03). In tandem with the Cooperative Language Learning (CLL) technique, creating a 'safe'

classroom environment creates space for students to escape FLA and LAA: ; "the teacher's transference from an 'ordinary teaching position' to that of an observer who 'overlooks' the errors and mistakes found in student speech is highlighted as one of the key characteristics'' in this process (Attanayake, 2019, p. 6). These studies demonstrate that a greater emphasis on fluency over accuracy will improve learners' ability to communicate in, learn, and eventually master a foreign language.

The study by Durdans et al (2017) exemplifies how "Sri Lanka faces several complex systemic challenges when it comes to the status of English language in general education". He emphasizes how these disparities are mostly reflected in the dissemination of resources in different parts of the country. Schools in rural areas tend to have fewer resources than those in the urban, south, and west parts of the island (Dundar et al., 2017). In rural areas, there is often a lack of qualified English teachers. "Although newly qualified teachers are required to spend time working in a rural area, they tend to then transfer to what are seen as more desirable locations, meaning that rural schools not only lack English teachers, but that the teachers that they do have may be inexperienced (Dundar et al., 2017), leading to lower-quality teaching. This problem is compounded by a relative lack of teacher training in rural areas (Little et al, 2018)" (38).

As demonstrated by these empirical studies, the present-day English teaching context in Sri Lanka demands change. Attanayake (2019) points out that after more than 70 years of teaching English as a second language in the educational system, Sri Lanka did not achieve a 50% pass rate in O/L English until 2017, when it narrowly passed 50%. Revisiting teaching methodology is one of the key remedial factors in addressing this problem.

An empirical study reviewed the English Language test papers from the 2016 and 2017 GCE O-Level and 2017 GCE A-Level in English Language. This study demonstrates how public tests are designed to assess language proficiency (grammar and vocabulary), reading comprehension, and writing – but not listening and speaking skills (Indrarathna, 2020). This exemplifies the overwhelming prominence given to reading and writing over speaking and listening in the classroom and in testing across Sri Lanka. And yet, this approach has not been shown to deliver successful outcomes in language proficiency. "The preliminary studies conducted in Sri Lanka, starting from 2007/2008 through the past decade, continually demonstrate that the learners' most sought-after skill is learning to speak in English" (Attanayake, 2017, p. 22). And yet, the most commonly taught skills to students are reading and writing. This raises the following inevitable concern: what is taught to the learners is not actually what they need or want.

Scholars in their studies of secondary schools in particular explain that "it is important for teachers to bring in authentic speaking samples to class and, also most importantly, highlight natural features of speech" (Indrarathna, 2020, p.02). This includes pauses, repetitions, back-channelling, hesitations etc. Script based speaking examples given in books lack these authentic scenarios and thus learners find it difficult to improve their competency and are unable to handle real-life speaking contexts. For these reasons, it is essential that learners' needs are meticulously studied in keeping with the notions of post method language teaching and that materials are customized accordingly before proceeding with teaching methodologies.

3. Methodology

In this case study, ethnographic research methods utilizing qualitative observational data and semi-structured interviews with Bandaranayake Secondary School English Teachers have been used. Qualitative data was collected while observing classes at Bandaranayake Secondary School over the course of four months from April to August of 2022. The relevant observations from this period have been incorporated into the findings below. In order to include teachers'

perspectives on the extent to which current English Language Teaching (ELT) methods at Bandaranayake Secondary School result in successful learning outcomes for students'

Table 1.

Codes	Categories	Concept/Themes
Singing songs	ELT Methods	ELT Curriculum
Group work		
Pair work		
Repetition		
Presentations		
Videos		
Concept checking questions		
Discussions		
Field trips		
Pair work		
Repetition		
Presentations		
Demonstration		
Matching varieties		
Visualizing		
Summarizing		
Highlighting		
Underlining		
Project-based learning		
Re-reading		
Practice testing		
Conduct extra classes for weaker students	Possible Improvements to ELT	Teachers' Perceptions of Effective ELT
Emphasis on the alphabet		
Help students feel less fearful of speaking English		
Make class more fun		
Use competitive methods to motivate students		

Thematic Analysis of Interview Data

English reading, writing, listening, and speaking skills, Bandaranayake English teachers were asked to respond via voice message to the following four questions: 1) Can you explain how you teach your English class? What techniques and methods do you use to teach English? (ex: showing video material, singing etc); 2) When students leave the school, how strong are each of their skills in English? Reading? Writing? Listening? Speaking?; 3) Which English skills (reading, writing, speaking and listening) do you think are most important?; 4) How do you think English teaching at Bandaranayake could be improved?. Responses to these questions have been coded and categorized using the thematic analysis method in Table 1. Where relevant, responses have also been transcribed.

4. Discussion

In order to retain teachers' anonymity, they are referred to throughout this paper by the first letter of their first names. S, T, and D have been working at Bandaranayake Secondary school for over twenty years, five years, and five years respectively. Below, Table 1 depicts teacher responses to the semi-structured interview questions.

Drawing from teacher responses, Table 1 seems to show a balanced curriculum employing both traditional and non-traditional approaches to all four language skills (reading, writing, speaking, and listening). Speaking- and listening-based experiential approaches such as 'project-based learning', 'field trips', and 'presentations' can be observed. Table 1 shows that these methods are balanced with traditional reading and speaking approaches such as're-reading', 'summarizing', and 'matching varieties.' However, on-the-ground observations depict a different reality.

When comparing the respective teachers' responses, fundamental differences in teachers' perceptions of effective ELT, especially in terms of the students' strengths and the most important English skills, become visible. For example, S states that students are strongest in speaking and listening, while T argues the opposite – that students are most competent in reading and writing. Similarly, S posits that reading and writing are the most important ELT skills, while T contends that speaking and listening are most important. In combination with her practical emphasis on extra classes on the alphabet, this data shows that S prioritizes written over spoken English. T on the other hand, highlights the need to help students feel less fearful of speaking English, showing that her teaching approach prioritizes spoken over written English. Both the discrepancy in assessment of strength and the disagreement on what is important in teaching English are cause for concern in Bandaranayake Secondary School's English curriculum. Researcher's observations below corroborate T's perception of student outcomes.

"I asked four students from grade 12, 'How old are you?'. All four students answered, 'Sixteen.' This seemed incorrect to me, so I wrote the number 16 on the board. 'No,' they said. 'Are you eighteen?' I wrote the number 18 on the board. 'Yes, we're eighteen.' The 12th graders could not correctly tell me their age."

"I asked students what the subject of their previous lesson had been. They responded, 'Uncountable nouns.'"

"One of the English teachers told me that the older students didn't want to work with me because they wanted to focus on their textbooks so that they could prepare for their O- and A-level exams. The textbook itself emphasizes reading and writing exercises with very little focus on speaking or listening."

These interactions show that 12th grade students at Bandaranayake are unable to understand and respond to basic questions in English, such as "How old are you?". Furthermore, these older students are largely uninterested in improving their spoken English; they would prefer to improve their written language skills so that they can perform well on their exams. This lack of motivation in speaking demonstrates that students do not understand the importance of being able to speak English in their own lives.

"At the beginning of class with grade 9, the regular teacher, D, asked if I wanted to work on grammar points. I suggested that we work on speaking and listening instead, as it is unusual for students to be able to practice their English with a native speaker (myself). I asked students to get into partners and then ask and answer the following question: 'What did you do today?' The students didn't understand the question. D spoke up, 'they aren't very good at speaking or listening, but they understand the textbook well.'"

Once again, this moment demonstrates students' struggle to successfully listen and speak, providing another piece of evidence consistent with T's perspective that students are weak in listening and speaking. Furthermore, by first suggesting work on grammar points and later highlighting students' ability to work in the textbook, D displays curricular focus on written over spoken English. In this way, two of the three English teachers – a majority – at Bandaranayake Secondary School prioritize reading and writing over speaking and listening in their ELT methods.

As explained by Indrarathne and McCulloch, "Pressure on teachers to focus on preparing students for national exams mitigates against developing listening and speaking skills, as these are not yet tested in the O- and A-level exams" (2022, p. 13). Because O- and A-level exams score students based on their reading and writing skills, it makes sense that S and D would believe that these skills are most important, and that this approach would then result in weaknesses in students' spoken English. Indrarathne and McCulloch go on to say that "Most students, by Grade 11, achieve only CEFR level A1 (basic user). Speaking and listening scores are particularly weak" (2022, p. 13).

Being unable to correctly state your age or explain what you did during the day is consistent with an A1 level. Given this fact, it is particularly concerning that S has evaluated students' speaking and listening skills as strengths. This perspective, especially of a teacher working at the school for over 20 years, indicates that assessment tools at Bandaranayake are not effective. In this way, not only do the school's ELT methods and curricula need improvement, but assessment methods must change as well.

"T asked me if I could do a listening exercise. She gave me a textbook from which to read. I read the passage three times, a discussion of two British men's experience visiting Sri Lanka. Based on my reading, students were asked to fill in the blanks in the text in their own workbooks."

"T suggested that I conduct class for the day using the textbook, a lesson on Leonardo Da Vinci and the Mona Lisa. A passage explained basic information about the artist and reading comprehension questions followed."

Such grammar and textbook-based lessons, even for the development of speaking skills, as compared to game-, experiential-, or discussion-based lessons, show thematic focus on accuracy over fluency in foreign language acquisition at Bandaranayake Secondary School. In addition, both textbook lessons that T suggested are Euro-centric in their content. The first takes the point of view of British tourists and the second analyzes the life and work of an Italian artist. Neither of these lessons focus on the actual lived experiences and contexts of students, taking a 'banking model' instead of a 'problem posing' model of education, as described by Okazaki and Freire. As a result, it might be difficult for students to actually connect the usefulness of English to their own lives; English usage is instead located elsewhere, beyond students and their community. Therefore it follows logically that motivation to learn this foreign language amongst students is low; teachers are not making apparent the utility of English right here in Sri Lanka.

At the same time, teachers at Bandaranayake Secondary school do show some interest in and occasional practice of non-traditional methods that foreground fluency over accuracy.

"T showed me the murals that she was starting to draw on the walls of the language learning room. 'This way we can use the classroom itself to teach English,' she said."

In this moment, T practices the "visualizing" ELT method that she had described in her semi-structured interview. Murals allow students to see English on their walls and read these sentences and words again and again to acquire vocabulary and sentence structure. This approach also ideologically opposes the suggestion to teach lessons on British tourists and Leonardo Da Vinci as it situates English directly within the lives of students. This mural teaching method therefore constitutes a fluency based, non-traditional approach to English language learning.

In her semi-structured interview, T noted that students are 'fear[ful]' to speak English, which is consistent with Attanayake's (2020) findings on South Asian English Learners. However, T states that she hopes to help her students feel less fearful. T is therefore indicating in her observation of fear and her desire to assuage it, in combination with her mural teaching approach, that she might be open to more non-traditional fluency based ELT methods.

5. Conclusion

These findings demonstrate that Bandaranayake Secondary School's English program prioritizes reading and writing over speaking and listening skills, while emphasizing accuracy over fluency. After six years of English classes at Bandaranayake Secondary School, students have skills consistent with an A1 level (basic user), indicating little to no improvement since they began their classes in grade 6. Further, although 12th grade students speak in English to an A1 level (basic user), one teacher assesses their speaking and listening skills as a strength. This mismatch between teacher assessment and student performance, combined with teaching methods that are ineffective at producing outcomes beyond an A1 level illustrates that Bandaranayake's approach to ELT must change if it is to effectively improve students' English proficiency.

Given this apparent need for improvement in teaching methods and outcome assessments along with the dearth of teacher trainings in rural Sri Lanka, it is posited that non-traditional fluency-based ELT teacher trainings for Bandaranayake Secondary School teachers through local tertiary institutions' ELT departments would be beneficial. Such a collaboration could serve as a model for the improvement of ELT methods and outcomes in rural Sri Lanka, especially in areas in which tertiary institutions are located. As such institutions teach in the English medium, teach the subject of English through their ELT departments, and have academics who conduct research in ELT best-practices, this kind of an

exchange of methods and knowledge would not only improve English fluency at the secondary school level, but would also improve students' English capacities if they are to enter university later in their academic careers.

Furthermore, tertiary institutions and secondary schools are already connected in their academic practices. The National Institute for Education (NIE), which is responsible for developing English curricula and teacher training (Indrarathne and McCulloch 21, 2022), is governed by both a council and academic affairs board made up of experts and academics. These academics include an acting vice chancellor, former vice chancellor, retired department chairs, retired professors, professors, and senior lecturers (NIE Academic Affairs Board 2022, NIE Council 2022). In this way, academics in tertiary education are already intimately linked to English teaching methods in secondary schools. Therefore, ELT workshops directly connecting tertiary and secondary school educators would be within the scope and convention of existing practice and policy.

Pursuing such an improvement to English capacity in Sri Lanka before students enter university would help to address the industry need for graduates fluent in English. In this way, English teacher training conducted by tertiary institutions with secondary schools has the possibility to positively impact both learning and employment across the country.

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Acknowledgements

The researchers would like to thank the principal, teachers, and students from Bandaranayake Secondary School who provided their perspectives and time in order to make this research possible. We would also like to thank KDU, Southern Campus and the US-SL Fulbright Commission for sponsoring this research.

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Implementing 6R Principles of the Circular Economy Concept in Sri Lankan Construction Industry

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Abstract*: This study is focused on implementing 6R principles of the circular economy concept in Sri Lankan construction Industry and provides a criteria, that can be applied to uplift the adaptation towards the circular economy concept in construction projects. Circular economy concept in the construction industry can be considered with the application of sustainable construction approaches to the whole construction process, from material extraction through building and infrastructure planning, design, and construction, as well as the ultimate demolition and the waste disposal. The purpose of the circular economy concept is to create economic strategies that allows to regenerate the materials, resources, and components while retaining their worth for as long as feasible. There are set of principles in the circular economy concept that have been identified in the literature, called 6R principles; reduction, reuse, recycle, redesign, re-classification and renewability. A qualitative data collection approach was followed to collect data and the semi-structured interviews were conducted among construction professionals. It was highlighted at the interviews that, the circular economy concept is a very new and unpopular concept to Sri Lanka and the applicability of the principles of circular economy is in the initial stage. Mostly, 3R out of 6R (reduction, reuse and recycle) principles have been applied for some of the mega-scale sustainable construction projects and the 6R principles are very new to the Sri Lankan construction industry. Lack of awareness on sustainable concepts like circular economy among construction professionals, their willingness to follow the traditional project management practices and consideration only on the initial cost of a project, than the life cycle cost of a project are the barriers which were highlighted at the interviews.*

Keywords: 6R Principles, Circular Economy, Construction Industry, Sustainability

1. Introduction

A construction can be identified as applying and management of capital, assets, specialized employees, materials, machineries and tools to get a required output using them effectively by tracing suitable drawings, technical schedules, and contractual aspects to fulfil an expectation of a client (Merrit, Loftin and Ricketts, 1996). Agu (2015) states that, the construction is a full-service sector whose goal is to turn the architect's plan and specifications into a finished project that the client approves.

Construction and demolition waste generates in a higher amount throughout the life cycle of buildings, due to lack of concern on waste disposal and waste reduction in early phases of a project (Esa, Rigamonti and Magrini, 2016). This is mostly due to usage of a linear economic model in the construction sector, and specially based on the concept of "take, make and dispose (EMF, 2015). In contrary, another economic model that has gained popularity in recent decades is the Circular Economy (CE), which is based on improved resource management (Pomponi and Moncaster, 2016). Further, the literature shows that, in order to use this concept widely in the construction industry, more information and tools must be developed (Lacy and Rutqvist, 2014).

CE in the construction is concerned with the of sustainable development techniques to the whole construction process, from material

extraction through building and infrastructure planning, design, and construction, as well as ultimate demolition and waste disposal (Tan, Shen and Yao, 2011). The primary purpose of CE is to create an economic structure that allows to regenerate materials, goods, and components while retaining their worth for as long as feasible (Grdic, Nizic and Rudan, 2020). According to the models in CE, at the end of a life of a building, the materials of that particular building should be reused and stored in the material bank. As a closed loop stored demolished materials can be used for the construction of new structures and buildings.(Hopkinson *et al.*, 2018).

Moreover, CE is expected to deliver economic advantages in the form of improved economy, employment growth, material savings, and decreased risk of material supply and price instability (Repp, Hekkert and Kirchherr, 2021). Sustainable construction can be identified as concepts to reach ultimate sustainable aims such as environmental responsibility, social awareness, and the economic profitability to carry forward in the built environment and the amenities for the community (Ali and Nsairat, 2009). Construction industry in Sri Lanka has been expanded dramatically during the previous decade, but concurrently it is facing environmental problems due to unsustainable construction methods (Karunasena, Athapaththu and Ekanayake, 2016). With increased construction activities, it is better to expect higher amount of resource consumption and waste disposal systems in the future. So that, it can be difficult to pay attention on sustainability of construction aspects in Sri Lanka (Liyanage *et al.*, 2019). However, Sri Lanka has more far to go before meeting global requirements for sustainable construction concepts. As indicated by the scarcity of publications in this area, sustainable construction concepts such as CE are relatively peculiar concepts for construction projects in Sri Lanka (Wijewansha, Tennakoon and Waidyasekara, 2021). Sustainable construction provides an excellent response to environmental and socioeconomic problems because it applies sustainable strategies to the entire construction period, from extraction of raw materials to planning, design, and construction of buildings and infrastructure to the demolition and waste management at the end of a project (Athapaththu and Karunasena, 2018). However, as a result of unsustainable development throughout the previous decades and its continuation, Sri Lanka faces not only environmental but also economic and social problems (Karunasena, Athapaththu and Ekanayake, 2016).

The main objective of this study is to increase the implementation level of circular economy concept and its principles for construction projects in Sri Lanka.

2. Literature Review

A. Circular Economy Concept

CE is defined as "a restorative or regenerative industrial system by intention and design". It replaces the idea of end-of-life with restoration, moves to the use of renewable energy, prevents the use of hazardous chemicals that hinder reuse, and attempts to reduce waste via improved design of materials, products, systems, and business models" (EMF, 2015). CE concept has been acclaimed internationally because the old linear economy concept, the "take make discard" paradigm, has repeatedly failed to satisfy the issues of the global sustainability, which demands sustainable economic development, environmental preservation, and the social well-being (Jawahir and Bradley, 2016). According to Kirchherr, Reike and Hekkert (2017), CE concept specifically focused on reuse, recycling and re-generate of materials and resources, when producing and using them for a purpose (Ghisellini, Ripa and Ulgiati, 2017). Also, CE concept helps to increase the life cycle of buildings by redesigning buildings with minimum changes and focuses on using renewable energy in an efficient manner (Birat, 2015). The life span of building will be expand by applying R principles in CE concept and it gives a better value for the construction project (Grdic, Nizic and Rudan, 2020).

According to the literature, CE adoption in the Sri Lankan construction industry is still in its early stages and there are three major processes: the three R principles of reduction, reuse, and recycling (Reh, 2013), which successfully contribute to the reduction of demand on global resource supplies, supporting sustainability in construction projects (Jawahir and Bradley, 2016).

B. R Principles in Circular Economy

Initially, the circular economy concept was founded on the 3R principle (reduce, reuse, recycle), but it has lately neen advanced into the 6R principle (reduce, reuse, recycle, re-design, re-classification and renewability) (Jawahir and Bradley, 2016).

The purpose of reduction is to use fewer resources per unit of value generated or to replace a higher proportion of toxic chemicals with less harmful substances per unit of value created (Ghisellini, Ripa and Ulgiati, 2017). During the pre-construction stage, the reduction principle may be put into effect by applying methods such as designing out waste, strategic design for the effective project life cycle, and design components for uniformity and modularity (Adi and Wibowo, 2020).

The "reuse" principle describes that, the reuse of any products and items that are not wasted and are reused for the same work of which they were originally used, as well as relationships between several industries in which by-products and waste from one industry can become resources and raw materials for another (Ma *et al.*, 2014). Applying of reuse principle have the ability to uplift the requirement of remanufactured items, tempt the creation of durable products with several reuse cycles, and motivate businesses to apply product take-back programs (Ghisellini, Ripa and Ulgiati, 2017).

Recycling is utilized to recover materials with usable values, resulting in a reduction in trash that must be handled or disposed (Birat, 2015). Further, the large corporations like Unilever have already produced design principles like "Design for recyclability", is used to create items, that may be reused and recycled several times (Patwa *et al.*, 2020).

The "redesign" idea highlights the significance of the design process in identifying methods to reduce trash disposal in landfills. This concept focuses on the design of objects that can be disassembled and reused when their useful lives are over (Ghisellini, Ripa and Ulgiati, 2017).

The "reclassification" principle divides materials into two categories: "technical" and "biological". The technological components are intended to be reused at the termination of the products' life cycle but the biological materials, which are often non-toxic, are intended to be returned safely to the biosphere or placed in a cascade of subsequent uses (Wijewansha, Tennakoon and Waidyasekara, 2021).

"Renewability" acknowledges renewable energy as a CE's major source of energy, and higher usage of toxic waste, when producing energy can be reduced by applying renewables (Geng *et al.*, 2013). In terms of the renewability principle, building design that supports the installation of circular economy principles of renewable energy sources may be recognized as a likely option that can be used at the pre-construction stage (Hargroves *et al.*, 2014).

C. CE in the Construction Industry

Over half of all waste created in the construction sector is linked with end-of-life activities and operations, predominantly demolition (Kibert, 2016). However, only around 30% of these components are reused or recycled (Macarthur, 2013). Present conditions and practices in the construction sector imply that CE can help the industry's sustainability. The first step is to understand how CE may help the construction sector, given that CE can help reduce the environmental effect of building operations (Ghisellini, Ripa and Ulgiati, 2017). The structures are frequently thrown away at the end of their life cycle, recent studies are not agree with that, reusing of materials in construction projects is unlikely. As an example, 45.8 million tons of waste generated annually,

as a result of demolition and construction (Akanbi *et al.*, 2018).

Present conditions and behaviours in the building sector show that, a concept like CE have the ability to help the industry to be more sustainable. The first step is to understand, how CE may help the construction sector, given that CE can help to reduce the environmental effect of building operations (Ghisellini, Ripa and Ulgiati, 2017). Moreover, resource productivity should be the key emphasis of the construction sector in the future, which might be accomplished by implementing CE principles inside the construction sector and CE adoption in the building sector is still in its early stages (Smol *et al.*, 2015). This is certainly relevant for developing countries like Sri Lanka, as indicated by the paucity of literature on the use of CE principles for the construction projects in Sri Lanka. Further, literature state that, 6R principles in CE have the flexibility to embrace adjustments to improve the sustainable practices and it will be implemented with reduced change costs at the pre-construction stage of a project.

There are recent research studies on implementing circular economy in Sri Lankan context (Wijewansha, Tennakoon and Waidyasekara, 2021; Athapaththu and Karunasena, 2018) but this study focuses on implementing circular economy and its principles for the whole life cycle of Sri Lankan construction projects.

3. Methodology

A qualitative data collection approach was followed in this study to get the idea about circular economy concept, its level of implementation in Sri Lankan construction sector and to provide a criteria to implement 6R principles in circular economy concept for construction projects in Sri Lanka. A qualitative approach is better in identifying a single piece of data or code is sufficient to incorporate it in the analytic framework (Mason, 2010). Semi-structured interview was the data collection method which was used in this study and interviews were conducted among twelve (12) construction professionals in the Sri Lankan construction sector to get their opinion on circular economy concept. Purposive sampling technique was used in this study and the sample includes project managers, engineers, designers, quantity surveyors and architects, who are having the experience in the area of sustainable construction.

4. Research Finding

This section includes the findings of the research, which were gained by semi-structured interviews.

A. General characteristics of interviewees

Table 1: General characteristic details of interviewees

Interviewee code	Designation	Type of the organization	Experience in the construction industry
E1	Project Manager	Contractor	24
E2	Project Manager	Contractor	10
E3	Project Manager	Consultant	13
E4	Mechanical Engineer	Contractor	15
E5	Civil Engineer	Consultant	09
E6	Mechanical Engineer	Contractor	14
E7	Quantity Surveyor	Consultant	22
E8	Quantity Surveyor	Contractor	12
E9	Quantity Surveyor	Consultant	08
E10	Architect	Consultant	15
E11	Designer	Consultant	08
E12	Designer	Consultant	16

B. Awareness of the Circular Economy Concept in the Sri Lankan Construction Industry and Its Advantages

According to the interviewees' point of views, they believe that, circular economy concept has been popular among countries such as Japan, Australia from few decades, but it is totally a new concept in the Sri Lankan construction industry. Further, the Sri Lankan construction sector still not adopted to circular economy and it is not implemented in a considerable manner. There are two sustainable strategies in using materials for a construction project which were identified at the interviews, "cradle to cradle" and "cradle to grave". In "cradle to cradle", materials in a particular construction project, can be used to another project with minimum modifications. But "cradle to grave", materials cannot be used for another project's beginning. Unfortunately, cradle to grave is the usual strategy in present Sri Lankan construction industry, "cradle to cradle" is only applicable for few sustainable projects.

Interviewees expressed that, the life cycle cost of a construction project can be reduced by applying circular economy concept and it provides a better value for the project.

However, interviewees' opinion was that, the most of construction professionals are still trying to complete the projects according to the project management concepts by considering only the time, cost and quality of the project. But this circular economy concept and its principles can be used to the project portfolio level and it makes the path for a flexible construction industry in the country.

C. 6R Principles in the Circular Economy Concept within the Sri Lankan Construction Industry

According to the interviewees' viewpoints, the Sri Lankan construction sector is applying the 3R principles which are reduce, reuse and recycle, but not in a proper manner. So Sri Lankan construction industry is more unfamiliar with 6R principles. Moreover, sustainable construction concepts such as green building concept also implemented in a limited level in Sri Lankan construction sector. As per the interviewees' point of view, most of the construction professionals haven't enough awareness about the 6R principles and specially on redesigning and re-classification.

However, interviewees expressed that, the natural resources in Sri Lanka to be conserved and the wastages to be minimized by applying the 6R principles of the circular economy concept. And also, it increases the energy preservation and will help to implement a better sustainable development in the Sri Lankan construction industry.

1) Reduction (R1) principle:

Under the reduction principle, most of the interviewees expressed that, while doing a construction, the wastages of resources and materials should be minimized. E4 and E6 highlighted that, the construction activities such as fabricating PVC and HDPE pipes generates a considerable wastage at construction sites in Sri Lanka. That can be occurred due to appointing unskilled labourers for that kind of activities in the construction sector. According to the E6's point of view, those kind of material wastages can be reduced by appointing skilled labourers for construction activities such as fabricating HDPE and PVC plumbing work.

When considering the reduction principle, E1, E5, E8 and E10 highlighted that, the construction industry in Sri Lanka should pay more attention to reduce, using of construction materials which are not recyclable or reusable. As examples, materials such as polythene and PVC cannot be reused and it is better to reduce using those kind of materials under the reduction principle. Also, E1 and E3 suggested that, the construction professionals and designers should pay more attention to use more recyclable materials such as glass for construction projects in Sri Lanka.

E6, E10 and E11 suggested that, a considerable amount of wastages in concrete mixing and plastering can be reduced by using new technologies for concrete mixing and wall plastering in construction projects. Further, resource consumption can be minimize by using waste where possible and there should be a proper storage location for waste material.

2) Reuse (R2) principle

When considering interviewees' opinion on reuse principle, E1, E4, and E12 expressed that, in the design stage of a construction project, it is better to select more reusable materials than recyclable materials because, there will be a higher cost for recycle process when comparing to reuse.

Under reuse principle, E4, E8 and E11 highlighted that, the demolished concrete parts from buildings can be used for filling works in road construction projects where possible. And also, those demolished parts of concrete can be used for land filling in construction projects. Also, double checking of materials before ordering materials and maintaining detailed specifications of materials can be practiced to save materials under reuse principle.

However, interviewees' opinion was that, it requires more awareness on the reuse principle in sustainable construction and it's cost effective advantages among industry professionals and the clients in the construction sector.

3) Recycle (R3) principle

When applying the recycle principle to the construction projects, interviewees were expressed that, it is better to select recyclable materials for construction according to the life span of the building.

Most of the interviewees highlighted that the glass material, to be selected as the major recyclable material for construction projects under the recycle principle. E2, E10 and E12 specifically expressed that, the glass material can be rebuilt as glass-concrete by a process and this is applying for construction industry in developed countries such as Australia, USA and United Kingdom. Further, glass-concrete is using as tiling finishes in buildings and it gives a better architectural view. Also, E2 and E10 suggested to invite construction professionals, designers and clients in the construction sector to aware of glass-concrete material, because it provides a better value for projects in Sri Lankan construction industry.

E9 and E12 suggested that, recycling paper waste in construction project offices is an effective method to save paper usage such as for project admin works and project coordination practices.

4) Redesign (R4) principle

According to redesign principle in the circular economy concept, most of the interviewees highlighted that, the designers and architects should be flexible when they are designing a building or an infrastructure in the design stage. It is better to provide some provisions to change the design or the structure after few decades to another requirement.

E1, E8 and E10 highlighted that, modular construction methods, mainly with steel and metal can be use under the redesign principle for construction of commercial buildings and buildings for temporary purposes to implement circular economy concept in Sri Lanka.

E4 and E9 specifically highlighted that, if a building cannot use as a commercial building due to the current conditions or current end user's needs, designers can change the particular building according to the needs of the end user. Further, designers should pay attention to redesign the existing building, by doing minimum changes such as changing a wall, installing a door, installing a window, fixing a partition and get the maximum usage with the remaining building's appearance and the structure.

5) Re-classification (R5) principle

Re-classification principle was the strangest principle from the 6R principles in circular economy for the interviewees and only E2, E9 and E10 have been read this principle previously. Also E2, E7 and E10 highlighted that, the designers should select more durable materials and it is better to select eco-friendly construction materials for projects.

However, interviewees highlighted that, the designers and architects should try to use reusable construction materials for projects at the design stages and save resources and materials for future usage.

6) Renewability (R6) principle

According to the interviewees' point of view, Sri Lanka has the opportunity to gain a better output from natural energy sources in the country. Most of the interviewees highlighted that the solar power can be used as the highly

available natural energy source in the country. Solar power systems can be install on top roofs of the buildings and the electricity can be generated.

E1, E8 and E12 interviewees highlighted that, the wind-power can be used as a renewable energy source to produce electricity in Sri Lanka.

E1 and E7 expressed that, Sri Lanka has the opportunity to purify rain water and use it, not only for domestic usage but also for commercial buildings, which is called "rainwater harvesting". Sri Lanka have two monsoons and there will be a great opportunity to use rain water as a renewable for a sustainable energy consumption.

E2 and E9 specifically highlighted that, the kinetic energy which is provided by water falls has the potential to circulate turbines and can turned in to electricity, according to this renewability principle. Furthermore, E2 explained that, as per the theories in fluid dynamics, the highest kinetic energy of a waterfall is in the middle area and there is an energy which can provide electricity for a mid-level building in Sri Lanka.

5. Discussion

When analysing the results of the interviews, all the interviewees expressed that, the circular economy concept and 3R principles have been used only very few mega projects in Sri Lankan construction sector and it is not applicable in small scale and middle scale construction projects. Also, implementation of 6R principles is in a very primitive stage because of lack of awareness among both internal and external stakeholders on sustainable construction concepts and circular economy concept in the country. Another significant fact was that, the construction professionals in Sri Lanka are still trying to complete construction projects only through the traditional project management concepts within the cost, given time period and to the required quality standards which are expected by the client. But this must be developed in the present construction industry in Sri Lanka and construction professionals such as project managers should pay more attention on project portfolio management and project process management. These are very significant in the sustainable construction concepts and the benefits are considerable according to the life-cycle cost analysis for the particular project at the inception and designing stages. But unfortunately, most of the clients in the construction sector are also only considering the initial investment of a project, and they are not analysing the project life cycle cost in a proper manner. So that, mostly there is not temptation for a concept such as circular economy from clients' side in Sri Lankan construction sector. Another barrier to implement the circular economy concept for the construction industry is identified during the interviews and that is lack of studies and researches in the area of circular economy concept and 6R principles in Sri Lanka.

6. Conclusion and Recommendations

This study analysed that, implementing 6R principles in circular economy concept for Sri Lankan construction industry. There are 6R principles in circular economy concept which were identified in the literature review and they were reduction, reuse, recycle, redesign, re-classification and renewability.

According to the interviewees' point of view, the above 6R principles and circular economy concept are new and unfamiliar concepts to Sri Lankan construction industry. Only 3R (reduction, reuse and recycle) out of 6R principles are applying in construction projects in Sri Lanka and those 3R also used for only few mega-scale construction projects which are following sustainable construction strategies. Further, "cradle to cradle" is one of ideal sustainable strategy for a developing country such as Sri Lanka to implement a better circular economy standards, through sustainability in construction projects. As per the interviewees' view point, the scope of the circular economy and 6R principles is to reduce material and resource wastages during the construction, considering the advantages of project life-cycle cost analysis. Moreover, the advantages of implementing circular economy concept, the study highlighted that, the life span of a building

will be expanding, essential materials and natural resources in the country will be conserved for future usage.

According to the analysed feedback of the interviewees, it can recommend that, solar power is the major renewable natural resource, which can produce electricity in Sri Lanka and government should take necessary steps to promote solar power systems not only for commercial buildings, but also for domestic buildings. Further, proper storage location for waste material, selection of eco-friendly materials as possible, adaptation for new technologies which generate minimum of wastage, applying modular construction methods, reuse and recycling of paper were highlighted at the interviews as the recommendations for implementing circular economy concept in Sri Lankan construction sector.

Most of the construction professionals and clients in the construction sector in Sri Lanka haven't enough awareness on the circular economy concept, 6R principles and the advantages of the life cycle cost management. Most of the clients are only considering the initial investment of a project and it is better to conduct awareness programmes in the field of sustainable construction, circular economy and its advantages among the construction professionals such as project managers, architects, engineers and quantity surveyors.

In Sri Lankan construction sector, project managers are still trying to complete a project according to only traditional project management parameters such as time, cost and quality of a project, but it should be par with the sustainable and circular economy concepts. This can be reduced the life cycle cost of a project, wastages of construction materials and conserve the natural resources in the country.

Circular economy concept is very crucial in the construction industry and therefore the government and the construction industry specialists should take necessary actions to promote and implement the 6R principals and other strategies of the circular economy concept in the Sri Lankan construction industry. Also it is important to have more awareness programmes on the principals of the circular economy concept with the intention to familiarize this concept among specialists in the construction industry.

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Abbrevations and Symboles

CE: Circular Economy
HDPE: High Density Poly Ethylene
PVC: Poly Vionyle Chloride

Acknowledgements

I would like to offer my sincere gratitude to Dr. A.R. Rupasinghe and Lecturer, D.M.S. Jayasuriya for their kind supervision to succeed this study. Further, I would like to be thankful to my parents, colleagues and all who supported me to complete this study in a successful manner.

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Spatial Pattern of Urban Expansion and Green Spaces: A Case Study of Tangalle Area, Sri Lanka

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Abstract: *Urbanization responses to urban expansion, and changes in green spaces. Moreover, urban expansion has a significant impact on urban management. Urban forests (Green Spaces) provide benefits of the natural environment to communities. Recognizing the spatial pattern of urban expansion and green spaces within a certain time period is vital for urban planning. This study conducts to examine the expansion in Tangalle town. Built-up expansion occurs in recent years because of the tourism industry in this study area. The remote sensing indices, Normalized Difference Built-up Index (NDBI) and Normalized Difference Vegetation Index (NDVI) have been used to extract built-up and green spaces for identifying the spatial pattern changes from the years 1990 to 2021. According to the results of the urban expansion/sprawl index, and urban areas have been expanded slightly between year 1990, and year 2000, but decreased urban expansion between year 2000, and year 2010. However, between the years 2010, and 2021, the urban area has sharply expanded by up to 13%. The study revealed that the built-up area has increased enormously. NDVI shows that the increase in this built-up area has led to a decrease in significant agricultural lands and open spaces. Thus, in the year 1990, the urban form was an isolated urban pattern and gradually became a cluster-based pattern. According to the urban expansion results, the urbanization is expanding towards the north direction from the city center.*

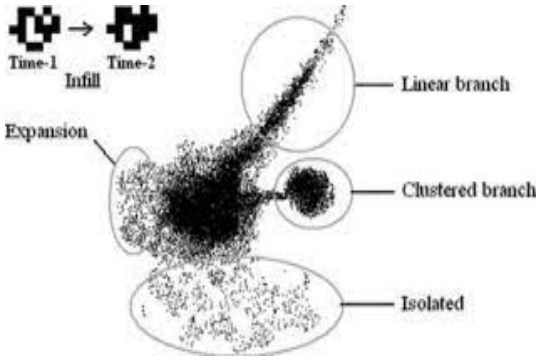
Keywords: *Urban spatial pattern, Normalized Difference Building Index (NDBI), Normalized Difference Vegetation Index (NDVI)*

1. Introduction

Urbanization is a process of increasing urban population and urban infrastructures. Due to urbanization, urban land carrying capacity is changing year by year. Most populations are trying to move to urban city areas to get high-demand facilities. However, the limited size of urban spaces, and growing population grants have become an issue in the present situation. Many environmental, geographical, and political factors, as well as economic factors, act as dynamic drivers of landscape change (Thapa and Murayama, 2011; Iqbal et al., 2012). The process of urban growth is complicated and dynamic. It entails modifications to the physical and functional components of the environment, which is constructed, and the transition of the landscape to an urban form (Castle and Crooks, 2006; Dahal et al., 2016). The scale of suburban growth and urban sprawl is used to quantify rapid urbanization (Harris and Ventura, 1995; Sajjad, 2014). Cities do not have enough resources to accommodate the population, and the new development will enable them to live in suburban areas. Urban expansion always has a negative connotation. It also affects the destruction of agriculture and nature (Ewing, 1997).

Urban expansion can be categorized as infill, edge Expansion, and outlying (Weerakoon, 2017). Mostly, outlying growth takes place in open areas, and areas sensitive to the city, and surrounding environment. Also, it

separates from the existing build-up area. That outlying growth can be divided furthermore into an isolated, linear branch, and clustered branch. It was recognized as the main growth type as infill growth. It occurs in the built-up area. The next type is edge expansion, and it is centered on infill growth. Therefore, edge expansion directly relates to the existing built-up area. Three types of urban growth have been identified: infill, expansion, and outlying growth. The outlying horizontal expansion is subdivided into isolated, linear, and cluster branches. Figure 1 shows the types of urban growth patterns (Bhatta, 2010).



Source : (Bhatta, 2010)

Figure 1: Urban growth pattern

Pixels represent isolated buildings and development in isolated growth types, and it implies that those areas may be developed in the future. Some isolated growth can be identified as non-developed areas. Linear urban development takes place from developed areas to undeveloped areas, like corridors or parallel to the new linear development. That is urban land connecting the pixel with the linear way in the visualization. Cluster urban distribution describes cluster or group development. It isn't like linear or isolated. Clusters spread out to a large urban area through a high urban density (Wilson *et al.*, 2003).

Nowadays, urbanization has spread out of city areas due to population growth. This expansion is a long-standing physical reading, and it is a way to identify urban expansion for future developments (Weerakoon, 2017). As a result of this expansion, forests have been destroyed, and concrete environment has been created. There is a significant relationship between changes in spatial pattern and population growth changes of urban growth for long years, its effects on changing of urban forms. It can be evaluated by combining GIS (Geographical Information System) and remote sensing. Due to urbanization, people are moving to cities to get better living conditions, education, and income. Padmanaban *et al.* (2017), state that the global population is predicted to grow by 72 % in 2030, with a 175% rise in urban centers. All this urban sprawl takes place over large areas. So, it is not possible to measure location to location, using traditional methods such theodolite, and total station, and a significant solution to avoid this problem using aerial photography and satellite imagery. It is a modern surveying technique that can be achieved targets with less time duration and less cost. The urban sprawl pattern is very important for the proper urban management of urban areas. Therefore, this research was conducted using satellite Landsat images. This is a very important computer-based method for analyzing Landsat data, and accuracy levels are enough to do case studies (Karanam and BabuNeela, 2018). Urban sprawl is prevalent

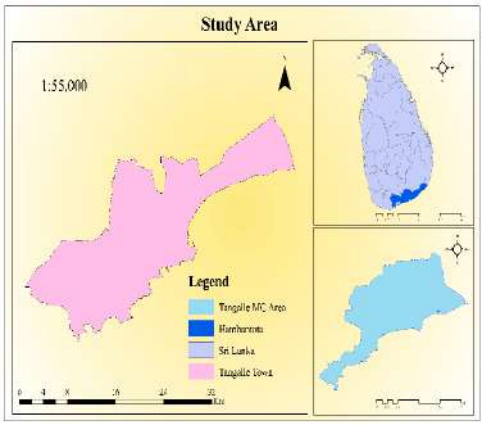
due to rapid population growth, destroying productive agricultural lands, and ancient forests, and adversely affecting ecosystem services. Quantification is critical to effective urban planning, and environmental management. Land Use and Land Cover (LULC) represent the relationship between environment and human activities and can be efficiently obtained from satellite imagery through image classification. Moreover, the availability of remotely sensitive data from multiple dates enables the study of multidimensional urban modeling. Using the algorithm, satellite imagery can automatically identify the size of urban areas as well as vegetation areas. Furthermore, spatial, and physical features of urban features, urban patterns, and their models can be quantified using several landscape measurements. It can be calculated from the images obtained, and used to scale effectively (Padmanaban *et al.*, 2017).

The Urban expansion /sprawl index (SI) is used to detect urban growth in a specific area. It can be divided into five groups. If SI <0.001%, it represents an area of no change; At 0.001% <SI <0.1%, this area shows a slight expansion; 0.1% <SI <1% This area expands moderately; At 1% <SI <5%, this district appears to have a fairly rapid expansion; SI> 5% means that this area has undergone a sharp expansion (Yang and Pu, 2008).

The confusing matrix method is the most used method for estimating the classification accuracy of remote sensing images. Previous research shows that the score should not be less than 75 to confirm the classification accuracy of a single class. Confused theories were established by comparing the classification results of these reference points at different time points with the corresponding field investigation results and the high-resolution remote sensing data from Google Earth. The manufacturer's accuracy, user's accuracy, and overall accuracy were used to measure land-use classification accuracy (Sun *et al.*, 2020).

Tangalle is an area that has developed in recent times. Its tourism industry is also booming. The government has decided to launch development projects in the tourism industry as well as other infrastructure in the area. In a short period of time, many buildings were erected, and development continued. We often see many areas such as vacant lands, barren lands, swamps, and plantations. But with the new development, it has grown into a coastal development. The main objective of this research is to identify the urban growth type in the Tangalle town area, and the sub-objectives are to identify the urban expansion/sprawl index of Tangalle town area, and represent the green area changes in this area.

Study Area



Source : (Survey Department,2020)

Figure 2: Study area

Tangalle is a town in the southern province of Sri Lanka, in Hambantota district. It is located with coordinates 6° 01′ N 80° 47′ E. Its elevation is 29 m /95 feet above the mean sea level. It has a mild climate, and sandy coastline compared to the rest of the district, and figure 2 shows the study area of the research.

This study examines the expansion of 16 Grama Niladhari Divisions in the Tangalle. In 2012, 72,500 population was in Tangalle DS Division (Department of Census and Statistics, 2022). Tangalle town has a

population of 10,497 by year 2022 (Population of Cities in Sri Lanka, 2022).

2. Methodology

The above figure 3 shows the flowchart of the study.

For this, satellite images from 1990, 2000, 2010, and 2021 were used. They were under Landsat Thematic Mapper (TM) imagery, Landsat 7, Landsat 8. The resolution of the satellite images is 30 meters.

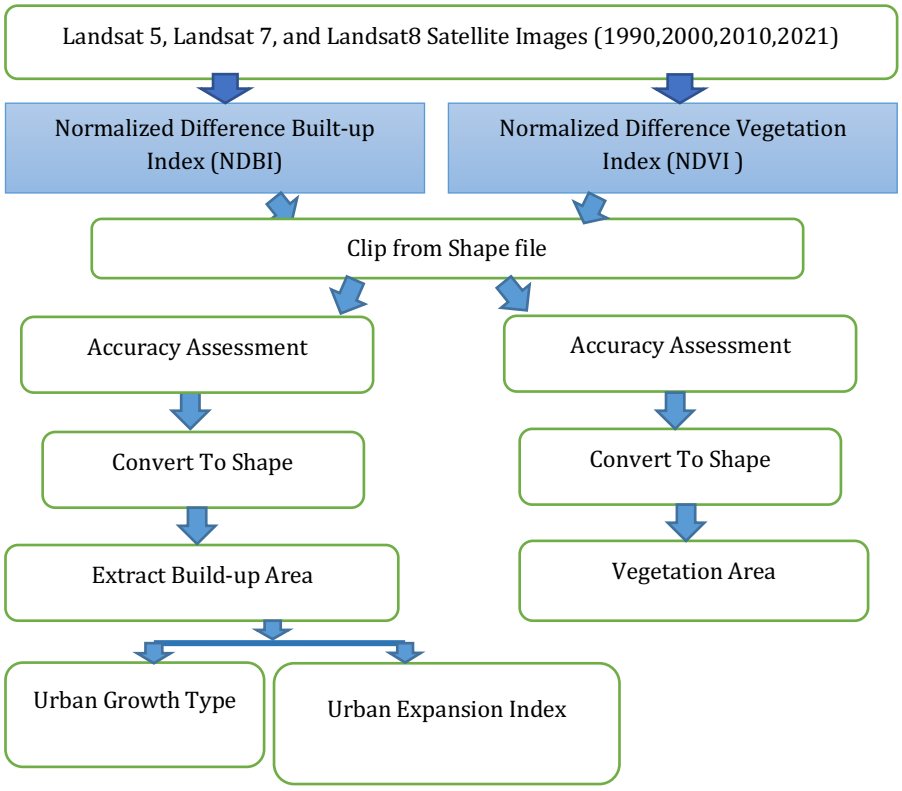


Figure 3: Flowchart of the study

NDVI is an important variable in urban expansion studies, which is obtained from remote sensing data using reflection in the red (RED) and near-infrared (NIR) segments of the electromagnetic spectrum. NDVI values indicate vegetation, as smaller positive values indicate bare soil or built-up areas. Equation 01 shows the NDVI calculation.

$$NDVI = ((NIR - RED))/(NIR + RED) \quad (01)$$

(Zha, et al. 2003).

Where, NIR = band 4 (Landsat TM) and band 5 (Landsat 8), RED = band 3 (Landsat TM) and band 4 (Landsat 8)

NDBI is an indicator for extracting built-in areas and was calculated from remote sensor data using the reflection of NIR and mid-infrared (MIR) components of the spectrum (Krishnaveni and Anilkumar, 2020). NDBI values are in the range between −1 and 1, values close to 0 indicate vegetation; Negative values indicate water bodies, and positive values indicate built-up areas. Equation 02 shows the way to calculate NDBI (Zha, et al. 2003).

$$NDBI = ((MIR - NIR))/((MIR + NIR)) \quad (02)$$

(Krishnaveni and Anilkumar, 2020)

Where, MIR = band 5 (Landsat TM) and band 6 (Landsat 8), NIR = band 4 (Landsat TM) and band 5 (Landsat 8)

After extracting the built-in area from NDBI and vegetation area from NDVI, they were clipped using the study area shape file. The

Table 1: Built-up area from year 1990 to year 2021

Year	Built-up area (ha)		Non-Built-up area (ha)	
1990	204.542	11%	1585.661	89%
2000	555.227	31%	1235.747	69%
2010	580.262	32%	1212.418	68%
2021	817.560	45%	975.546	55%

built-up areas are then examined using ground truth values, and Figure 4, and figure 5 show the validated map of built-up areas and vegetation areas. Table 4 shows the classification accuracy of the constructed areas. Figure 5 shows the map that has been built in Tangalle town after the field verification.

During the study period, the urban expansion index, the ratio of the area of urban land expansion to the total area of a geographical unit was calculated. This indicator normalizes the yearly median expansion rate based on a spatial unit's land area, allowing for comparison. (Sun *et al.*, 2020).

According to Tian et al. (2005), the urban expansion index/ sprawling index can be calculated using equation 03.

$$SI = ((UL_{(i+n)} - UL_i)/(nTUL)) \times 100\% \quad (03)$$

(Tian et al., 2005).

Here, SI = Sprawling Index/Urban expansion, $UL_{(i+n)}$ = Land area at year i+n, UL_i = Land area at year n, TUL = Total land area

Verification of available building coordinates files was very important to identify built-up areas on maps. Table 1 and Table 2 show statistics of the vegetation area and built-up area from year 1990 to year 2021, and Figure 7 and figure 8 show the built-up area and vegetation area constructed using graphs for more details. The urban density or expansion was then identified in relation to the area formed over the years as defined shown in figure 10. Finally, the Urban Expansion Index was calculated for specific periods and is shown in Table 4.

3. Result and Discussion

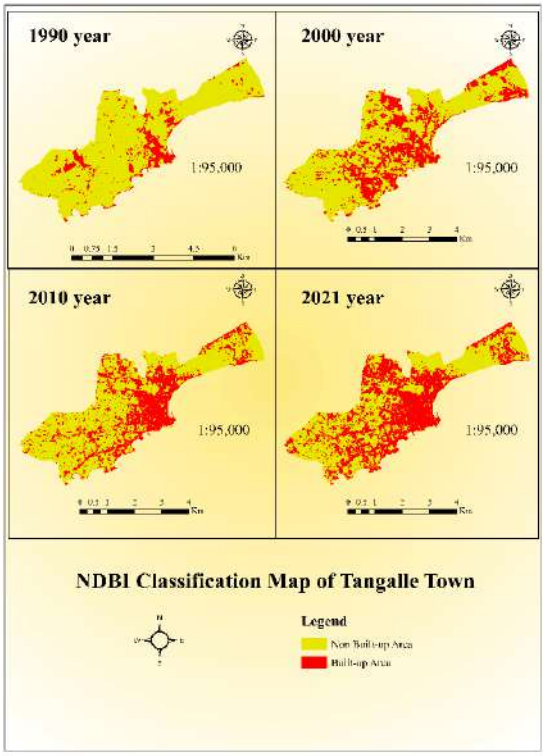


Figure 4: NDBI classification map of Tangalle

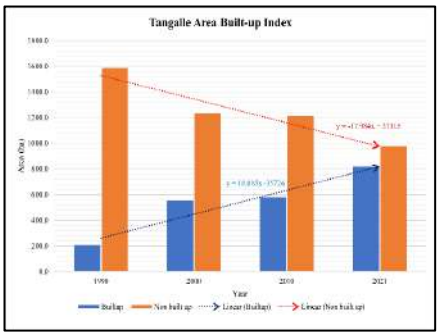


Figure 5: Built-up variation over last years

Year	Vegetation Area(ha)		Non-Vegetation Area(ha)	
1990	1622.324	91%	172.224	9%
2000	1603.861	90%	189.330	11%
2010	1571.805	88%	221.311	12%
2021	1395.207	78%	396.906	22%

Table 2: Vegetation area from year 1990 to year 2021

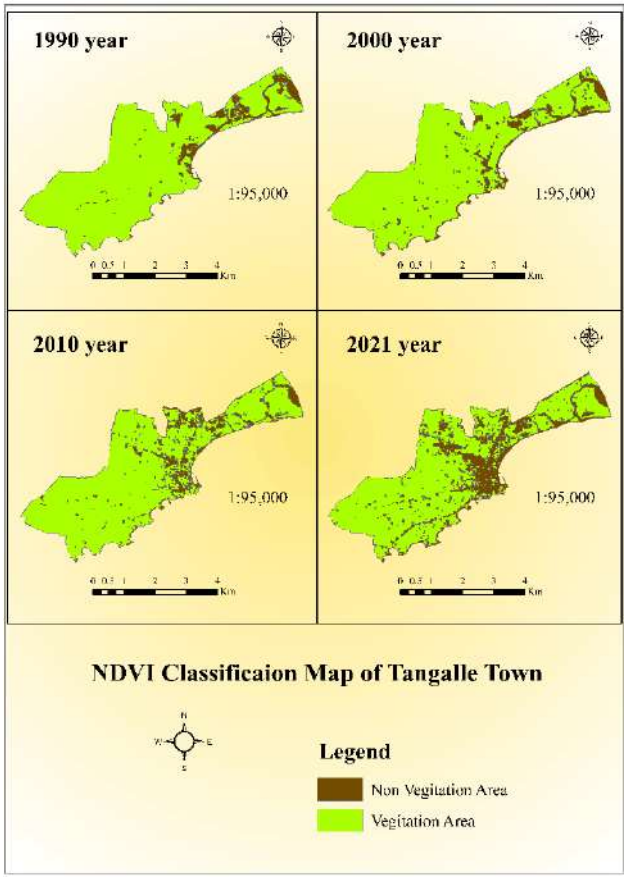


Figure 6: NDVI classification map of Tangalle

Table 3: Vegetation area from 1990 to 2021

Year	SI(Sprawl Index/ Urban Expansion)
1990-2000	20%
2000-2010	1%
2010-2021	13%

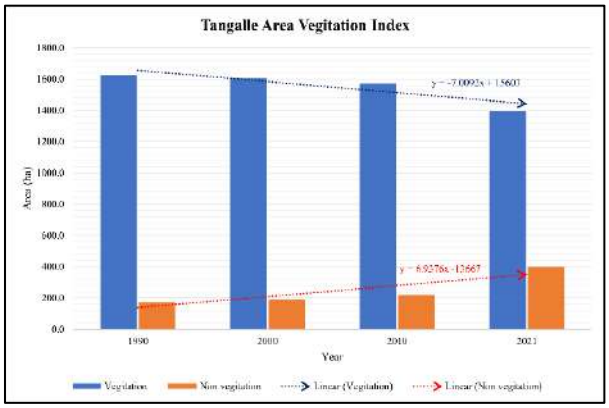


Figure 7: Vegetation area from year 1990 to year 2021

Table 4: Accuracy assessment

Year	Overall Accuracy for NDBI	Overall Accuracy for NDVI
1990	82% (Google Earth)	81% (Google Earth)
2000	86% (Google Earth)	82% (Google Earth)
2010	88% (Google Earth)	84% (Google Earth)
2021	93% (Field Verification)	90% (Field Verification)

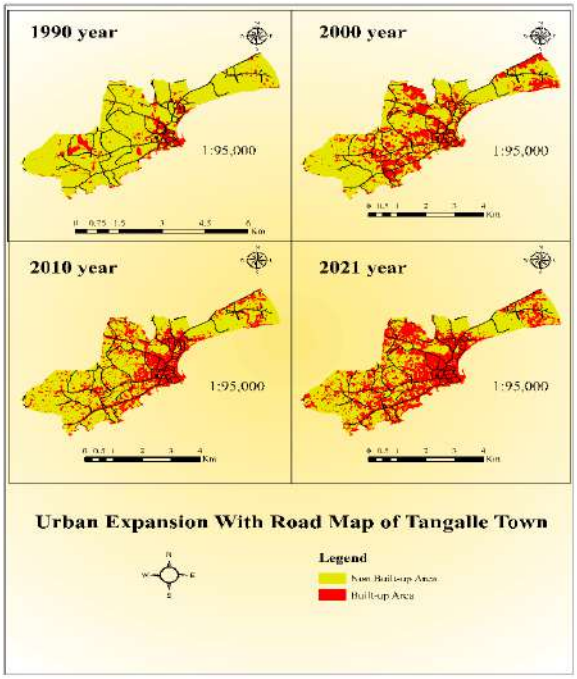


Figure 8: Urban expansion map of Tangalle town

Figure 4 shows how the urban area has changed over the past years. Also, table 1 shows the difference in areas between built-up and non-built-up areas in the study area. According to that, the area difference that occurred during the expansion of buildings in Tangalle city can be seen. However, according to the figure 5 graph details, the growth of the built-up area, and its expansion directly affect the non-built-up lands in the region. The NDBI classification map created here shows the distribution of buildings in Tangalle town from year 1990 to year 2021. Also, according to the area data obtained, the built-up area and non-built-up area are given in hectares and as a percentage. Accordingly, in year 1990 it showed 11% built-up area and 89% non-built-up area. Also, a 31% built-up area for the year 2000 shows 32% and 45% areas for year 2010 and year 2021 respectively. And 69%, 68% and 55% respectively are non-built-up areas.

Similarly, the linear equation for changing the buildup area is set using excel. It can predict built-up, and non-built-up areas in 2025. According to this study, by year 2025, 897.4 ha will be a non-built-up area and 896.125 ha will be a built-up area.

Similarly, the NDVI map is designed to achieve sub-objectives. Accordingly, in 1990 it showed 91% vegetation area and 9% non-vegetation area. Similarly, 90% vegetation area for the 2000 year, 88% and 78% vegetation area for 2010 and 2021 respectively. In comparison, the percentage of the non-vegetation area has increased.

A sharp urban expansion of 20% occurred from year 1990 to year 2000. But from year 2000 to year 2010, the result is 1%. It is a middle-speed urban spread. So, this proves that there has been minimal urban growth in 10 years. But again, from year 2010 to year 2021, there is a 13% sharp expansion result.

Figure 8 shows the built-up area with the road network in the Tangalle area. It shows an isolated urban growth pattern in the year 1990 and changed to a cluster-based one in the year 2000. But again, in year 2010, the isolated pattern shows. But Tangalle town area has a cluster-based urban growth pattern in the year 2021. This urban area has changed from an isolated urban pattern to a cluster-based pattern. This urban expansion was mainly directed in the north direction.

The study has a high precision as more than 80% of all analyzes were obtained when calculating the precision of the study.

4. Conclusion

Using satellite and remote sensing technology, urban expansion can be monitored quickly. This paper studies the urban land expansion and distribution in the Tangalle town area during the three periods years 1990-2000, years 2000-2010, and years 2010-2021. Constructed areas and green areas can be extracted from the classification of remote sensing technology. Although the urban form remained isolated in the 1990s, it has since changed somewhat linearly in the 2000s and 2010s. And 2021 shows a cluster-based urban expansion. The use of NDBI is effective in capturing the urban distribution pattern of the area. The urban sprawl index (SI) is used to measure and quantify urban expansion. With the expansion of the city, the green area has decreased. The years 1990 to 2000 show high developments in Tangalle town. But tourism developments slowed down between years 2000 to 2010 due to politics and the LTTE war in Sri Lanka. Therefore, at that time there was only 1% development. But, after the year 2010, all tourism developments were started in Tangalle city area. Moreover, developments are increasing along the beach areas.

Finally, the result shows urban expansion from Tangalle coast to the city center. It is the northward direction of urban expansion. It is due to natural and environmental reasons

such as barren areas, paddy fields, and coastal lines. The urban sprawl extends less from the city center to the east and west. The land on both sides of the main road through Tangalle town is primarily affected by this. Those roads are Beliatta road, Mahawela road, and Kataragama road. All lands have affected the development of Tangalle town. If there is a high resolution of the satellite image used, the results of the study will change. Urban planning authorities can use these techniques to extract built-up areas and green areas to effectively control urban planning and spreads and to analyse urban sprawl. Further, this study can be developed to identify the relationship between the spatial forms and population.

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Acknowledgment

I would like to express my special thanks and gratitude to the lecturers of the faculty of the built environment and spatial sciences to do

this study. Also, I appreciate the excellent contribution of the GIS Branch of the Survey Department in providing all the digital data layers for creating 2D maps. I came to know about so many new things, and I thank my parents, friends, and all the people who helped me a lot in finalizing this study.

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A Case Study on Detecting and Mapping Individual Coconut Trees using YOLOv3 in Conjunction with UAV Remote Sensing for Smart Plantation Management

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Abstract*:Location and number data of individual coconut trees are important for surveying planting areas, predicting coconut yield, and managing and planning coconut plantations. This data had usually obtained through manual investigation and statistics, which is time-consuming and tedious. Deep learning object recognition models, widely used in computer vision, can provide an opportunity to accurately identify individual coconut trees, which is essential for rapid data acquisition and the reduction of human error. This study proposes an approach to identify individual coconut trees and map their spatial distribution by combining deep learning with unmanned aerial vehicle (UAV) remote sensing. UAV remote sensing collected high-resolution true-colour images of coconut trees at the Mahayaya Coconut Model Plantation in Sri Lanka. An image dataset of deep learning models of individual coconut trees (ICTs) had constructed by visual description and field survey based on coconut tree images captured by UAV remote sensing. YOLOv3 was selected to train, validate and test the image dataset of coconut trees. The results show that the average accuracy of the YOLOv3 model for validation reaches 91.7%. The number of ICTs in the study area was calculated using YOLOv3, and their spatial distribution map was created using the non-maximum suppression method and ArcGIS software. This study will provide basic data and technical support for smart coconut plantation management in Mahayaya coconut model plantation and other coconut-producing areas.*

Keywords: *Individual Coconut Tree (ICT) detection; deep learning; YOLOv3; remote sensing; Unmanned Aerial Vehicle (UAV); spatial distribution*

1. Introduction

Smart plantation management requires accurate planting area survey, disease and pest prevention and control, and data on the location and characteristics of individual coconut trees (ICT) in a plantation for coconut yield prediction. Traditionally, field surveys and statistics were used to collect this data, such as locations, spatial distribution, number of ICTs, etc. These surveys are time-consuming, labour-intensive and expensive but fail to meet the requirements of smart plantation management. There is a need to develop a fast, cheap and accurate methodology for ICT investigation to obtain this data.

Remote sensing images of coconut trees in relatively large plantations can be captured by satellite or aerial photography. When using satellite remote sensing, cloudy weather is initially a major challenge, and due to the poor quality of images, coconut trees are difficult to detect. Limiting the spatial resolution of satellite imagery is another major challenge for accurately identifying ICTs. Aerial photography is taking pictures using manned or unmanned aircraft. Manned aerial vehicles are not suitable for ICTs detection due to high costs and difficult operations. Unmanned aerial vehicles (UAV) remote sensing is the best

option to accomplish this task. Drones are a subset of UAVs that are generally very small, light and inexpensive. A drone usually has one or more high-resolution cameras that can capture medium to high-quality images depending on the height it flies (Jintasuttisak, Edirisinghe & Elbattay 2022). UAV remote sensing has automation, intelligence, and specialization advantages to quickly obtain space remote sensing information such as land, resources, environment, and events, and conduct real-time processing, modelling, and analysis of advanced emerging aerial remote sensing technology solutions (Li & Li 2014). Recently, it has been widely used in many practical fields, such as photometry, precision agriculture (Khanal, Fulton & Shearer 2017), geohazard assessment (Li & Li 2014), forest fire detection (Ghali, Akhloufi & Mseddi 2022), and environmental monitoring (Wu, Shan, Lai & Zhou 2022; Immerzeel et al. 2014). UAV remote sensing has great potential to quickly and economically acquire image data of coconut trees in plantations.

In the recent decade, with the development of computer hardware devices and the rapid development of artificial intelligence (AI) technology, deep learning convolutional neural network (CNN), the core technology of AI, has pioneered new object recognition methods and feature extraction. In remote sensing images (Osco et al. 2021; Zhang, Zhang & Du 2016). Many CNN architectures have been proposed for object recognition in computer vision and image analysis, and they are divided into two categories, two-stage and one-stage models. (Girshick, Donahue, Darrell & Malik 2014) proposed an R-CNN (Region-based Convolutional Neural Network) two-object detection model based on classification problems. Based on R-CNN, fast RCNN and fast R-CNN are then proposed to improve performance and accuracy. (Redmon, Divvala, Girshick & Farhadi 2016) single-stage based object recognition model YOLO (You Look Only Once). The YOLO model not only simplifies the neural network size but also improves the recognition speed while improving the recognition accuracy. (K et al. 2022) proposed a pipeline based on YOLOv2 to perform fast multiscale object detection in large-scale satellite imagery. (2021) (Osco et al. 2021) present a comprehensive review of the fundamentals of deep learning related to UAV-based imagery, providing a key reference for integrating deep learning with UAS remote sensing for ICT detection.

More recently, (dos Santos et al. 2019) proposed and evaluated the use of CNN-based methods combined with high spatial resolution UAV imagery in red-green-blue (RGB) to identify legally protected tree species. Three state-of-the-art object detection methods were evaluated: fast R-CNN, YOLOv3 and RetinaNet. RetinaNet gave the most accurate results, with an average accuracy of 92.64%. Satellite imagery analysis by (Brandt et al. 2020) found isolated tree canopies over a large area of West Africa. Their results show that mapping the location and size of each tree worldwide can be done quickly with some limitations (Brandt et al. 2020; Hanan & Anchang 2020). (Safonova, Guirado, Maglinets, Alcaraz-Segura & Tabik 2021) used masked R-CNN and UAV imagery for olive tree canopy and shadow segmentation to further estimate the biomass of individual trees. (Sun et al. 2022) applied an end-to-end tree count deep learning framework (CMask R-CNN) to regional tree recognition by calculating the tree population in the subtropical metropolis Guangzhou and representing the crown of each tree. (Hu et al. 2022) presented a pipeline for tracking and clustering 259 peach tree crowns based on UAV images of a peach orchard in Southeast China and constructed conditional generative adversarial networks (cGANs) to extract the crown area. The results of (Yu et al. 2022) showed that the mask-R-CNN model achieved the highest accuracy (F1 score = 94.68%) for identifying a single tree

compared to the local maxima algorithm and marker-limited watershed segmentation.

Motivated by the great progress in single tree detection by deep learning and UAV remote sensing, we proposed an approach to build an accurate Individual Coconut Tree (ICT) detection model by combining deep learning with UAV remote sensing images to fill the gap in the above studies. With this model, the location and spatial distribution of ICTs can be quickly and accurately mapped, and the number of ICTs can also be quickly calculated. We envision that state-of-the-art deep learning methods can detect ICTs in high-resolution, true-colour images with low cost, high accuracy, and high performance. Coconut trees are selected as a case study and will be empirically determined as a deep-transfer learning model for training and validation to test the YOLOv3 hypothesis. It aims to provide reliable and timely baseline data and technical support for intelligent plantation management and precision farming development.

More specifically, three main contributions were reported in this paper. First, high-resolution images gagged by the UAV sensor were set for a sample set of tree images of individual coconut trees. Second, using the new data, the yolov3 model was trained and evaluated for realizing accurate and fast detection of ICTs. Third, a thematic map showing the location, spatial distribution, and the number of the ICTs in the large-scale coconut plantations of the study area. It can provide important reference information for precision plantation management.

2. Materials and Methods

A. Study area

A large coconut plantation is selected as the experimental study area. It is located in Makandura, Gonawila. (Figure 1). The coconut tree (Cocos nucifera) is a member of the palm tree family (Arecaceae) and the only living species of the genus Cocos. The coconut tree provides food, fuel, cosmetics, folk medicine and building materials, among many other uses. A mature coconut tree's height can reach 20-22 meters on average, and its crown diameter generally goes to 8-9 meters. Thus, it can be recognized in high-resolution UAV-based images by visual interpretation.

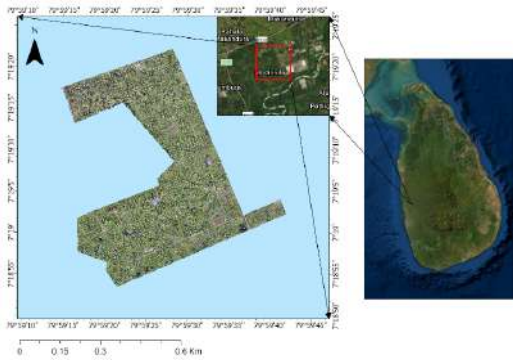

Figure 1. Overview of the experimental study area. The location map shows the study area in a red rectangle

Therefore, detecting ICTs, mapping their location and spatial distribution, and counting their planting area and the number of trees are important. It is desired to provide reference information for cultivation area investigation, yield prediction, and smart plantation management and plan in Sri Lanka.

B. Our proposed approach for individual coconut tree detection and mapping.

This study proposed an approach for detecting ICTs, mapping their spatial distribution, and counting their planting area and number by integrating deep transfer learning of YOLOv3 with high-resolution low-altitude UAV remote sensing images. The workflow of the proposed approach is illustrated in Figure 2, containing six steps shown as follows.

i. Capturing and processing UAV remote sensing images;
ii. Creating a dataset of Individual Coconut Tree Image Samples (ICTIS);

iii. Training, validating, and testing the YOLOv3 model;
iv. Evaluating the accuracy and performance, CocoNet, for the detection of ICTs will be obtained;
v. Mapping the location and spatial distribution of ICTs using the predicted results of CocoNet;
vi. Counting the planting area and the number of ICTs

To test and validate our proposed approach, the coconut trees were selected as the example targets to carry on the study on ICT detection and their spatial distribution mapping. The main methods and critical steps of the workflow are explained in detail in Figure 2.

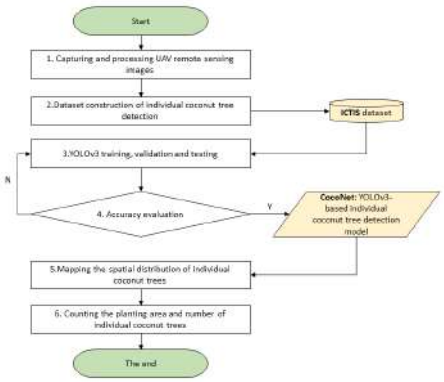

Figure 2. Workflow chart of our proposed approach to detecting and mapping individual coconut trees integrated YOLOv3 with UAV remote sensing.

1) Capturing and processing UAV remote sensing images: The DJI M300 RTK multispectral drone was used as a UAV system to capture low-altitude remote sensing images, equipped with 1/2.3" CMOS, 12 MP, including one RGB sensor for visible light imaging and five monochrome sensors for multispectral imaging (Blue, Green, Red, Red-Edge and Near-Infrared bands). It integrates RTK-enabled GNSS, including GPS and Galileo. So, it can capture high-quality multi-band remote sensing images without ground control points required in the traditional aerial survey. Furthermore, it can provide efficient tools for farmers in precision agriculture, significantly improving the efficiency of environmental data acquisition. To obtain high-quality UAV raw data, aerial photography tasks need to be planned before take-off.

A flight altitude of 150 m was set to capture high-quality UAV raw data with a spatial resolution of 5 cm, with 60% heading and lateral overlaps. Figure 3 shows some examples of the raw true-colour images collected by UAV aerial photography, which were used later to construct a dataset of RGB true-colour image samples of ICTs.

Figure 3. Examples of the raw true-colour images captured by UAV remote sensing.

The original images obtained by UAV remote sensing on date was pre-processed to generate a digital orthographic mosaic image model of the study area. The pre-processing steps mainly include:

i. Confirming the integrity of original image data, including camera parameters in the segment and segment attributes and GNSS information;
ii. Establishing engineering files and importing original image data, creating engineering, adding image data, setting image attributes, and camera model parameters in the Pix 4D Mapper software;
iii. Automatic processing of the UAV images, including initialization, point cloud encryption, regional 3D reconstruction, and digital orthographic image model generation

The digital orthographic mosaic image model of the study area generated through the above processes is shown in Figure 4. It spent about 60 minutes, two flights of UAV aerial photography, completing the task of capturing remote sensing images in the entire study area. During this task, the battery onboard needed to be replaced multiple times, causing the flight to start from a different place and thus, some images of different extent areas would be captured and the study area is consist with 3600 coconut trees and the area covered was 0.3 km^2.

Figure 4. Digital mosaic orthographic image of the study area.

2) Construction of a dataset of individual coconut tree image samples: The processed mosaic orthographic images of coconut trees were imported into ArcGIS Pro 2.8, and its deep learning module was used to label individual coconut tree samples. After labelling, cropping, and exporting, an individual coconut tree detection dataset based on a UAV remote sensing image was generated and named the Individual Coconut Tree Image Samples (ICTIS) dataset. The steps are as follows. Firstly, we created a shapefile of the surface element class vectors in ArcGIS Pro, drew circle elements for the coconut sample annotations manually according to the records of field investigation, added a class file in the properties table of surface element class vector, and identified the individual coconut tree sample's category. The annotation example is shown in Figure 5a. Secondly, the polygon feature-class file was used to export the images and their corresponding annotated sample data, suitable for the subsequent research requirements. The digital orthographic image of the study area was cropped into clip images with the size of 640 × 640 and zero overlaps. The images without coconut tree annotations were excluded when exporting in ArcGIS Pro. Lastly, a dataset of ICTIS was created according to the PASCAL VOC (Everingham, van Gool, Williams, Winn & Zisserman 2010) data format by combining all exported clip images, with a total of 570 images. The label example of the clip images of the dataset obtained after cropping and exporting is shown in Figure 5b. The actual label of an individual coconut tree is the minimum bounding rectangle of the drawn circle, which will be the ground truth for model training and validation in deep learning.

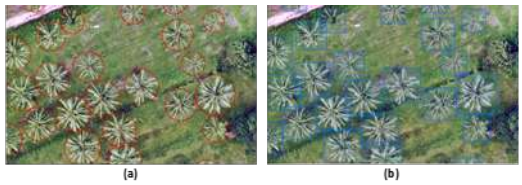

Figure 5. Annotation samples (a) in ArcMap and label samples (b) of the dataset of individual coconut tree image samples in the study area.

3) YOLOv3 deep learning object detection model: Based on the dataset ICTIS, the single-stage object detection algorithm of YOLOv3 (You Only Look Once) was empirically selected to train, validate, and test the model for individual coconut tree detection. YOLOv3 is the third version of the YOLO model family and has been widely used in object detection tasks such as pedestrians, vehicles, and ships. The YOLO model is divided into three parts: backbone network (Backbone), neck network (Neck), and head network (Head) (Figure 6). A backbone network is used to extract features from the input data; the neck network collects and distributes features of different scales; the head network is used to judge the positioning and category of the target box. In YOLOv3, the backbone network adopts a

cross-stage local network (Wang et al. 2020) to solve the problem of gradient information duplication and gradient disappearance of network optimization; it adopts a path aggregation network (Liu, Qi, Qin, Shi & Jia 2018) and spatial pyramid pooling network (He, Zhang, Ren & Sun 2015). As a neck network, the model enhances the detection of objects with different scaling scales to identify the same object of different scales; the head network uses the same detection layer as YOLOv1 and YOLOv2, applies the best anchor box to the feature map, and generates the final output vector with category probability, object score, and prediction bounding box.

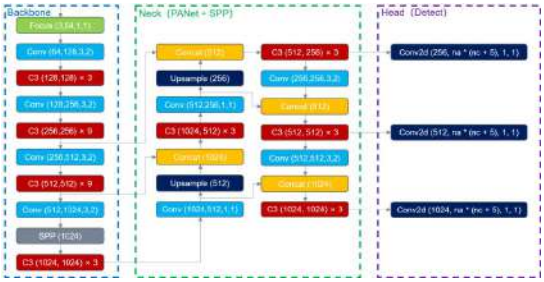

Figure 6. The YOLOv3 model structure.

The YOLOv3 model was used for training and validation. This model was named CocoNet for short. Finally, CocoNet was used to detect ICTs in the experimental area, and its spatial distribution map was made.

C. Evaluation metrics.

Model evaluation is very important in deep learning. Only by choosing an appropriate evaluation method can we quickly discover potential problems with the model in the training process and find suitable ways to optimize the model. The confusion matrix is not only a standard format for evaluating the accuracy but also a visualization tool capable of using special matrices to present the effect of model performance. The confusion matrix consists only of positive and negative examples. Table 1 shows the confusion matrix for a classic example of binary classification. Each column represents a predicted value, and each row represents an actual category.

Table 1. Confusion matrix of binary classification of artificial intelligence.

Confusion matrix		**Predicted label**	
		true	**false**
Actual label	positive	TP*	FP
	negative	TN	FN

* TP (True Positive) means that the actual category of the sample is positive, and the result predicted by the model is also positive. TN (True Negative) means that the actual category of the sample is negative, and the model predicts it to be negative. FP (False Positive) means that the actual category of the sample is negative, but the model predicts it to be positive. FN (False Negative) means that the actual category of the sample is positive, but the model predicts it as negative.

The present study is an example of a binary classification. We evaluated the accuracy of the trained YOLOv3 model using the precision, recall, F_1 score, and average precision(AP).

1) Precision and recall: According to Table 1, the precision (P) and recall (R) metrics are defined as Equations 1 and 2, respectively. Precision indicates the percentage of samples that were actually positive out of all results that were predicted to be positive samples. The recall indicates the ratio of samples predicted positive by the classifier to the actual number of positive samples. Also called sensitivity, it represents the classifier's sensitivity to the category of positive examples.

$$P = \frac{TP}{(TP+FP)} \quad (1)$$

$$R = \frac{TP}{(TP + FN)} \quad (2)$$

Where, P and R denote the precision and recall, respectively. TP, FP, and FN indicate the same meanings as in Table 1.

2) F1-score: The F1-score is the harmonic mean of precision and recall, taking both metrics into account in Equation 3.

$$F_1 = \frac{2 \times P \times R}{(P+R)} \quad (3)$$

Where, F_1 denotes the F1-score; P and R denote the precision and recall, respectively.

3) Average precision: In the domain of deep learning object recognition, Average Precision (AP) measures how well a model recognizes a particular category and is represented by a Precision-Recall Curve (PRC) plot (Figure 7). The PRC chart is a horizontal recall and vertical precision, and is a monotonically decreasing curve. The area under the PR curve for a particular category is defined as AP as defined in Equation 4.

$$AP = \int_0^1 f(c)d(c) \quad (4)$$

Where, AP is the average precision and f(c) is the precision recall curve for category c. The closer the curve is to the upper right corner in the PR plot, the more accurate the model is. In addition to using the model to estimate the area under the curve, we can also draw a line with a slope of 1 on the PRC plot and the intersection of this line with the PR curve is the equilibrium point F1. This score is known as F1 score.

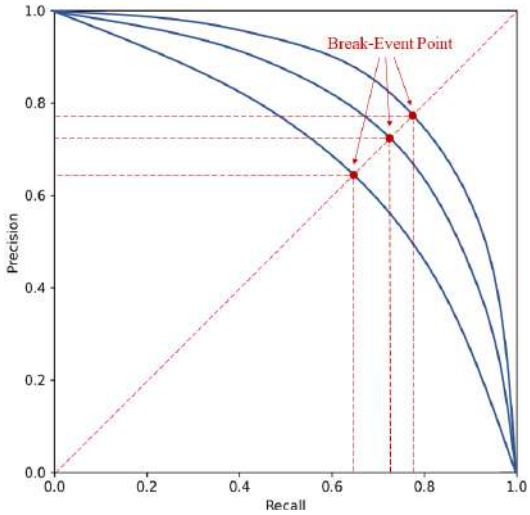

Figure 7. Precision-Recall Curves

4) Average precision: In object detection, the strength of a representation model is not only the prediction probability of categories, but also the accuracy of the positioning of prediction boxes. The Intersection over Union (IoU) ratio is commonly used as the matching degree evaluation metric for predicted bounding boxes and ground truth boxes in a data set (Figure 8), and their area intersection and intersection ratio are calculated according to the Equation 5. The higher the ratio value, the better the match. The ideal result is a perfect overlap between the prediction box and the ground truth box that achieves a ratio of 1.

$$IoU = \frac{\text{Area(B)} \cap \text{Area(G)}}{\text{Area(B)} \cup \text{Area(G)}} \quad (5)$$

Where, The area of the prediction bounding box is shown by Area(B) , and The area of the ground truth box is shown by Area(G).

Figure 8. Intersection over the union of ground truth and prediction bounding box.

The threshold criterion for positive is IoU > 0.5, otherwise negative. Therefore, AP@0.5 used below represents the average precision when IoU > 0.5 and AP@0.5:0.95 used below represents the average accuracy when IoU is between 0.5 and 0.95. Furthermore, inference time is also an important metric for evaluating the model's ability in object detection. Frames per second (FPS) is commonly used to measure model inference speed.

5) Experimental environment and setup: The experimental platform was configured with the following:

- AMD RYZEN 7 5800X CPU with 3.8GHz processor
- MSI RTX 3050 VENTUS 8GB GPU independent graphics card
- 64-bit Windows 10
- Python 3.7,
- PyTorch 1.8.1

By cross-validation, 513 (90%) images were randomly selected as the training set and 28 (5%) images were selected as the validation set. The remaining 28 (5%) images were used as a test set to test the final model.

3. Result and Discussion

A. Model Characteristics

1) Accuracy of the YOLOv3 model: Figure 9 shows the average precision (AP@0.5) variation of the YOLOv3 model during the training process from 20 to 120 epochs. With the help of the pre-trained model weights, the model can achieve high accuracy quickly. After 75 epochs of training, the AP of YOLOv3 reaches the fitting state and remains stable.

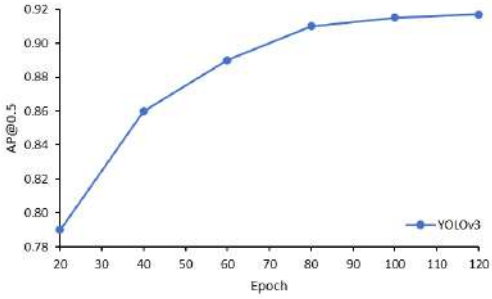

Figure 9. Average precision (AP) variation of each YOLOv3 model (20~120 epochs).

By comparing the accuracy evaluation metrics of the model in Table 2, it can be found that YOLOv3 accuracy performance is suitable for ICT detection.

Table 2. Results of the evaluation metrics of the YOLOv3 model.

A. **odel**	*B.* **recisio n**	*C.* **ecall**	*D.* **1 Score**	*E.* **P@0.5**
F. OLOv3	*G.* .871	*H.* .859	*I.* .867	*J.* .917

*AP@0.5 means the average precision when the Intersection over Union > 0.5

2) Training and validation loss of the YOLOv3 model: Based on the training and test loss curves in Figure 10, the model has performed well, and there is no overfitting. If the training loss value is close to the value of the validation loss, the model is not overfitting. The lower the loss, the better the accuracy of the model.

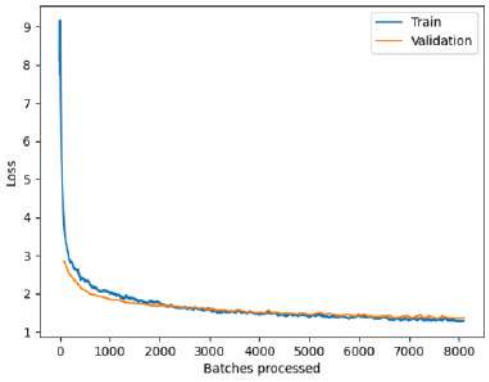

Figure 10. Training and validation losses curve of the YOLOv3 model.

B. Statistics and mapping of the individual coconut trees

A thematic map (Figure 11) was made to show the spatial distribution of the detected ICTs using the retrained YOLOv3 model. As shown in the two inserted square boxes of Figures 11b and 11c, it can be found that different sizes of ICTs are almost detected accurately, indicating that CocoNet could have a high enough accuracy to complete the task of individual coconut tree detection. It is necessary to test further and validate the feasibility of the application of CocoNet in other coconut plantations.

The original square labels detected by using CocoNet were converted into the corresponding circles to reduce the overlapping effect on the map. The planting area and the number of the detected ICTs in the experimental study area were counted with the ArcGIS Pro software and shown in the thematic map. The results show that the cultivated area is 297,156.83 $m^{2,}$ and the total number of coconut trees is 3,306.

C. Limitations and future work

Despite a lot of hard work, there are some limitations in dataset creation, deep learning model selection and design, and hyperparameter optimization. First, although we acquired both RGB and multispectral images using UAV remote sensing, only the UAV-based RGB images were used to construct the ICTIS dataset in the present study. The UAV-based multispectral images will be used in future studies to improve the model's accuracy. Other UAV-based high-resolution images such as hyperspectral or LiDAR imagery would be better options for the detection of ICTs because their more spectral information or highly effective point cloud data (Hu et al. 2022; Jaskierniak et al. 2021) could reveal more detailed features and improve the performance of CNNs that helps distinguish ICTs from the images. Second, more CNN models such as Faster R-CNN, U-Net, SDD, and Mask RCNN (Yu et al. 2022; Safonova et al. 2021; dos Santos et al. 2019) should be trained and tested to obtain a better model to fulfil the task. The structure of the model could even be modified to improve accuracy and performance for better precise applications of smart plantation management. Third, data augmentation and hyperparameter optimization need to be further carried out to obtain a more robust performance model. These all deserve further research.

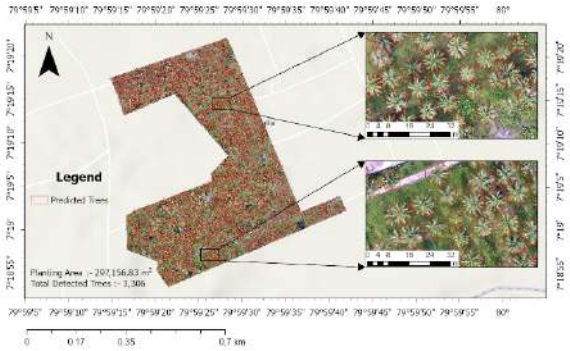

Figure 11. A thematic map shows the spatial distribution of the detected individual Coconut trees using the YOLOv3 and their planting area and number information with two enlarged square regions inserted.

In the future, our proposed approach can be used to obtain these kinds of spatial and attribute data about the individual coconut trees in a plantation. These data could be easily integrated into a smart plantation management system that could provide fast growth monitoring of individual coconut trees, accurate yield estimation of the coconut, real-time disease prevention and control, and precision cultivation and management. Town-level, county-level and city-level thematic maps of ICTs will be made through our proposed approach in the coming study. The coconut yield estimation based on the thematic map of ICTs will be an important topic in our future research.

4. Conclusion

In the present study, we proposed a deep learning approach to detecting and mapping individual coconut trees in UAV remote

sensing imagery, taking the coconut trees in Mahayaya Coconut Model Garden, Sri Lanka, as an example. UAV remote sensing technology was applied to acquire high spatial-resolution images of the study area. These images were pre-processed in the Pix 4D Mapper software. A dataset of individual coconut tree image samples (ICTIS) was constructed through visual interpretation and the deep learning tools in the ArcGIS software combined with fieldwork investigation. YOLOv3 object detection model was used to train and validate the dataset. The evaluation results show that the model achieves relatively high detection accuracy. The trained YOLOv3 model, namely CocoNet, was thus selected to detect and post-process ICTs in the whole mosaic orthographic image of the study area. Finally, a spatial distribution thematic map of ICTs was made according to the detection results. This study provides reference information for related research and smart plantation management.

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Optimum Site Selection for Fire Brigade in Ella, Sri Lanka by Utilizing GIS

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Abstract: *As an island nation, Sri Lanka is facing different disasters while the forest fire disasters that are dominant in the highlands of the country are significant. In the Ella neighbourhood, forest fires occur every year near the end of the dry season. Further, the absence of other fire stations near the area is a considerable issue and under the investigation found a suitable location for the forest fire brigade and analysed the network connectivity to the selected location from any place of the Ella. To find the best placement for a fire station, a site selection analysis was performed in a GIS context via weighted overlay analysis. As the data sources of the study population, Land use land cover, elevation, water sources, road, building, pre-fired area, and pre-hazardous areas were utilized in the ArcMap 10.5 software platform through spatial analysis tools and network analysis tools. For the determination of weights for each factor, the Analytical Hierarchy Process was used as the main statistical technique of the study. Finally, the selected areas were examined via visual validation in Google Earth and selected the most suitable location for fire brigade establishment along with the network analysis. In addition, the establishment of the fire brigade is crucial in the central part of the country due to the magnitude and the frequency of the disaster. Further, the proposed study can be utilized as a comprehensive guideline for any organization before the establishment of the fire brigade.*

Keywords: *Analytical Hierarchy Process, Forest fire, Geographical Information Science*

1. Introduction

The Ella area of Sri Lanka is very popular not only for locals but also for foreign tourists and most people come to Ella every day, the fire brigade is not available near Ella city for their safety of them because this area is extremely vulnerable to occurring forest fires. It is difficult to mitigate if forest fire occurs in the Ella area because of the geographical situation like winds blowing fast as well as mountains with forest and the distance for the nearest fire brigade situated at Badulla is more than 23 Km. Therefore, the availability of a fire brigade is significant for the Ella area and searching for a suitable location in the Ella area to establish the fire brigade is currently an ongoing significant research area. The Geographic Information System (GIS) is a system of collection of modern software and computer technology for creating, managing, analysing, and mapping all types of data and it is vital for selecting a suitable location for the fire brigade with an optimum path to access location via network analysing (Nay *et al.*, 2019). Thus, the objective of the study is to find a suitable geographical location for the fire brigade in Ella, Sri Lanka, and find the optimal path for accessing the selected place from the pre-fire locations.

2. Methodology

Various environmental variables need to be considered when selecting a place for construction, especially in sensitive factors like constructing a fire station. A considerable extent of experimental design reports, documents, and case studies to

identify both critical success factors and failures and different hardware and software tools in data gathering, analysis, and conceptual design building were studied for that. In the study, the Ella city area was selected as the study area, and it is shown in Figure 1.

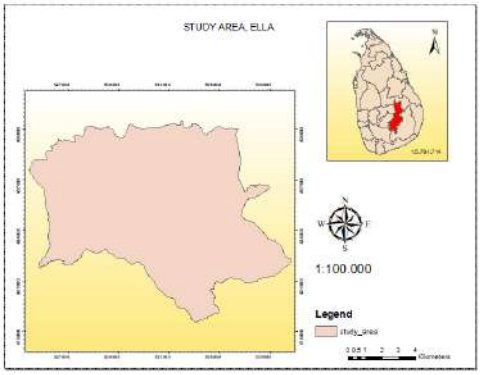


Figure 1: Study area

First, spatial data from the survey department and population data from the statical department website were gathered. In the study, eight data layers such as land use, road, water, population, building, pre-fired area, pre-hazardous areas, and slope are used for achieving the objective. During the analysis, pre-processing was conducted, and all required layers were converted into a raster format. My case analysis has two parts spatial analysis to find the best location for the fire brigade and network analysis to find the optimum path from the selected fire brigade to pre-fire locations.

The four scale values used in the land use layer were forest, cultivation, home gardens, and others. Among those scale values, priority was given to forest. The second place was given to cultivation and home gardens were given the third place. Others were given the least priority.

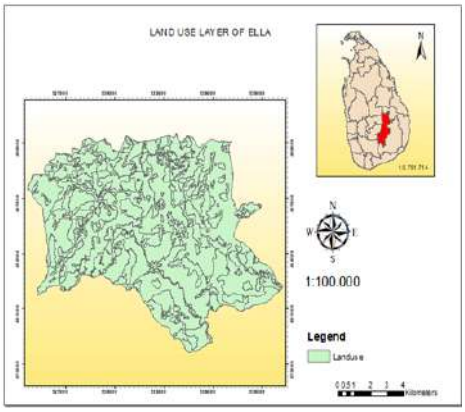


Figure 2: Land use layer of Ella

The road layer in the GIS model was divided into four parts 0-75, 75-150, 150-225, and 225 or more according to the distance from the road. In this layer, the Euclidean distance method was used according to the parameters.

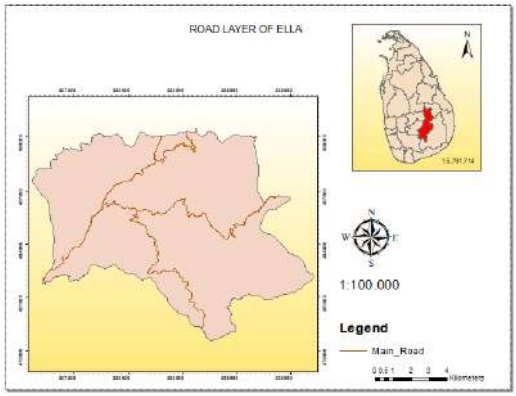


Figure 3: Road layer of Ella

The water layer also ranks according to the distance from the water feature as below 200m, 200-400m, 400-600m, and above 600m.

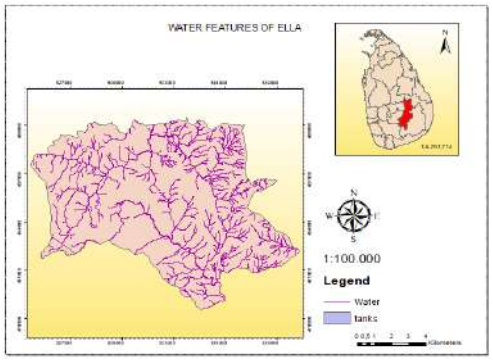


Figure 4: Water features layer of Ella

The population layer was divided into three layers less than 1000, 1000-2500, 2500, and more.

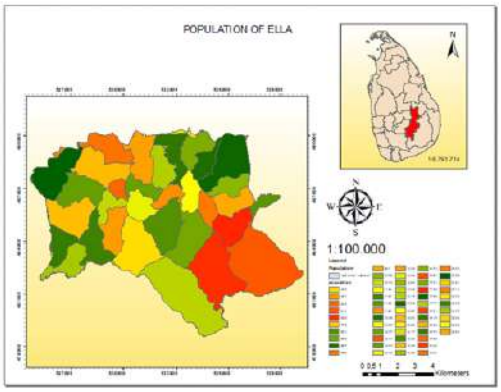


Figure 6: Population layer of Ella

Figure 5: Population statistics of Ella

The building layer was divided into four scale values 0-500m, 600-1000m, 1100-1500m, and 1600-2000m according to the Euclidean distance.

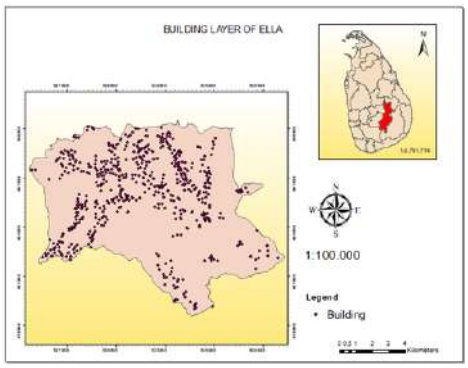


Figure 6: Building layer of Ella

When constructing a fire station, it is vital to locate it far from fired areas. By considering this, according to the distance from pre-fire locations, it was scaled as 250m, 500m, 1000m, and 1500m. Pre hazards also should be considered when constructing a new fire brigade and it was scaled as 100, 200, 400, and 600 m distances from hazard. And, the slope of the ground should be considered, and a flat area was considered the most suitable area to construct the building. It is also scaled by using slope values.

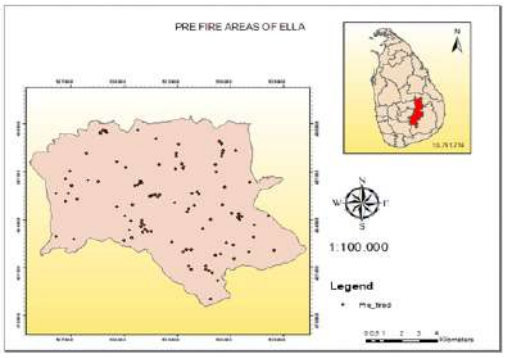
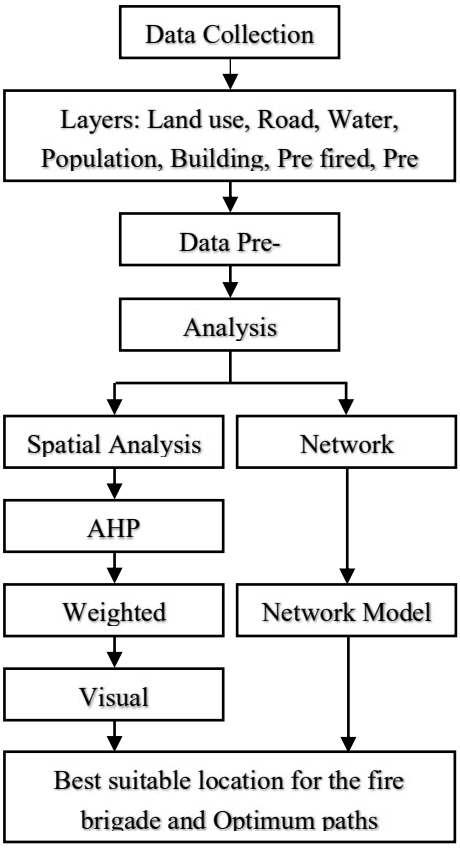


Figure 7: Pre-fire layer of Ella

Before doing the spatial analysis, it is needed to assign weights for each data layer. So, Analytical Hierarchical Process (AHP) was used to determine the weights of data layers. The AHP is a powerful simple method for making decisions and it is commonly used for project prioritization and selection as well as it is a method that is mostly used in past research and most findings when the final choice or selection is uncertain. (Green

et al., 2014). The procedure of using AHP is to define alternatives, define the problem and criteria, establish priority amongst criteria using pairwise comparison, check consistency and finally get the relative weights (Kaleji, 2019). Before-mentioned layers were reclassified into four classes and applied the weighted overlay, as well as

Figure 8: Methodology flow chart



again reclassification, was done for selecting suitable areas for the fire brigade. Finally found a suitable place by visual validation for the establishment of the new fire brigade with optimum access from pre fire locations with the help of network analysis. The above-mentioned methodology is shown in the Figure 8.

3. Results

As mentioned in the methodology, land use, road, water, population, building, pre-fired, pre-hazard, and slope layers were utilized for the study. GIS model had selected to complete the analysis which consists of eight layers. In the study, weights are assigned by using the AHP method and based on the calculated weights, a pairwise comparison matrix was prepared, and it is appearing in Table no 1.

After that above eight data layers were weighted overlayed by using the weighted overlay tool and obtained output is shown in Figure 09.

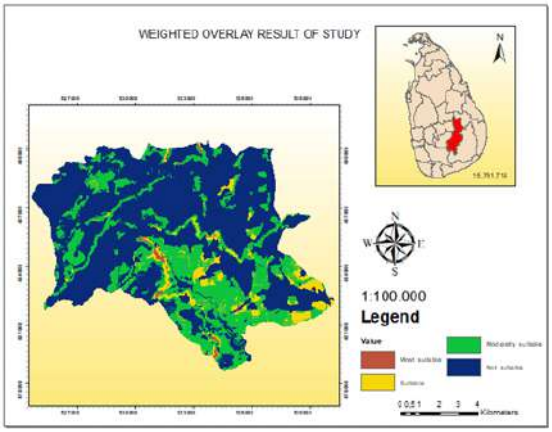


Figure 09: Output of weighted overlay

Based on a weighted overlay, several land lots were obtained to establish the new fire brigade and these suitable locations are shown in Figure 10.

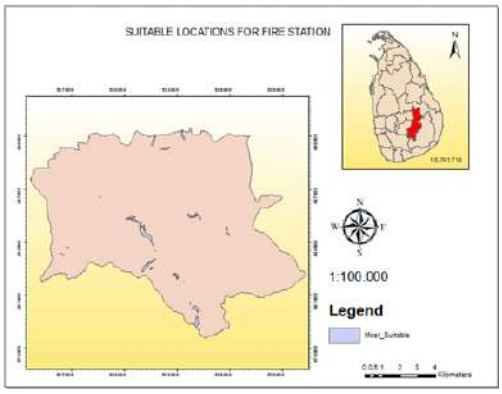


Figure 10: Suitable locations for the fire station

Table 1: Weighted overlay matrix

A. No	B. Layer	C. Influence	D. Field	E. Scale Value
F. G. 1	H. Land use	I. 28%	J. Forest	K. 9
			L. Cultivation	M. 3
			N. Home Garden	O. 2
			P. Others	Q. 1
R. 2	S. Road	T. 19%	U. 0-75m	V. 9
			W. 75-150	X. 4
			Y. 150-225	Z. 2
			AA. 225-300	BB. 1
CC. 3	DD. Water	EE. 15%	FF. <200m	GG. 9
			HH. 200-400	II. 6
			JJ. 400-600	KK. 2
			LL. 600-800	MM. 1
NN. 4	OO. Population	PP. 13%	QQ. Less than 1000	RR. 9
			SS. 1000-2500	TT. 5
			UU. 2500-5000	VV. 3
WW. 5	XX. Building	YY. 9%	ZZ. 0-500m	AAA. 9
			BBB. 600-1000m	CCC. 5
			DDD. 1100-1500m	EEE. 2
			FFF. 1600-2000m	GGG. 1
HHH. 6	III. Pre fire	JJJ. 6%	KKK. 1500-1001	LLL. 9
			MMM. 1000-510	NNN. 8
			OOO. 500-260	PPP. 3
			QQQ. less than250m	RRR. 2
SSS. 7	TTT. Pre hazard	UUU. 7%	VVV. 600-400	WWW. 9
			XXX. 400-200	YYY. 6
			ZZZ. 200-100	AAAA. 2
			BBBB. <100m	CCCC. 1
DDDD. EEEE. 8 FFFF.	GGGG. lope	HHHH. 3%	IIII. Flat<2	JJJJ. 9
			KKKK. Gently sloping2-3	LLLL. 4
			MMMM.sloping3-6	NNNN. 2
			OOOO. Steep>6	PPPP. 1

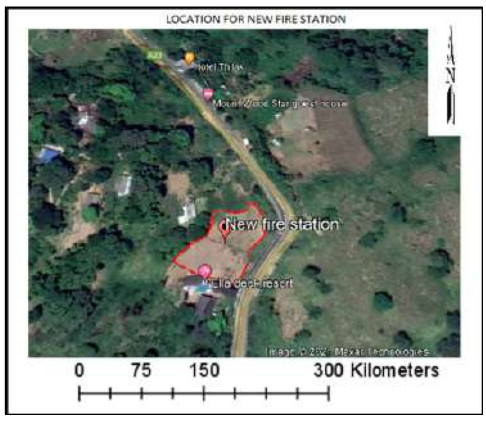


Figure 11: Location of the new fire station

With help of Google Earth, visual validation was done to find the most suitable location to establish the new fire brigade and the selected place is shown in Figure 11.

Lastly, network analysis was performed to find the optimum path from pre-fire locations to the location selected to be established for the new fire brigade.

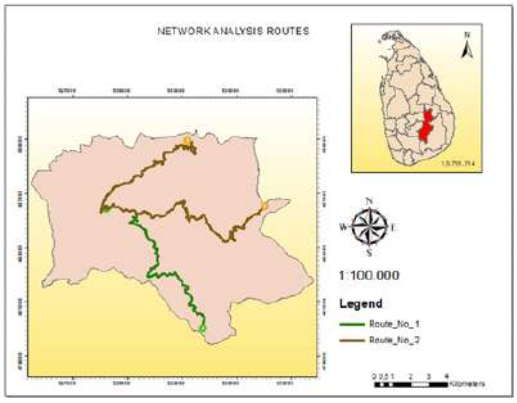


Figure 12: Output of Network analysis

4. Discussion and Conclusion

There are many subcategories under-identified factors and hard to identify and select the factors among all available factors. It is challenging to design experimental design as selecting a geographical location is different from others. According to the analysis, there are suitable areas that can be used to locate the fire bridge at Ella, Sri Lanka. Using GIS tools and technologies with ArcGIS software could map and display the geographical areas graphically to identify the suitable place with factors considered in the study. This research paper focused on finding a suitable geographical location for a fire bridge in Ella, Sri Lanka. According to the requirement of the factors used in the research, the ArcGIS tool was used to analyse the compatibility of factors and identify the most suitable places. Finally, the visual validation through Google Earth is incorporated for the selection of the best location. Further, the experimental workflow can be utilised as a guideline for future forest fire brigade site selection.

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An Assessment of RTK and PPK Solutions in a CORS Network

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Abstract*: Recently, Sri Lanka has developed a greater interest in surveying applications based on Continuously Operating Reference Station (CORS) technology. CORS Real Time Kinematic (RTK) can perform well through a good Global System for Mobile Communications (GSM) coverage area by receiving the corrections in real-time. It is very difficult when facing the GSM network coverage limitation issue in remote areas. As an alternative solution, Post Processing Kinematic (PPK) is a good solution to face that problem because it does not need a real-time data communication link for the correction signal when doing the survey. This study aims to compare the RTK and PPK solutions in a CORS network in Sri Lanka. Seven known points were selected near the Belihuloya area. The CORS reference station was the SULECO SUSL station. Position solutions were compared for both PPK and RTK methods with several sets of observations. According to the results, the horizontal variation of the PPK was accurate as the same as the RTK solution, which was below the 1cm mean difference. However, the vertical accuracy was lower than the horizontal accuracy in the PPK technique. This was around 10 to 15cm variations in the study area. In conclusion, both PPK and RTK techniques gave similar results in terms of horizontal accuracy in a CORS network. Therefore, the issues of real-time corrections transfer in a CORS network can be overcome by adopting PPK mode for the boundary and detail survey without interrupting the progress.*

Keywords: *Accuracy Assessment, CORS Network, GNSS, PPK, RTK*

1. Introduction

Global Navigation Satellite System (GNSS) is the latest satellite-based surveying technique in the modern-day which mainly contribute to the worlds positioning and navigation applications. At the very beginning of the GNSS technology, it was not much accurate due to satellite orbit errors, satellite clock errors, signal delay errors in the troposphere and ionosphere, receiver noise errors, multipath, and so on (Karaim et al., 2018). End users have been moving to the new technology of GNSS to their ease of use in real-life applications by avoiding out-of-date technologies (Lilje, et al., 2009).

Continuously Observation Reference Stations (CORS) network, which installs permanent GNSS base stations with a network server is one of the present trends in which people are moving rapidly to use real-time accurate positioning (Lilje, et. al., 2009). It uses ground-located high accuracy GNSS receivers to obtain location data from GNSS receivers and it gives real-time corrections. This CORS Network combines the fixed base stations and creates a model to act as a Virtual Reference Station (VRS) for clients and decrease the base station distance to increase the position accuracy (Burns and Sarib., 2010). The raw data which are collected through high accuracy GNSS receivers, send lively to the control centre and corrections are processed in the control centre. Radio Technical Commission for Maritime Services (RTCM) corrections instantly broadcast as Network Transport of RTCM via Internet Protocol (NTRIP) to the rover receiver via General Packet Radio Service (GPRS). This Network covers a large area than a conventional single GNSS base station and it does not bias toward one station in this method. There should be at least three base stations to make the network. At present time this is very

essential because the client can collect data only with one rover receiver and no more worries about setting up physical base stations (Janssen *et al.*, 2011).

When considering Sri Lanka, SLCORSnet of the Survey Department of Sri Lanka and the CORSnet of Suleco (Pvt) Ltd. provide the services of CORS network experience to the clients. It provides (Differential GNSS) DGNSS, single-base (Real Time Kinematic) RTK, (Network RTK) NRTK, and (Receiver Independent Exchange Format) RINEX data for post-processing applications. Both systems are still upgrading to give the best coverage in Sri Lanka.

RTK uses a carrier-based range to deliver positions with more precision. The distance between the base and the rover should not exceed 20 Km to maintain the high accuracy of the RTK solution (Shouny et al., 2017). CORS Network needs a good (GSM) network coverage to pass the correction data when using the CORS RTK method. In this method, corrections transmit through a GSM sim card from the CORS Network server to the rover. Sometimes it is not possible to maintain a good signal transferring between the CORS and the rover in real-time due to the limitation of GSM network coverage in remote areas in Sri Lanka.

PPK is one of the solutions that is widely used in surveying and mapping to obtain high-precision or centimeter-accurate position data (Pirti, 2021). PPK technology does not require any real-time data communication between the base station and the receiver (Ahmed Fouad Metawi El-Shouny, 2008). Surveying with PPK technology could be the best option in the modern-day due to the use of the post-processing method with carrier phase signals when surveying challenging and low or limited GSM coverage areas.

According to the *opensingnal.com* website, they reported the 4G coverage of Sri Lanka by considering the four national mobile telecommunication operators; Airtel, Dialog, Hutch, and Mobitel. Opensignal.com have gathered data for 90 days from the start of October 2021 to December 2021 to analyse the data. The best service provider, Dialog is also providing 87% in coverage as shown in Figure 1 (Opensignal Limited, 2022).

Figure 1 : Network Coverage in Sri Lanka | Source: https://www.opensignal.com/reports/2022/02

The website, *nperf.com* provides details about the quality of your internet connection and collects a huge amount of data on mobile network coverage per year. It shows the main GSM service provider's network coverage in Sri Lanka using the collected data from 2020 (Figure 2) (Nperf, 2022).
Sri Lanka has several network service providers such as Dialog, Mobitel, Airtel, and Hutch and there is not fully covered entire Sri Lanka by any service provider according to the above online records.

CORS network is rapidly growing in the GNSS world due to its accuracy, reliability, and ease of use. A lot of end-users in Sri Lanka have moved to access CORS Network because of its benefits.

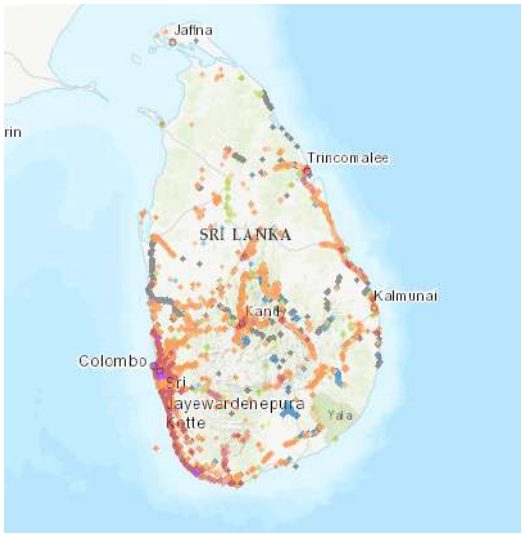


Figure 2 : Dialog GSM Coverage Maps in Sri Lanka |Source: https://www.nperf.com/en/map/LK/-/24443.Airtel/signal/?ll=7.976239853732186&lg=80.23452758789064&zoom=10

But there are not such end-users who have engaged with PPK solution, due to a lack of knowledge of the position accuracy of PPK over Sri Lanka. This research emphasizes the accuracy assessment between RTK and PPK in a CORS network in Sri Lanka.

2. Methodology

A. *Study Area*

The study was carried out over the Sabaragamuwa University premises located at Belihuloya which belongs to Ratnapura district in Sabaragamuwa province Sri Lanka as shown in Figure 3.

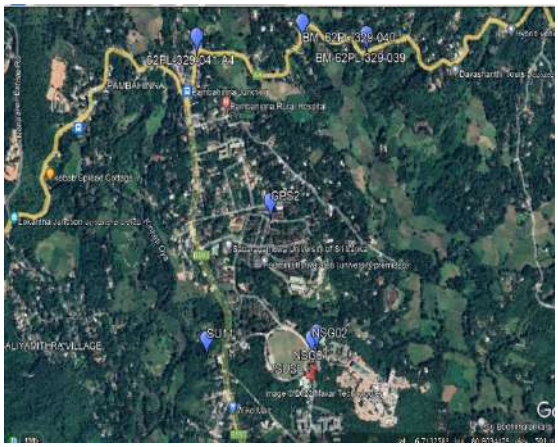


Figure 3 : Study Area

QQQQ. *Methodology Flow Chart*

Figure 4 explains the overall research methodology. Here, the priority was to collect the RTK and PPK data of the relevant stations around the study area and to compare the variation of the results.

As the secondary data, three survey department ground control points around the study area were obtained from the survey department of Sri Lanka (BM-62PL-329-039, BM-62PL-329-039, and BM-62PL-329-039). Previously established four ground control points (NSG1, NSG2, GPS2, and SU11) by the Faculty of Geomatics at the Sabaragamuwa University of Sri Lanka were also selected. These points were re-established by making a one-hour static observation using the same CORS Network base station (SUSL station).

RTK observations were taken for 10min, 5min, 1min, the 30s, and 5s time on the same station, and three data sets were obtained for each time interval for the statistical analysis. Similarly, the PPK observations were also taken for 10min, 5min, and 1min time intervals as three sets.

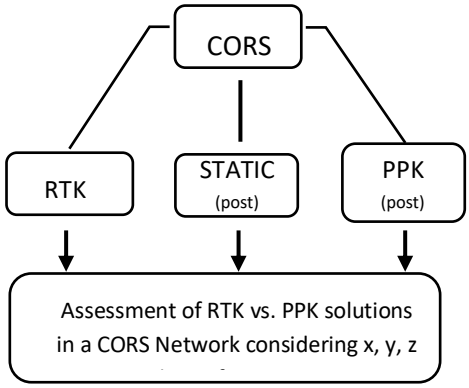


Figure 4 : Flow Chart Methodology

Figure 5 : Data Collection

Leica GS15 GNSS receiver and the Leica Infinity 3.0 post-processing software were used for the data acquisition and processing. Figure 5 shows the RTK and PPK field data acquisition procedure.

3. Results and Discussion

The result of the RTK and PPK solution in the SUSL CORS base station for East, and North coordinates and the height variation have been graphically represented in Figure 6 and Figure 7 graphs respectively. Most of the time horizontal coordinates have shown a similar variation and the vertical component variation shows considerable variation between the two solutions.

Figure 8 represent the Easting differences between RTK and PPK solutions. Figure 9 represent the Northing differences between RTK and PPK solutions, and Figure 10 represent the Height differences between RTK and PPK solutions. The mean differences between the PPK method and RTK method did not exceed 0.015m for the horizontal component (ΔE and ΔN) and 0.15m for the vertical component (ΔH).

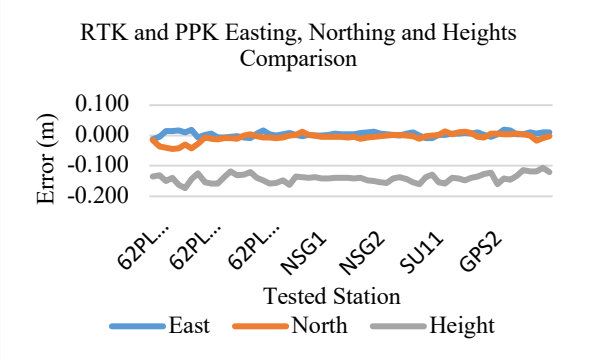


Figure 6 : RTK PPK North, East, Height Comparison | Line Graph

The standard deviation was 0.005m for ΔE and 0.07m for ΔN and 0.07m for ΔH components as shown in Figures 8,9, and 10. The best fit line has shown the variation of the difference between the RTK and PPK coordinates which is below 0.02m in the horizontal component and below 0.15m in the vertical component.

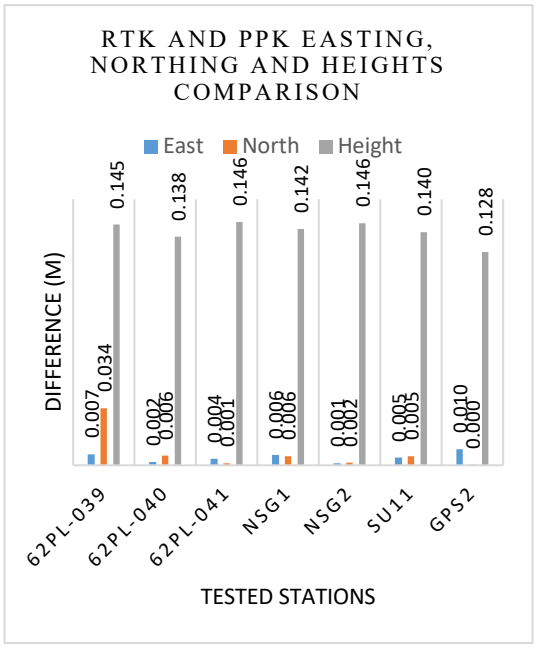


Figure 7 : RTK PPK North, East, Height Comparison | Average value in Bar Graph

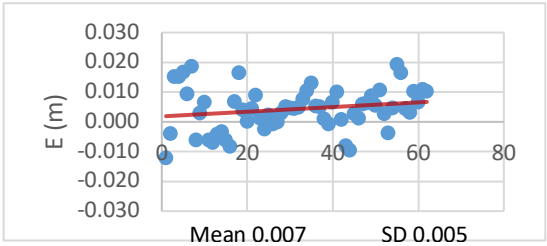


Figure 8 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔE

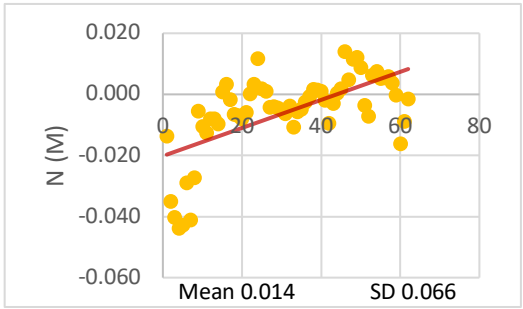


Figure 9 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔN

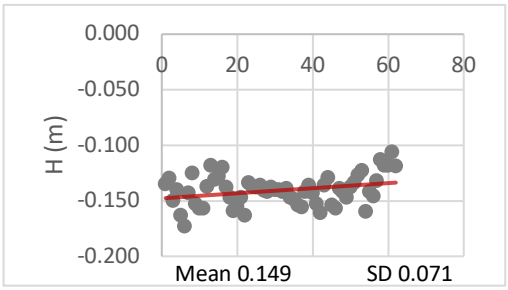


Figure 10 : Comparison of the coordinates of the test points for RTK vs PPK methods| ΔH

Then, a comparative analysis of a simple box and whisker plot was used to compare the difference between the RTK and PPK solution's northing, easting, and height variation as shown in Figure 11.

According to the analysis, horizontal variation of the PPK was accurate same as the RTK solution at sub-centimetre level i.e. below 1cm mean difference. Vertical accuracy was lower than horizontal accuracy i.e. it was closed to 10-15cm variations in the study area. According to the theories of Dilution of Precision (DOP) value, vertical direction accuracy is lower than the horizontal accuracy (Tahsin *et al.*, 2015).

As a secondary objective, obtained data was sorted as the observed time interval period of the Northing and Easting accuracy variations for both RTK and PPK solutions in a CORS network. Analyse was used to see the performance of the accuracy when changing the observation time period of each solution.

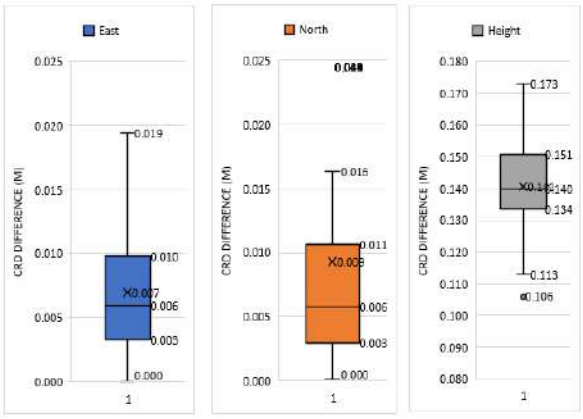
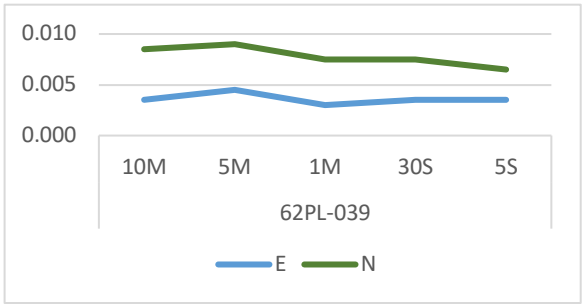
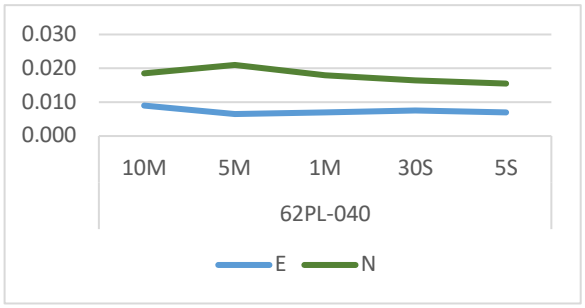


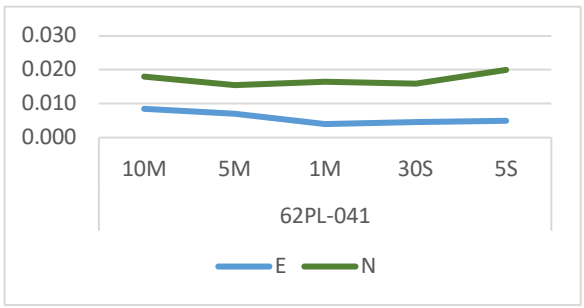
Figure 11 : Simple Box and Whisker Plot for E(left), N(middle), H(right) of RTK-PPK

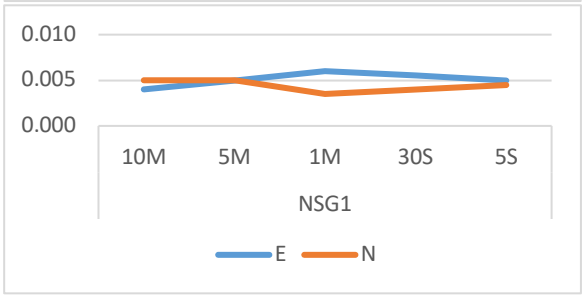
Figure 11 illustrates the lower quartile, median and upper quartile of the Easting difference were 0.003m, 0.006m, and 0.010m respectively. The same statistics for the Northing difference were 0.003m, 0.006m, and 0.011m. Northing difference has some outliers i.e. a piece of data that is an abnormal distance from other points, in the data set. It was from only one set of data variations. 75% of the Easting and Northing variation is around the 0.01m range. The lower quartile, median and upper quartile values of the Height differences were 0.134m, 0.14m, and 0.151m. It is emphasized that 75% of the height variation is below the 15cm range.

Horizontal accuracy of the RTK solution was graphed to analyse the accuracy variation pattern according to the observation time period as shown in Figure 12. Horizontal accuracy of the PPK solution was graphed to analyse the accuracy variation pattern according to the observation time period as shown in Figure 13.









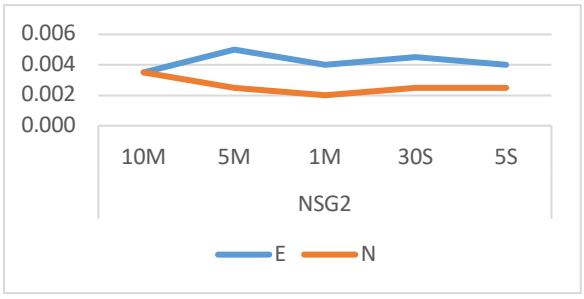
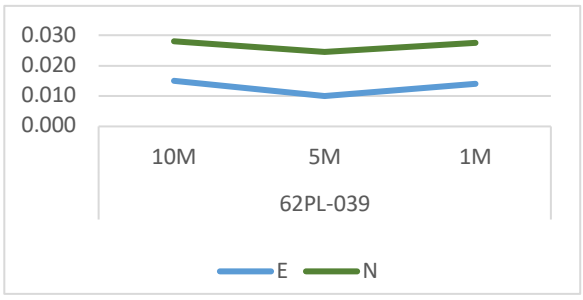
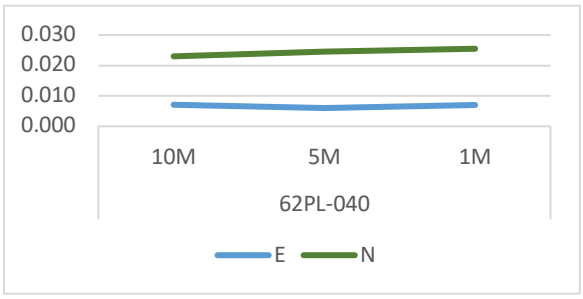
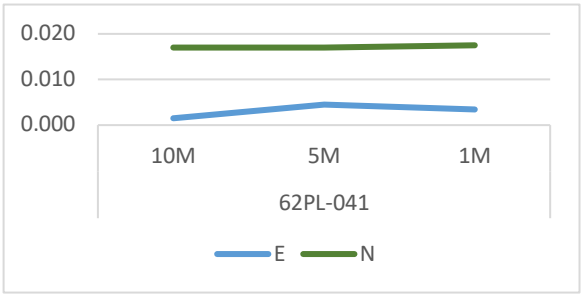
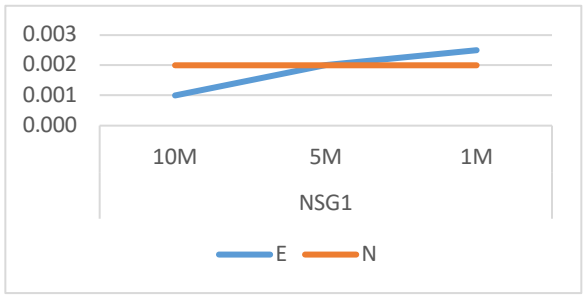


Figure 12 : RTK Position Accuracy Pattern considering the observation time interval









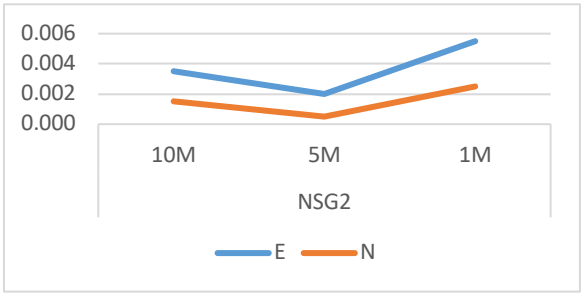


Figure 13 : PPK Position Accuracy Pattern considering the observation time interval

Figures 12 and 13 illustrate the RTK and PPK

northing and easting accuracy pattern considering the observation time interval. Most of the time, the number of epochs were 601 for 10min, 302 for 5min, 61 for 1min, 31 for the 30s, and 7 for 5s. According to the graphs, the obtained position accuracy of both solutions was not biased by the observation time interval period in GNSS observations in the study area.

4. Conclution and Discussion

RTK solution is the most suitable solution when comparing the PPK method according to the final results of the research. Although PPK solution has also performed the same as the RTK maintaining a good horizontal accuracy i.e.75% of the Easting and Northing variation is around the 1cm range. Considering the vertical component of the assessment, that has a low accuracy for both solutions when comparing the horizontal accuracy. The mean value ΔH of RTK was 6.4cm and 8.1cm for PPK solution and both solution average variation was nearly 14cm.

As a sub-objective, obtained data was collected for comparing accuracy pattern according to the observation time intervals. Results were not good enough to get a clear idea of the accuracy variation with the number of epochs of the signal. Because figure 12 and 13 does not show the accuracy enhancement when increasing the observation time period.

Comparing the results, PPK has performed the same as the RTK in horizontal accuracy in a CORS network. It would be a good solution to use in a low GSM coverage area to solve the problem of correction transferring in real-time a CORS network. The final results of the research have justified the importance of understanding the concept of PPK solution replacement for RTK in the Belihuloya region through a CORS network.

Due to the practical difficulties, this study was limited only to the Belihuloya region, only SUSL CORSnet base station and suggested to do the test for the other parts of the country to get a better picture of the entire CORS network performance.

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Acknowledgment

Special thank goes to the Survey Department of Sri Lanka and Suleco PVT LTD for providing the necessary data to successfully conduct this research

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Feasibility Analysis of Unmanned Aerial Vehicle Survey for Outer Boundary Surveys

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Abstract: *Cadastral surveying is the intellectual and technical process by which the boundaries of each of the land parcels within a given area are defined in a consistent manner. The main problems of the Sri Lankan cadastral system are increased time consumption, high cost and inefficient methods for data acquisition. In cadastral surveying mainly there are three operations. Those are determination of boundaries, survey of boundaries, and the demarcation of boundaries. This paper presents a modern method of close-range photogrammetry using Unmanned Aerial Vehicle (UAV) as a solution in the scope of determining and surveying boundaries. This study analyses the capability of UAV surveys to function as a rapid, cost effective and accurate alternative to current data acquisition techniques in the hope of accelerating the cadastral mapping process of the country. The accuracy of UAV to survey outer boundaries was measured by comparing land extents of typical land parcels obtained via two methods, UAV and Total Station (TS). The results of this study show the point cloud generates from UAV images generate a similar extent output as conventional methods. The only limiting factor was boundary visibility which was not an issue in the research scope. The advantage of UAV systems lies in their high flexibility and efficiency in capturing the surface of an area from a low flight altitude*

Keywords: *Boundary detection, Cadastral Surveying, Mapping, Surveying, Total Station, Unmanned Aerial Vehicle*

1. Introduction

Cadastral mapping is a vital and complex process of a country. Cadastral mapping is not just about surveying the geometric area but maintaining the legal aspect as well. Choosing a proper cadastral mapping method has many advantages for the land management and administration of a country. Currently in Sri Lanka, the cadastral mapping process is conducted under the guidance of the Survey Department of Sri Lanka. The process has been going on for decades. Even though the cadastral mapping process has been completed in certain regions, still a major part of the country has not been surveyed for cadastral purposes. Furthermore, a proper method for updating cadastral maps has not been employed in Sri Lanka as of today. Total Stations are widely used in Sri Lanka for cadastral data collection. Recently the survey done using Global Navigation Satellite System (GNSS) was accepted by the Survey Department of Sri Lanka for the cadastral data collection (Sri Lanka Survey Department, 2020). Still the gaps in the local cadastral systems to become an efficient system have not been fulfilled. By switching the data collection method over to a low cost and quick method, the cadastral mapping process can be drastically accelerated. It is a global growing interest in updating geo-data (3D data and cadastral data) to be used in GIS and mapping tasks. There is a current high demand for a quick-efficient surveying method that integrates additional information for data acquisition to derive different outputs such as orthoimages, 3D-models of buildings and infrastructure, and elevation models. UAV is one such method (Manyoky, et al., 2011).

UAVs are a cutting-edge platform for carrying sensors and flying at the needed heights, in contrast to conventional aerial

photogrammetry. UAVs are capable of transporting Lidar, multispectral, thermal, optical, and thermal sensors. They are now used to obtain aerial photos from below the cloud cover, with a high ground resolution, and in a safer and more cost-effective manner than manned aircraft thanks to the recent rapid development of UAVs and the advancement of automatic navigation technology and stable imaging gear. In light of this, UAVs are able to conduct airborne operations at various altitudes in accordance with the needs of the mission, obtaining high- spatial-resolution photographs and creating orthophotos, digital surface models, and topographic maps. Safety of surveyor in dangerous places is also increased by the use of UAVs. In a study of feasibility assessment for boundary verification survey using UAV in Taiwan, it was discovered that UAV aerial photogrammetry can generate many landfill points, more detailed maps, and orthoimages. The digitized cadastral maps in Taiwan showed great similarity to collected data (Chio & Chiang, 2020).

The need for an efficient cadastral mapping system has been emphasized by the global surveying organizations. The cadastral system is expected to be fully digitized in the future and cadastral mapping is expected to be substituted with cadastral modelling (Kaufmann & Steudler, 1998). To be in sync with these growing needs modern technology should be integrated to the local cadastral system. This study was initiated with the hope of discovering methods to assist the local cadastral system. The results show that UAVs are well equipped for boundary detection. Further research in various conditions can be done to determine the limitations of UAVs.

2. Methodology

The methodology used in this study is shown in Figure. Initially a field survey was conducted using total station to acquire Ground Control Points for geo-referencing the UAV images. Survey points were also collected simultaneously for parcel delineation in the Total Station method. The UAV method for data collection was done using "Pix4Dcapture" software. The grid method was used to generate appropriate flight plan for autonomous flight and the flying altitude used was 60m. But the UAV was navigated using assisted flight mode around building complexes. Both front overlap and side overlap was assigned as 70% in this process. The camera angle was also maintained at 90°. The output image was then processed using "Pix4Dmapper". This software package facilitated the georeferencing process as well as point cloud generation. The boundary of the parcel was extracted, and area was calculated using "AutoCAD" software. The same software was used to calculate the extent of the parcel obtained using Total Station Survey. For the area comparison of the two different methods, they were applied to six study areas shown in Figure 1,2, and 3 that could simulate the environment for various but typical cadastral mapping instances. All the study areas shown below are located within Kotelawala Defence University – Southern Campus premises.

3. Analysis

The outputs from UAV and Total Station were compared and the area of each study area was compared. The Difference in extent is mentioned in **Error! Reference source not found.** 1.

Table 1: Difference of extent in study areas

Location	Area (Perch)		Difference (Perch)
	UAV	Total Station	
Bo Maluwa (L01)	20.81	20.83	0.02
Parade Ground (L02)	309.72	309.9	0.18
Basketball Court (L03)	16.87	16.89	0.02
Volleyball court (L04)	22.39	22.34	0.05
Faculty Garden (L05)	25.34	25.38	0.04
Netball Court (L06)	17.37	17.34	0.03

Figure 1: Left: Basketball Court (L03), Right: Volleyball Court (L04)

Figure 2: Left: Overview image of Boo Maluwa (L01), Right: Image of Parade Ground (L02)

Figure 3: Left: Faculty Garden (L05), Right: Netball Court (L06)

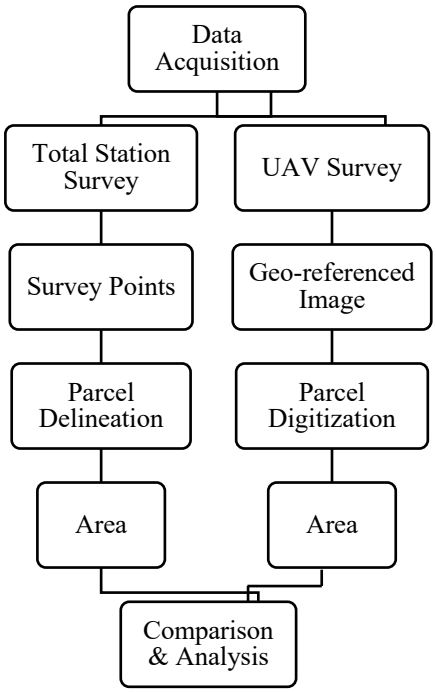

Figure 4: Methodology

4. Discussion

The future cadastral system is expected to be completely digital and cost recovering (Kaufmann & Steudler, 1998). The cadastral surveying system allocates top priority for the records of parcel boundary survey than physical location landmarks on the ground. So, the total land area that exists in the land totally depends on the parcel boundary. UAVs can capture a large area within a shorter period. Also, UAVs can easily access areas that humans can't access. This research focuses on accelerating the cadastral surveying process of the country. By using UAVs, even human resource utilization in surveying can be reduced. This can speed up the process and reduce costs as well. A UAV takes up less time when compared to almost any other field survey method. But there are limitations when using UAVs for getting information about the ground features. During data acquisition using traditional methods, much time is taken up to collect data in places with abrupt variations, such as curves, circles, and other irregular features. Time taken by UAV surveys do not depend on the physical shape of the feature. When there is a high canopy area, determining the actual boundary is a problematic. Selecting the best overlapping criteria is crucial. If it is not properly selected, the orthomosaic layer cannot be modelled from the UAV images. When performing field tasks valuable features can be lost and the possibility of missing data in the field may be very low when having UAV images. This is because in UAV surveys often redundant data are obtained and they reside in photographs. The UAV images act as pictorial evidence of the boundary conditions at the time of survey. This cannot be seen in conventional data collection methods.

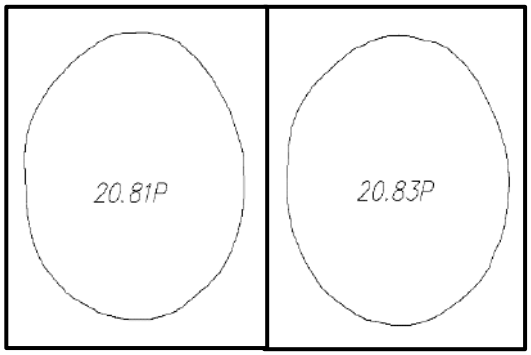

Figure 5: Left: Output of study area L01 from UAV, Right: Output of same study area from TS

One of the limitations of UAVs is battery power. A high-capacity battery pack can develop the capabilities of UAVs. In the past when using UAVs, a well-trained person was essential to pilot the UAV. But currently most UAVs are equipped with automation and flight planning systems that has reduced the need for high qualifications for the pilot. The analysis of point cloud data can also be done with ease using new software to extract parcel boundary records. Some such analyzing software are Pix4Dmapper, ArcGIS Pro, Trimble Business Center (TBC), Autodesk ReCap, Autodesk Civil 3D etc. The point cloud data from UAV images can also be used to drive alternative products that can assist the cadastral modelling sector too.

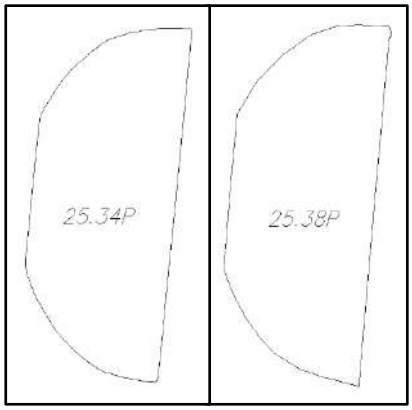

Figure 6: Output of study area L05 from UAV, Right: Output of same study area from TS

5. Conclusion

The purpose of this study is to accelerate the current cadastral procedure by suggesting an alternative to conventional methods. The study focuses on determining capabilities of UAVs. In terms of accuracy, thoroughness, and time commitment, UAVs appeared to be equivalent. The advantage of using UAV systems is their fast surface scanning capabilities while flying at low altitude. UAV systems have shown to be a useful

adjunct to conventional surveying techniques for acquiring additional data through the acquired photographs, such as overview images or orthoimages.

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Acknowledgment

I would like to thank lectures of the Faculty of Built Environment and Spatial Sciences, General Sir John Kotelawala Defence University. And I wish to express my sincere thanks and gratitude to all the people who helped us in many ways.

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Mapping the pattern of distribution of Threatened Marine Species from the X-Press Pearl Ship explosion using GIS techniques

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Abstract*: Over 90% of global trade is done by shipping the world, the marine sector supports the transportation of a variety of critical items while balancing the global economy and keeping countries united in such a complex global market. Sri Lankan ports are strategically positioned ports for vessels going from west to east and east to west. The X-Press Pearl ship Explosion recorded on the 20th of May 2021 was investigated under the study by utilizing the Geographic Information Systems in the spatial domain. It severely polluted some of the coastal zones of Sri Lanka including Colombo, Kalutara, and Galle due to its chemical explosion and oil spreading. Under the research, we explored the marine species wash-out incident through records and reports on social media and news reports as the main source of data. First, all data is stored in the spatial database before the analysis and along with the location coordinates. Then the spatial analysis was carried out in the Arc GIS 10.5 platform and generated maps to illustrate the pattern of expansion. According to the study, it has found out the most vulnerable areas were western and southern coastal regions while some incidents were recorded in the east part as well. The data collected and reported on social media or news was utilized in the data collection phase and it indicates the public involvement in disaster management practices. Further, data analysis done through the GIS context would be significant in the decision-making and implementation phases as a future direction of the study.*

Keywords: *Coastal, GIS, Marine pollution*

1. Introduction

A. *Background of the study*

In the world, over 90% of global trade is done by shipping. It is considered a secure, cost-effective, and environmentally friendly mode of business transportation. Commodities and goods must be transported across oceans, in the air, and across railways and highways for the global economy to function. The marine sector supports the transportation of a variety of critical items such as fuel, chemicals, food, vehicles, clothing, and household appliances, as well as playing a significant role in the natural resource and energy trade. As a result, many communities rely heavily on their ports for revenue. There are numerous shipping routes and ports all over the world, and some of them are the busiest shopping channels.

International Maritime Organization in 2012 reports suggests that ship-generated pollution continues to pose a hazard to the maritime ecosystem. Even though pollution-related rules have reduced the frequency of accidents and incidents, ships continue to contaminate the marine environment around the world, including in Sri Lankan waters. Some of the incidents are the result of human error, while others are the result of physical circumstances. Whatever occurs, humans will not be able to change the fact that ship-caused "environmental disasters" devastate habitat and marine life, endanger the survival of marine flora and fauna, cause major ecosystem distress, and harm people's livelihoods and quality of life

B. *Case Study*

In comparison to other countries, Sri Lanka cannot respond to maritime emergencies such as oil spills and chemical spills, posing a considerable risk. It was discovered that the expansion of world industry has a direct impact on ocean pollution and poses a substantial risk to the marine environment in all states, both global and local. The rise of global industry has a direct impact on ocean pollution and poses a substantial risk to the marine environment, according to all states at the global and local levels.

The X-Press Pearl was registered in Singapore and departed the port of Hazira on 15 May 2021 and arrived in Colombo on 19 May, and was anchored off Colombo Port. On 21 May the vessel reported a fire on the deck which continued for up to 13 days. According to the views of the experts, X-Press Pearl Explosion was the biggest sea environment pollution. It affects not only for explosion area because chemical explosion and oil spreading affect the creature's life. It damages sea creatures and features in a huge area. Sri Lanka is still a developing country, so this type of pollution cannot be accepted in the future of the country. Most people in Sri Lanka do not have a great understanding of the problem of this case. Many species have died as a result of oil spills and chemical contamination. Experts estimate that about 10% of dead animals are dumped on the beach. According to the data we have obtained, the total number of animal deaths we have encountered is about 150.

The main objective of the study was to reveal and mapping the pattern of distribution of threatened marine species due to X-Press Pearl Ship explosion around the coastal belt of Sri Lanka by succeeding sub-objectives as follows,

- To prepare a spatial database of the incidents based on social media and News Reports
- To analyse the frequency of dead creatures reported to the coastal area statistically
- To map the pattern of distribution through GIS

2. Methodology

A. *Study Area*

In terms of the Sri Lankan setting, the Sri Lankan Ocean is one of a kind, with vibrant marine environments (whales, turtles, dugongs, and so on) and a diverse range of fauna and vegetation.

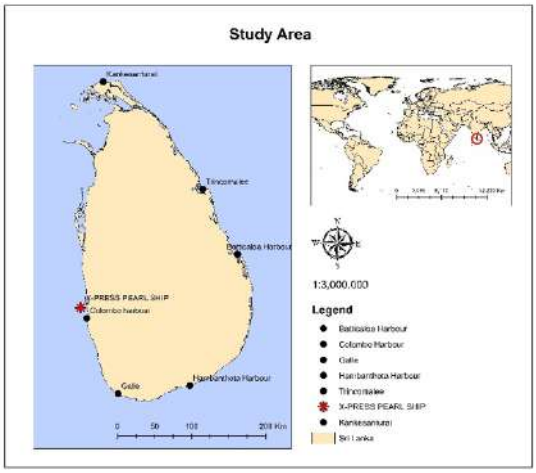

Figure 1: Study area of the experimental study

Nevertheless, incidents near or within the coastal area can have severe repercussions for vulnerable ecosystems. Furthermore, due to its central location in the global trade and shipping network, Sri Lankan ports are the most strategically positioned ports for vessels going from west to east and east to west. Colombo, Galle, Hambantota, and Trincomalee are the four largest seaports on the island of Sri Lanka. Colombo has a deep natural harbor that receives a lot of traffic from adjacent shipping routes, and the port of Colombo is one of the top 50 container ports in the world in terms of the volume of containers handled. Furthermore, as seen, many shipping channels are located throughout the country and are connected to major international shipping ports.

B. *Data*

Mainly, the data were collected through the various platforms that are available for free and open access. Interestingly the Facebook groups and news reports were used as the basic source

of data collection. The spatial database was prepared through the ArcMap software platform while adding appropriate attribute information as well.

ID	Date	Location	Y	X	Spices	Quant	Source	Spices_Com
1	2021.05.27	Wellawatte	6.876241	79.856722	Eel_Moray	1	Social media	Eel_Moray
2	2021.05.28	Dehiwala	6.848117	79.861944	Giant_Slender_	1	Social media	Giant_Slender
3	2021.05.29	Payagala	6.529646	79.97494	Green_Turtle	1	Social media	Green_Turtle
4	2021.06.01	Kalkawala	6.371277	80.01104	Puffer_fish	1	Social media	Puffer_fish
5	2021.06.01	Kalkawala	6.371277	80.01104	Dolphin	1	Social media	Dolphin
6	2021.06.02	Unawatuna	6.009439	80.248274	Turtle	1	Social media	Turtle
7	2021.06.05	Payagala	6.529646	79.97494	Turtle	1	Social media	Turtle
8	2021.06.05	Panadura	6.710885	79.906617	Turtle	1	Social media	Turtle
9	2021.06.05	Thalpitiya	6.682717	79.916654	Turtle	1	Social media	Turtle
10	2021.06.05	Dehiwala	6.848117	79.861944	Turtle	1	Social media	Turtle
11	2021.06.05	Thalaramba	5.937161	80.479273	Spotted Box Fi	1	Social media	Spotted Box F
12	2021.06.05	Agulana	6.794915	79.872671	Turtle	1	Social media	Turtle
13	2021.06.05	Morazgalla	6.445829	79.984834	Turtle	1	Social media	Turtle
14	2021.06.06	Egoda duwa	6.344736	80.022192	Turtle	3	Social media	Turtle
15	2021.06.06	Ahungalla	6.098387	80.032424	Turtle	1	Social media	Turtle
16	2021.06.06	Dehiwala	6.848117	79.861944	Turtle	1	NewsFirst	Turtle
17	2021.06.06	Iduruwa	6.368223	80.011372	Dolphin	1	Social media	Dolphin
18	2021.06.06	Payagala	6.529646	79.97494	Turtle	1	NewsFirst	Turtle
19	2021.06.06	Kosgoda	6.333678	80.027259	Turtle	3	NewsFirst	Turtle
20	2021.06.06	Kalpitiya	8.247967	79.738705	Turtle	1	NewsFirst	Turtle
21	2021.06.06	Agulana	6.794915	79.872671	Turtle	1	NewsFirst	Turtle
22	2021.06.06	Kalpitiya	8.247967	79.738705	Dolphine	1	Social media	Dolphine
23	2021.06.07	Puttlalama	8.025103	79.830836	Turtle	1	NewsFirst	Turtle
24	2021.06.07	Kosgoda	6.333678	80.027259	Whale	1	NewsFirst	Whale
25	2021.06.07	Thalpitiya	6.682717	79.916654	Dolphine	1	NewsFirst	Dolphine
26	2021.06.07	Pothupitiya	6.632713	79.937965	Turtle	2	Social media	Turtle
27	2021.06.08	Rekawa	6.043008	80.860604	Turtle	1	NewsFirst	Turtle
28	2021.06.08	Wellawatta	6.876241	79.856722	Turtle	1	NewsFirst	Turtle
29	2021.06.09	Kalpitiya	8.247967	79.738705	Dolphine	1	NewsFirst	Dolphine
30	2021.06.10	Ambalangoda	6.238226	80.049185	Turtle	1	Derana_News	Turtle
31	2021.06.10	Hikkaduwa	6.137466	80.099925	Turtle	1	Derana_News	Turtle

Figure 2: Spatial Database

LD 99 Sri Lanka grid was used as the geographical reference coordinate system of the study. To analyze the impact initially found the washed-up location coordinates including the name of the species, washed-up date, number of animals washed up at the place, and finally, the coordinate of the MV X-Press Pearl ship accident happen. To discover the details we have investigated the social media news reports by television channels and newspapers. All the latest updates were given on those social media groups and pages with the dead photo of the washed-up animals recorded in the spatial data based more than four months from the incident. Recorded the details to the spatial database with reference ID, Date, Location, X, Y, and spices Quantity and source were filled. The reference number was saved with the photograph of the washed-up animals. Coordinate of each location was taken by Google Earth Pro.

A. Methodology

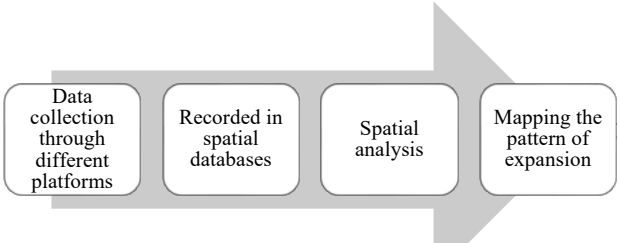

Figure 4: Methodology implemented over the study

flow map, hotspot analysis, and kernel density mapping.

The Flow Maps are a sort of cartographic themed map that depicts the flow of items between different places and were created to exhibit how the dead animals were distributed in Sri Lanka from the place of the ship accident. Hotspot and Cold spot analysis were employed in the study the measure the magnitude. Vectors are used in Hotspot Analysis to locate statistically significant hot and cold places in data. The Kernel Density tool determines the density of features in the vicinity of those features. Both point and line features were calculated. Thus, Kernel Density was used to create in which area high density of impact happens.

3. Results and Discussion

According to the data collected over four months from the incidents, we have recorded around 200 cases through the open-source platforms. As per the records, most of the sea

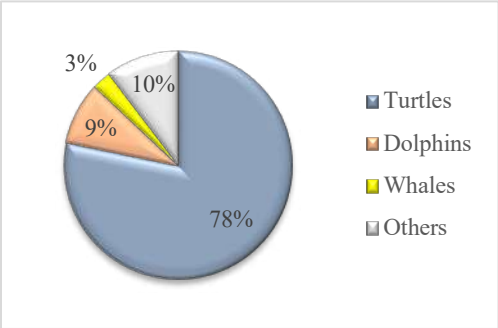

Figure 5: Number of species recorded

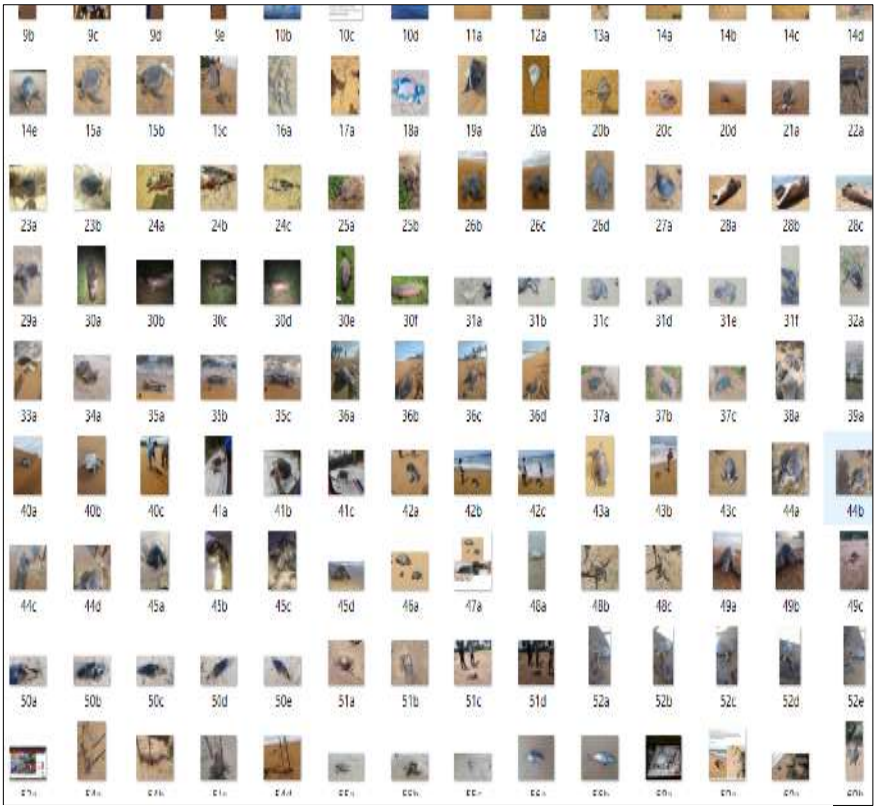

Figure 3: Photographs of the incidents recorded along with the spatial coordinates

Turtles were threatened (more than 75 %) by the accident while dolphins' and whales' deaths were at 9% and 3% respectively as in the pie chart below.

Throughout Sri Lanka, there were many sea creatures were washed out. From Colombo to Rekawa and there are several animals washed up to Batticaloa and Trincomalee because of inter-monsoon. From Colombo to Jaffna there were some sea creatures were washed up. Some animals were injured because of burning containers in the vessels and they washed up to the coastal due to disability to swimming through the deep-water rough waves. Moreover, Kaltura, Galle, and Gampaha were recorded as the highly affected districts as per the data collected by the study Hotspot analysis is a spatial examination and planning procedure inspired by the recognizable proof of grouping of spatial peculiarities.

These spatial peculiarities are portrayed as focusing on a guide and allude to areas of occasions or items. Such an investigation hotspot analysis helps to understand the magnitude of the incident relative to the location.

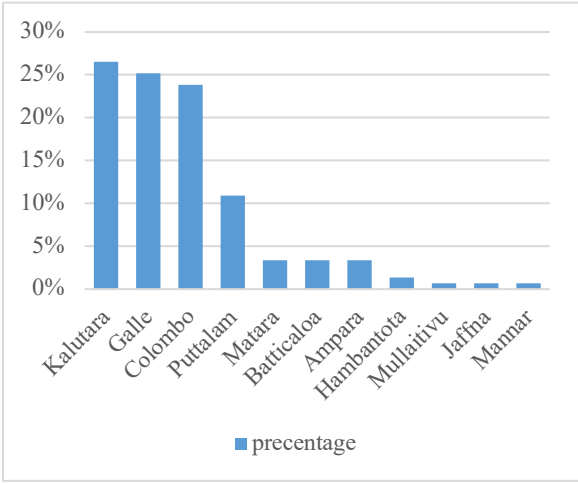

Figure 6: Species recorded in each region of the country

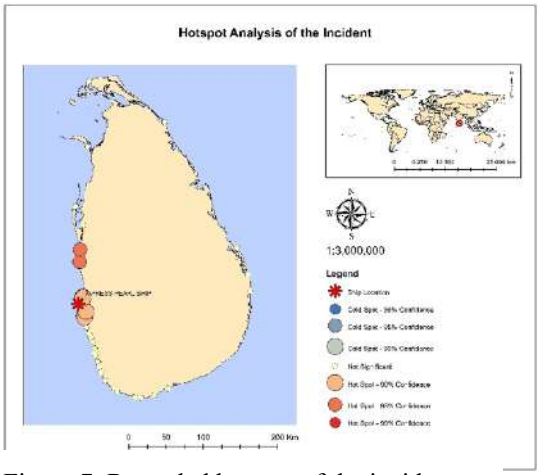

Figure 7: Recorded hotspot of the incident

The IDW model expects a weight for every estimation point in the relay of the distance between that point and the place of the point with value. These weights are then constrained by the weighting power. It implements that the assessed worth of a point is impacted more by neighboring known focuses than those farther. thus, under the investigation, the IDW interpolation was implemented to identify the hotspot and the pattern of distribution of the incident. As per the reported dead marine species, the effect not only on Sri Lankan coastal line but also affected the larger portion of the Indian ocean.

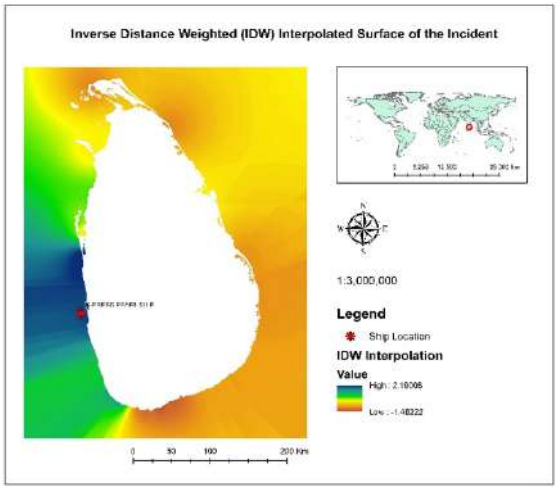

Figure 8: IDW Interpolation surface

Kernel density assessment is a significant nonparametric method for point-based or line-based data that use the technique for estimation of the probability density function.

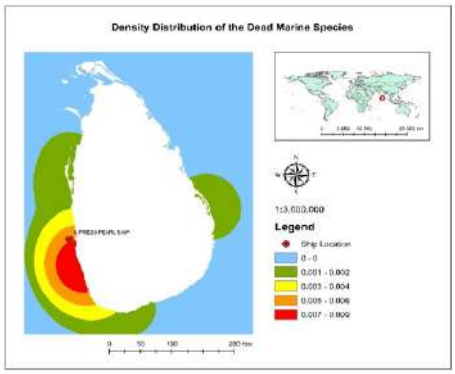

Figure 9: Density distribution of the dead

The kernel density estimation at an area will be the amount of the negligible parts of all perceptions at that area. In a GIS context, kernel density estimation normally brings about a density surface where every pixel is delivered a value in the cell center. Thus the resulted map illustrates the density distribution of the dead species. Nevertheless, it shows significant density in the Colombo area as well as the Batticaloa area mainly due to the surface water circulation, ocean currents, and monsoon pattern of the period.

Flow maps are a type of thematic map used in cartography to show the movement of items between various regions. Thus, under the study, the flow direction map indicates the flow of dead species from the accident location to various parts of the coastal zones of the island.

4. Conclusion and Recommendations

There are several reasons for facing such incidents in the Sri Lankan context, including a lack of resources to deal with such a fire, an absence of protocols in place to seek necessary assistance from better equipped marine powers, a lack of mutual agreements with other countries to deal with and avoid similar situations, and a lack of technical instruments and knowledgeable personnel. It should

establish a disaster planning and risk analysis body to avoid a repeat of the situation It is now time to begin risk analysis and disaster preparedness in the event of a maritime tragedy.

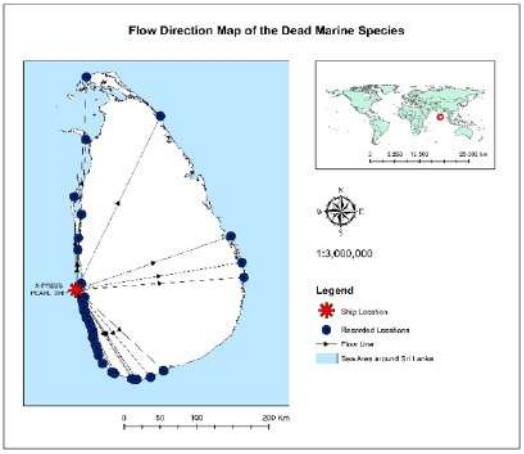

Figure 10: Flow direction map of the dead marine

However, integration between GIS as the main tool of analysis and public involvement in data collection would be beneficial to deal with such situations to overcome the difficulties. The data collected and reported on social media or news cannot be neglected and further, can be able to include in the data collection phase as in the disaster management practices. Further, data analysis done through the GIS context would be significant in the decision-making and implementation phases as a future direction o the study.

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Acknowledgment

We would like to acknowledge every person who helped us in different ways during the research work.

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Spatial Analysis Approach for Identification of Urban Sprawl Pattern: A Case Study of Matara DS Division

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Abstract*:In this study the urban sprawl of Matara DS Division was analyzed from 1990 to 2020. Landsat satellite imageries were used in this study to extract the built-up area. Shannon's Entropy method and Fractal Dimension of Box Counting method were used to analyze urban sprawl. NDBI was used to extract build up area from Landsat TM/ETM+/TIR satellite imageries which are necessary to calculation of both methods and number of grids coincide with built-up vector layer had used to calculate fractal dimension. The accuracy assessment shows more than expected (above 80%). As well as built up area has changed with huge number.1.097km^2 area is showed in year1990 and when it comes to year 2020, it showed as 11.669km$^{2.}$ Shannon's Entropy was increased 1990 to 2020 with 1.23 to 1.67 and year 2000 showed from 1.46 and year 2010 shows 1.52. It has increased gradually and reach to error range (>1.5). Fractal Dimension also was increased 1990 to 2020 with 1.24 to 1.65 and year 2000 showed 1.498 and year 2010 showed 1.520. It's also reached to error range (>1.5). Hence these results proved that urban sprawl has increased in the study area and the Shannon's entropy calculation categorized as high sprawl, sprawl and no sprawl. Isadeen town, Kadawediya east, Kadawediya west, Kotuwegoda North, Kotuwegoda South, Mathotagama, Noope, Uyanwatta, Uyanwatta North, Welegoda east, Welegoda west, Weliweriya east, Weliweriya west GN Divisions have identified as high sprawl GN Divisions. and there is a close relationship between Shannon's Entropy and Fractal dimension method as revealed by the graphical representation. Finally, this study was identified the pattern of urban sprawl such as low-density development, commercial strip development, scattered and dispersed developments in the study area. The result revealed that, in year 1990 only scattered development happened in the study area. But when it came to 2020, it shows three development patterns of urban sprawl and didn't show leapfrog development.*

Keywords: *Urban Sprawl, Dimension, Shannon's Entropy, Landsat*

1. Introduction

Urban sprawl is one of the most important problems in urban development due to its impacts on environmentally, socially and economically. Understanding urban sprawl and analyzing urban sprawl pattern are useful for determining current and future needs. It is essential, especially for the management of natural resources and the construction of infrastructure. Some of the causes of the sprawl include; population growth construction work, economy and proximity to resources and basic amenities and also often encourage the regional development which eventually lead to urbanization. Urban sprawl led to serious problem in both short- and long-term infrastructure planning. Developing countries are experiencing the urban sprawl phenomenon. Because there are so many urban development activities in developing country.

Urban sprawl is one of the key challenges facing Sri Lanka's today. Sri Lanka is a developing country with high population density. It is experiencing rapid urbanization by converting agriculture and natural lands in to build up area. Due to this, there are lot of issues occurred and

badly effected to the human life and environmentally (Amarawickrama, Singhapathirana and Rajapaksha, 2015). Matara is the one of most important commercial cities in Sri Lanka. It is located in Matara DS Division area. It is highly accompanied by residential and commercial development Considering the existing situation in the Matara DS Division, many ongoing urban development projects have been carried out within last few decades. Some studies have examined the urban land use changes in this area and these studies provide an insight into why this area necessary for studying sprawl pattern (Serasinghe Pathiranage, Kantakumar and Sundaramoorthy, 2018). Identification of the patterns of sprawl and analysis of spatial changes would help immensely in the planning for proper infrastructure facilities. Pattern of sprawl and analysis of spatial changes could be done cost effectively and efficiently with the help of spatial technologies such as Geographical Information System (GIS) and Remote Sensing.

Urban sprawl in this region was analyzed by integrating Remote sensing and GIS. Remote sensing is the science of acquiring information about an object or phenomenon by measuring emitted or reflected radiation. Satellite remote sensing provides an important source of spatial data. GIS is a system designed to capture store, manage, analyze, manipulate and present spatial data. Integrated analysis will help to urban planners to in their decisions making process. Shannon's Entropy and Fractal analysis carried out with integrating RS and GIS technologies. In here build up area were extracted by using NDBI (Normalize difference build up index) and create fishnet tool on ArcMap were utilized to create different scale grid box. Hence, this study will help to understand relationship among Shannon's Entropy and Fractal Dimension.

Nowadays, urban sprawl phenomenon has been seen in many of cities in the developing and developed countries. More than half of the world's population currently lives in metropolitan regions. Therefore, on a global scale, all potential population rises will be focused more in towns and cities. This massive increment in the urban population, together with an unprecedent rate of urbanization, many cause unplanned, uncontrolled or unrestricted growth of urban areas into the peripheries may be recognized as urban sprawl (Derya *et al*, 2016). There is no unique definition for urban sprawl. However a widely accepted definition is uncontrolled ,unlawful ,unplanned ,and uncoordinated low- density single use development facilitates that does not provide for a functional and appealing combination of land use mixes and /or and is not functionally connected to neighboring land use and which variously appears as leapfrog, or isolated development ,ribbon or strip with scattered residential neighborhood and commercial strip development ,with auto mobile dominance which are aesthetically displeasing in nature (Nelson *et al*,1995,Hiller *et al*,2013).

More than half of the world's population currently live in around the urban cities and can see massive increment of world population day by day. So, land has become a scares resource. But this scares resource has built up with focusing well developed /established cities. Urban area is increasing faster than the urban population itself. Urbanization is the most dramatic form of irreversible land transformation of agricultural and prolific lands to urban areas affecting landscapes and people who live in and around cities. There are so many countries have been reached their maximum level of urban sprawl and they have identified effects of urban sprawl such as impacts on society, impacts on housing, impacts on jobs, fiscal impacts, political impacts, impacts on transport, impacts on agriculture, open space (Neslihan Serdarogle Sag, 2021). So, in global scale, have arranged so many systems to minimize and manage the urban sprawl. Urban sprawl is a worldwide problem. So, most studies have been focused on effects of urban sprawl in global scale (Kriti Rastogi *et al*, 2018).

Sri Lanka is the one of developing country in the world and it has rapid urbanization. Sri Lanka is experiencing speedy urbanization by converting the agriculture land and other natural land cover into built-up land. The rapid growth in urban population and urban areas in Sri Lanka may cause urban sprawl. This rapid growth in urban Population, may create serious sprawl disparities which are hard to fix. Sri Lanka is experiencing a speedy urbanization over the last three decades. Today, nearly 40% of the Sri Lankan population live in urban areas and it is expected that 65%of the population will live in urban areas by 2030. This will make cities grow both in number and in physical size than experienced in the past, aggravating urban sprawl-related problems in the future (Serasinghe Pathiranage, Kantakumar and Sundaramoorthy, 2018).

A. Study Area

The Matara DS Division is located in the southern coast of Sri Lanka. The Matara DS Division is 21.2 km2 (8.2 sq mi) in area. The average elevation above sea level is 16 m (52 ft). It is the administrative capital of Matara district and one of the main commercial centers in Sri Lanka (Serasinghe Pathiranage, Kantakumar and Sundaramoorthy, 2018). It has massive population increment in the last few decades. Thus, UDA initiated major infrastructure development projects, such as the construction of Southern expressway with four lanes from Kottawa to Matara and Matara to Mattala & railway track from Matara to Beliatta. This development led to population growth and urban sprawl in the suburbs of the study area. So Matara DS Division area is chosen as the study area.

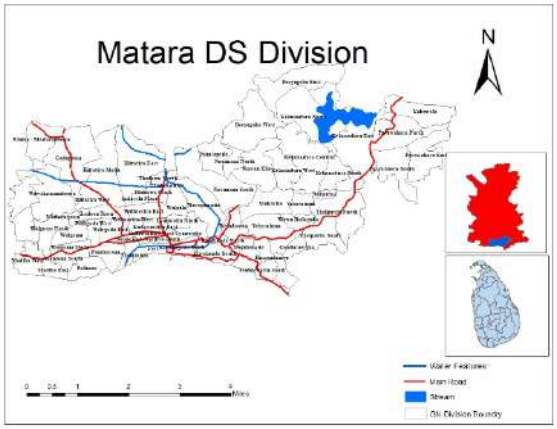

Figure 1: Matara DS Division Area

2. Data and Methodology

Satellite images were downloaded free of charge from USGS Earth Explorer and Matara district, Matara DS division and GN Division shapefile, road shapefile and stream shapefile were also downloaded from website of the Survey Department of Sri Lanka.

Table 1: Detail of Acquired Satellite Image

Year of the image	Resolution	Sensor	Band Used	Scene Cloud Cover
1990	30m	TM	Band 4 Band 5	30%
2000	30m	ETM+	Band 4 Band 5	20%
2010	30m	TM	Band 4 Band 5	20%
2020	30m	TIR	Band 5 Band 6	25%

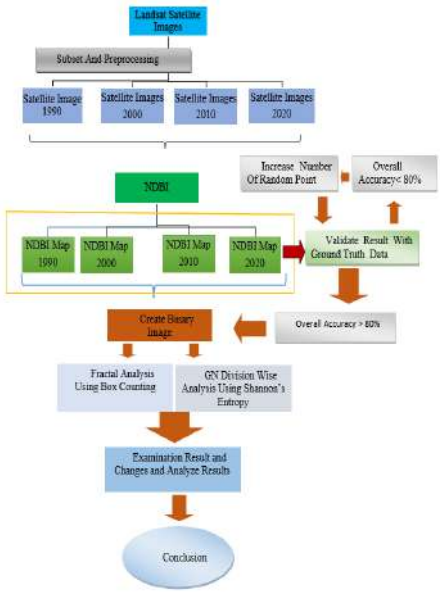

Figure 2: Flow Diagram of Methodology

The downloaded satellite images were subset using study area shape file to extract built-up area. Then preprocessing part has done. Then NDBI has applied to extract built-up area. The built-up area maps have validated with ground truth data. After accuracy assessment test the maps converted in to binary image. Then the Shannon's entropy and fractal dimension was calculated. Then the results and changes were analyzed and conclusion also done.

B. Built-Up Area Extraction

Urban sprawl is mainly defended on built up area. Due to uncontrolled population density growth the built-up areas expanded without any control. This built-up area expansion considered as most influential driver of urban sprawl and most effective in urban sprawl analysis.

Image subset were continued to extract the Matara Ds Division area for each satellite image. Then NDBI (Normalize Difference Build Up Index) were used to extract build - up area.

$$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$$

Source: (Aswal, Saini and Tanzeem, 2018)

Above equation is the equation which was used for extraction of build-up area from other areas. when it comes to Landsat 8 satellite imagery it used Band 6 as SWIR and Band 5 as NIR. But, when it comes to Landsat 7 and Landsat 5, it is asked Band 5 as SWIR and Band 4 as NIR. Add the related band to ArcMap and open the raster calculator window to write the formula of NDBI.

Threshold values were calculated for each year to categorized area as Build-Up and Non-Buildup. The accuracy assessment was continued to validate data which have used. It compares the classified image to another data source that is considered to be accurate or ground truth data. Ground truth data were collected by using Google Earth Pro which was maintained with high resolution. It compares with a classified map with real world.

C. Urban Sprawl Patterens

Urban sprawl characteristics, which are low density development, leapfrog developments, commercial strip or ribbon developments, scattered and dispersed developments were mainly identified in the many developing countries (Seevarethnam *et al.*, 2021) .

[2] Low density development(a)
[3] Leapfrog Development(b)
[4] Commercial Strip Development(c)
[5] Scattered Development(d)

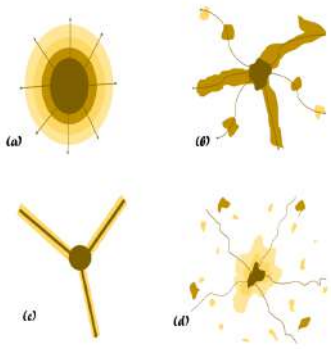

Figure 3: Development Patterns

Source: (Seevarethnam *et al.*, 2021)

D. Shannon's Entropy

Shannon (1948) employed the concept of entropy to measure the uncertainty of a variable like urban form. This uncertainty is expressed as the average expected value of information continued in a study. The Shannon's entropy has potential to measure the uncertainty of random process. Shannon's entropy method is used to determine whether the growth of urban areas was divergent or compact. Urban sprawl identified as the scatteredness of an urban area or urban development (Quezada et al,2009). Urban sprawl can be analyzed by using Shannon's entropy method and it was identified as an effective method.

$$Hi = -\sum_{j=1}^{m} Pj \log_e(Pj)$$

Source: (Mohammady and Delavar, 2016)

The Shannon entropy values range have had identified from 0 to loge(n), values closer to 0(smaller values) indicate very compacted distribution and the value closer to $\log_e(n)$ (larger value) indicates that the distribution is much dispersed in urban form (Mohammady and Delavar, 2016)

E. Fractal Dimension

The notion of "fractal" was introduced by Mandelbrot (1983) and came from the Latin term "fractus", meaning is irregular and fragmented. One of the methods of determining the fractal dimension is identified as box counting method. Box counting method consisting another two sub methods called the vector method and the grid method. Fractal dimension of region can be calculate using both methods and Grid method is more effective.

The fractal dimension value has a value between 1 and 2. Value close to one indicate more compact and sustainable urban area. Value close to 2 indicate less compact or more sprawling and disperse situation (Torrens, Alberti 2000).

Two ways have had identified to realize the box counting method. The Vector method and the grid method are the identified methods (Ge and Lin, 2009).To calculate the fractal dimension values for each years following formula is used.

$$D = \frac{\ln N(X)}{\ln (1/X)}$$

Source: (Rastogi and Jain, 2018)

N(X)= Number of boxes intersecting with Built-up area

X=Side Length of Box

D= Fractal Dimension

Vector maps were created by using raster maps of study area which was created using NDBI. Then vector maps were reclassified built up area as 1 and non-built-up area as 0. Then built-up areas were extracted for each map. Grids were created using fishnet tool and respect to the eight scale. After those grids and extracted vector areas were overlapped. Finally calculated number of non-empty grids for each maps respect to the eight scale grids. The fractal dimension is given by slope of the straight line which is formed by plotting lnN(X) and ln(1/X) (Rastogi and Jain, 2018).

3. Results and Discussion

A. Built-Up Area And Urban Growth

Built up area maps are very important because of its influence on urban sprawl analysis. Both Shannon's Entropy and Fractal Dimension methods are based on built up area and all calculation parts expected built up areas.

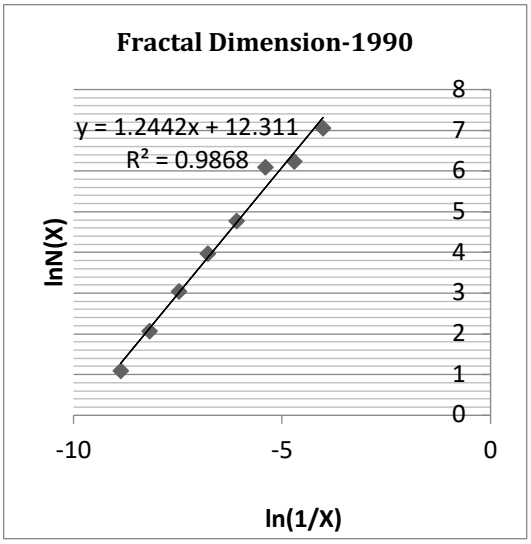

Figure 4: The Ln -Ln Plot on Fractal Dimension of the Build-Up Area of Matara DS Division 1990

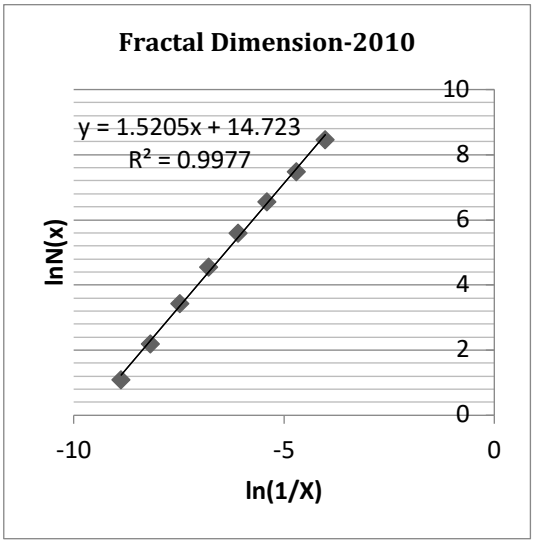

Figure 6: The Ln -Ln Plot on Fractal Dimension of The Build-Up Area of Matara DS Division 2010

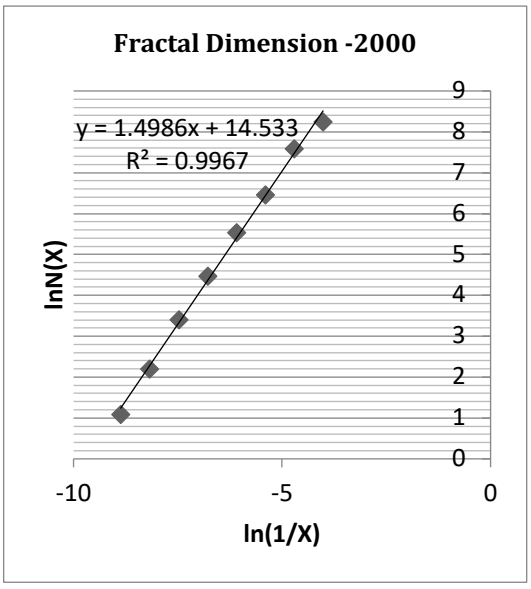

Figure 5: The Ln -Ln Plot on Fractal Dimension of The Build-Up Area of Matara DS Division 2000

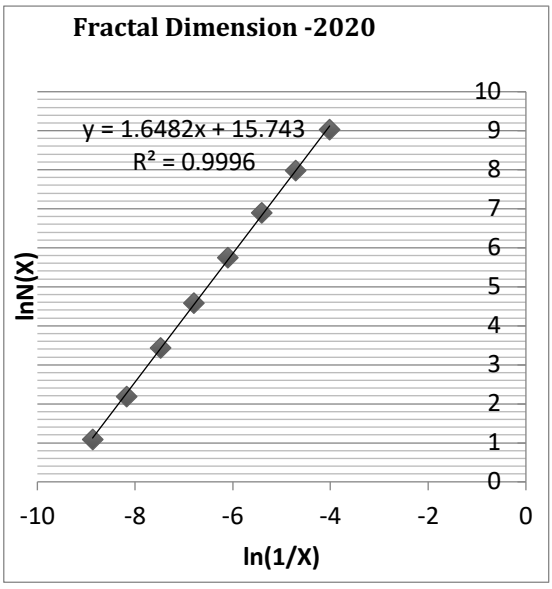

Figure 7: The Ln -Ln Plot on Fractal Dimension of The Build-Up Area of Matara DS Division 2020

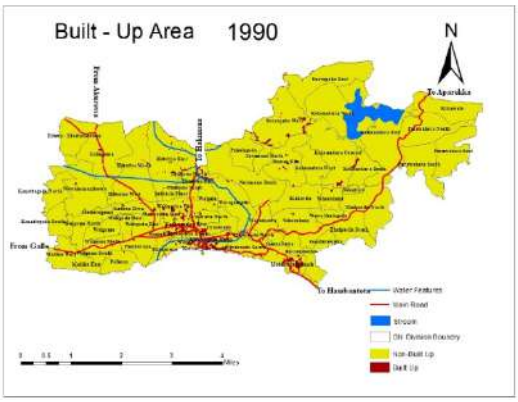

Figure 8:Build-Up Map of Matara DS Division 1990

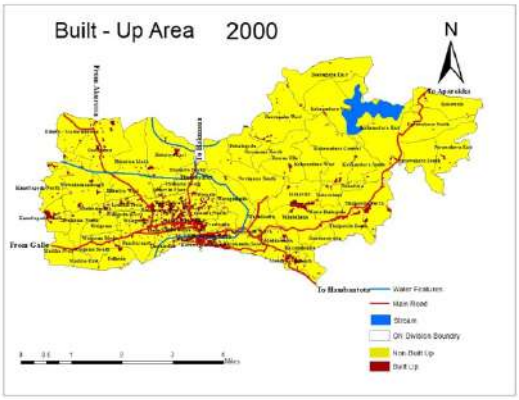

Figure 9:Build-Up Map of Matara DS Division 2000

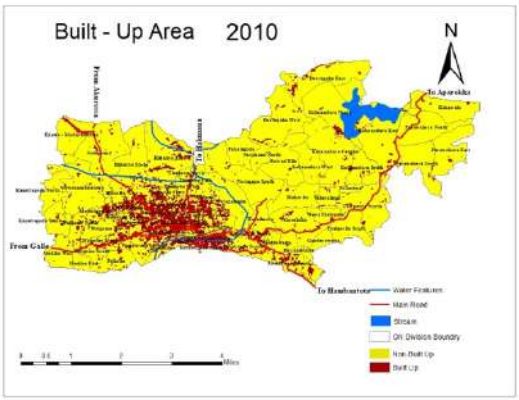

Figure 10:Build-Up Map of Matara DS Division 2010

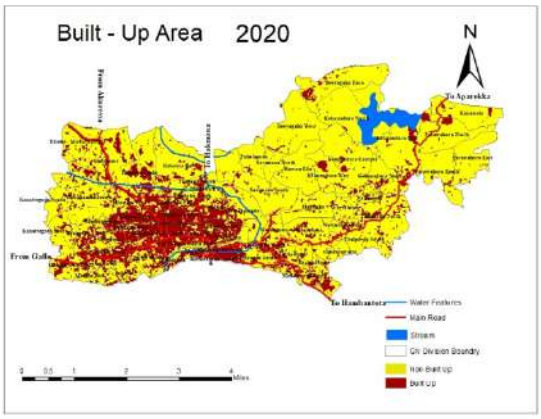

Figure 11:Build-Up Map of Matara DS Division 2020

Table 2:Built-Up Area Changes

Year	1990	2000	2010	2020
Built-Up Area (km^2)	1.097 km^2	2.971 km^2	6.635 km^2	11.669 km^2

Based on above Table 2 a rapid increase in built-Up growth rate was calculated for fast decades.

Table 3:Built-Up Area Changes for Each Decade

Decade	1990-2000	2000-2010	2010-2020
Built-up Changes(km^2)	1.874 km^2	3.364 km^2	6.635 km^2

B. Shannon's Entropy And Urban Sprawl

Shannon's entropy is a widely accepted urban sprawl analysis method. Shannon's entropy is an indicator of urban sprawl. It is an important tool calculating the compactness or dispersion of urban growth.

Table 4: Shannon's Entropy Values and Relative Shannon's Entropy Value for year 1990, 2000, 2010, 2020

Matara DS Division				
	1990	2000	2010	2020
Shannon's Entropy	1.23	1.46	1.53	1.67
Relative Shannon's Entropy	0.676	0.802	0.840	0.918

The Table 4 shows Shannon's Entropy Value and relative Shannon's Entropy values for year 1990,2000,2010,2020. It shows less Entropy value for year 1990 and 2000 and it shows high entropy value for year 2010 and 2020. It shows large Entropy value for year 2020 and it indicates high sprawl condition in year 2020. The Figure 12 showed GN Divisions which are high sprawl, low sprawl and no sprawl in year 2020 and this result showed respect to the Shannon's entropy method.

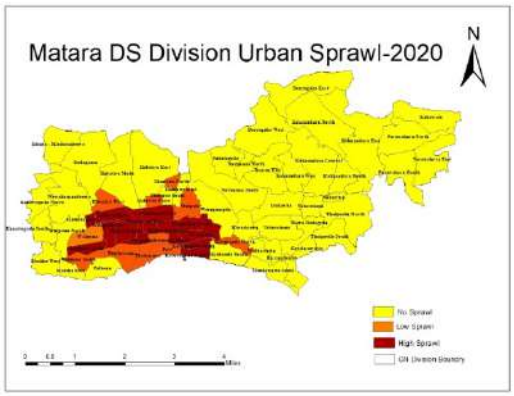

Figure 12: Urban sprawl Categories in Matara DS Division 2020

C. Fractal Dimension And Urban Sprawl

Table 5: Fractal Dimension of Matara DS Division Year 1990, 2000

Fractal Dimension - Matara DS Division				
Year	1990	2000	2010	2020
D (Fractal Dimension)	1.244	1.498	1.520	1.648

Above Table 5 shows increase of Fractal Dimension among 1990 to 2020 decade by decade. These value show that study area was not sprawl in 1990 and when it comes to 2020, it had become a sprawled because the fractal dimension value of year 2020 had reached to error range (>1.5).

D. Comparison Of Shannon's Entropy And Fractal Dimension

Graphical representation is the simplest way of the visual inspection. Its help to understand similarities and differences between the result. In this study to compare the results of Shannon's entropy and fractal dimension results, the Figure 20 has used.

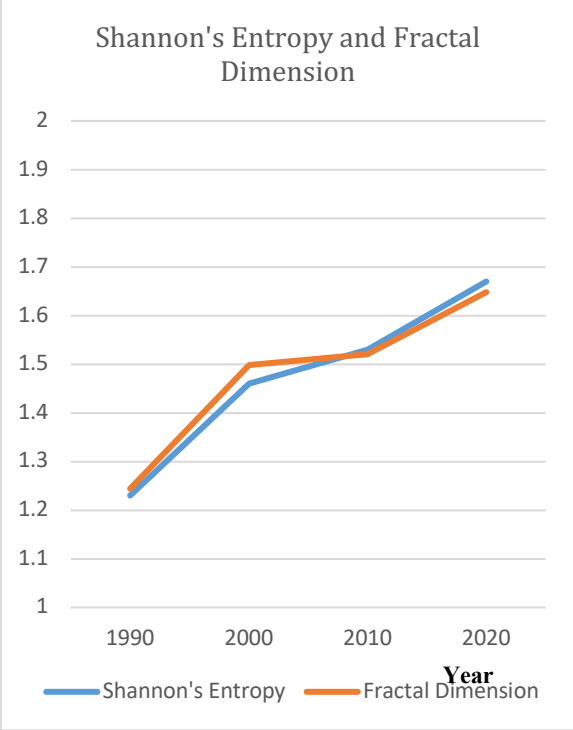

Figure 13: Fluctuation of Shannon's Entropy and Fractal Dimension Among 1990 to 2020 Decade by Decade.

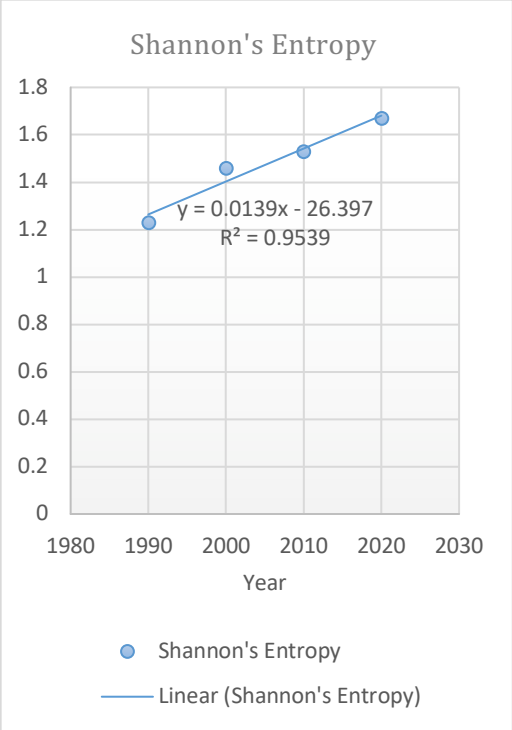

Figure 14: Linear Form of Shannon's Entropy Among 1990 To 2020

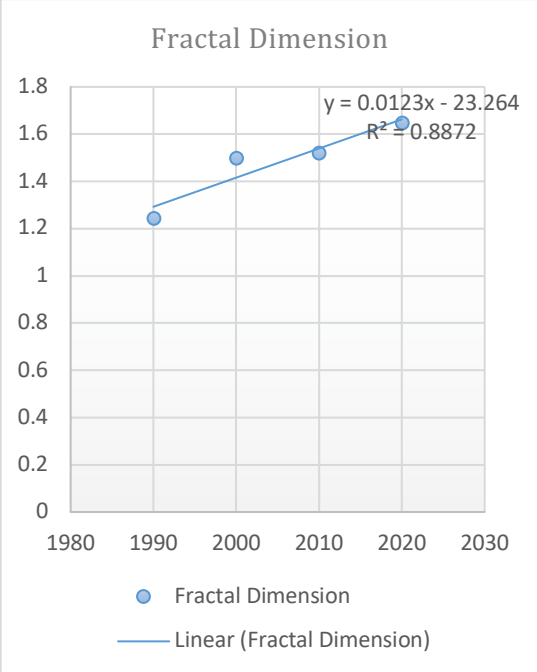

Figure 15: Linear Form of Fractal Dimension Among 1990 To 2020

Above Figure 14 and Figure 15 shows close relationship between Shannon's Entropy and Fractal Dimension. Above two graph shows approximately equal slope and it reveal that relationship among Fractal Dimension and Shannon's Entropy. R^2 is the measure of the goodness of fitness of a model. R^2 near to one means regression prediction approximates the real data points.

E. Characteristics Of Urban Sprawl

There are four characteristics identified which effected to the urban sprawl and increment of urban sprawl. Low density developments, Leapfrog developments, scattered growth, Commercial ribbon developments.

F. Low Density Development

Low density is one of the main risky phenomena which effected to the urban sprawling in urban area. It is the most generally indicated factor of urban sprawl in most, many literatures. Matara DS Division area also shows low density development in selected some years. Below Figures16 shows low density development in selected some years. It shows some GN Divisions (Isadeen town, weliweriya east, weliweriya west, kadeweediya west, Kotuwegoda South, Kotuwegoda North) with high compact urban area. Outward from other GN Divisions, built up density had decrease. This finding reveal that the study area has experience low density development.

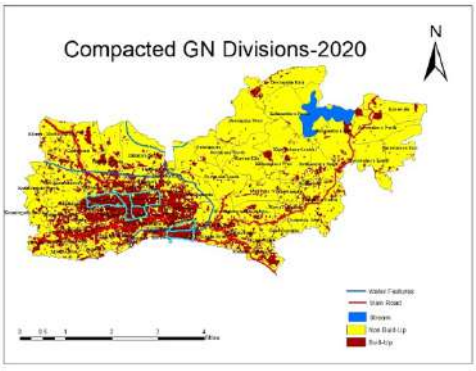

Figure 16: Compact Built-Up Area 2020

G. Scattered Development

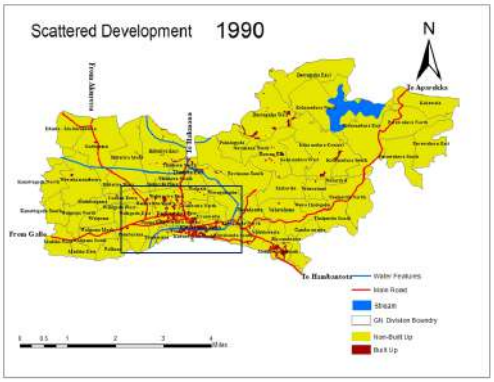

Figure 17: Scattered Development in Built-Up Area in 1990

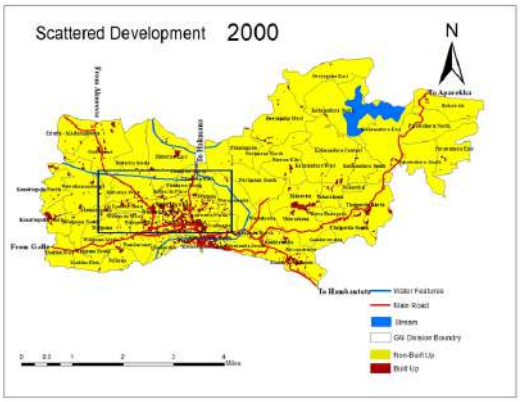

Figure 18: Scattered Development in Built-Up Area in 2000

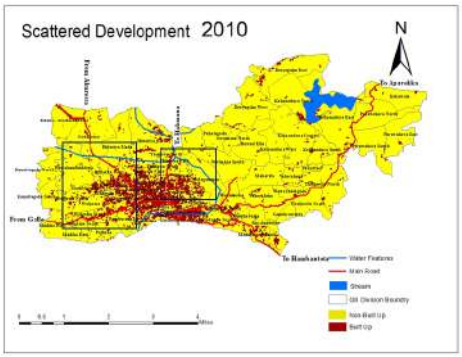

Figure 19: Scattered Development in Built-Up Area in 2010

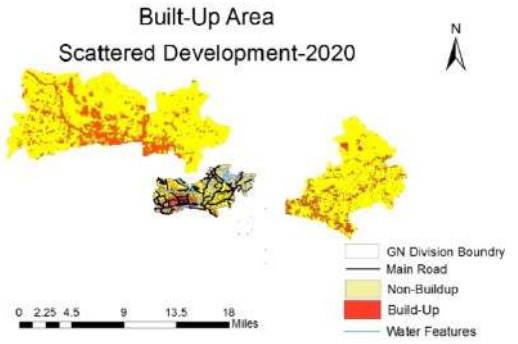

Figure 20: Scattered Development in Built-Up Area in 2020

Fractal dimension also give some idea about scattered development. If fractal Dimension closure to the 1 indicate that development is compact and if it is closure to 2 indicate that development is scattered. In Table 5, Fractal dimension value of year 1990 ,2000 ,2010 ,2020 reveal that scattered development has increased decade by decade and when it comes to 2020 high level of scattered development shows in study area. It reveals that area has treated with more sprawling characteristics.

H. Commercial Strip Development

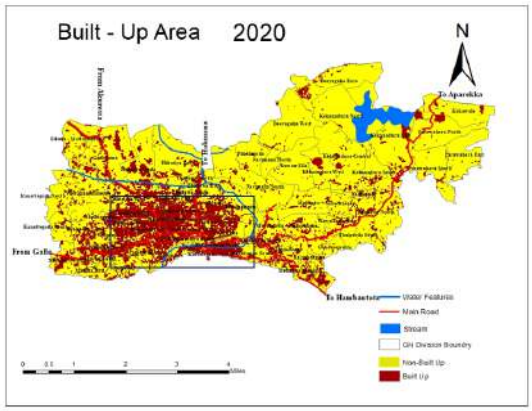

Figure 21: Commercial Strip Development in Matara DS Division 2020

The above Figure 21 highlighted area is the Matara commercial area. It contains with some road network and both sides of the road network had developed. So, it has commercial strip development and the GN Divisions are Kadawediya east, Kadawediya west,

Kadawediya south, Noope, Uyanwatta, Kotuwegoda South, Kotuwegoda North, Welegoda east, Welegoda west, Weliweriya. This commercial strip development could be cause for huge traffic problem in Matara city. Below Figure 22 and Figure 23 also shows commercial strip development in Matara DS Division.

Figure 22: Commercial Strip Development in Matara DS Division in 2020

Figure 23: Commercial Strip Development in Matara DS Division in 2020

4. Conclusion

Remote sensing and GIS prove to be are very useful tool in urban sprawl analysis. The study further shows that remotely sensed data coupled with Shannon's Entropy and Box Counting approach act as a good indicator to recognize urban sprawl. The accuracy assessment result shows accuracy of the result. It shows overall accuracy more than 80% for every year. In this study satellite imageries play a vital role in mapping and quantifying built up area. In this study, the urban sprawl in Matara DS Division was measured using Shannon's Entropy method and Box Counting method. This study reveal that urban sprawl of Matara DS Division has been increase decade by decade. Both methods confirm that urban sprawl has increased in study area because both fractal dimension and Shannon's entropy values are in error range. Because both methods show lower value in 1990(Fractal Dimension shows 1.244 and Shannon's Entropy shows 1.23). But when it comes to 2020 Fractal dimension shows as 1.648 and Shannon's entropy shows as 1.67. The findings of the study reveal that urban sprawl is a problem for Matara DS Division area. This study found that there is a close relationship between Shannon's Entropy method and Box counting method. The linear graphs of Shannon, entropy and fractal dimension, it shows same slope both methods and it talks about close relationship between both methods. Four development pattern which led to urban sprawl used to evaluate urban sprawl in study area. It shows that when it comes to 1990 there was no much sprawl characteristics and when it comes to 2020 it shows high sprawl conditions because in 1990 there were only one development pattern and in 2020 it had four development patterns. Scattered development shows in 1990 near Matara city. Other development patterns didn't show in 1990.When it comes to 2000 urban area expanded outward from the Matara city and it shows commercial strip development and scattered development. When it comes to 2010 the GN divisions around the Matara city has fully urbanized and the urban edges has expanded further more outward from the city with scattered development and near city shows commercial strip development and the GN Divisions are Kadawediya east, Kadawediya west, Kadawediya south, Noope, Uyanwatta, Kotuwgoda South, Kotuwegoda North, Welegoda east, Welegoda west, Weliweriya. when it comes to 2020, scattered development, commercial strip development and low-density development shows in study area. But leapfrog development could not be showed in study area. The commercial strip development could be cause for huge traffic problem in Matara city. The GN Divisions, Isadeen town, Kadawediya east, Kadawediya west, Kotuwegoda North, Kotuwegoda South, Mathotagama, Noope, Uyanwatta, Uyanwatta North, Welegoda east,

Welegoda west, Weliweriya east, Weliweriya west GN Divisions have identified as high sprawl GN Divisions. The development patterns also used to identify sprawl in study area and they are very effective.

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Shoreline Change Detection Based on the Monsoon Seasonality by means of 'CoastSat' toolkit

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Abstract*:The sand accretion/erosion process is mainly responsible for the shoreline position changes in coastal zones. Understanding sand accretion/erosion response due to monsoon seasonality and anthropogenic effects is vital for coastal management to apply the best suitable coastal protection strategies. However, long-term monitoring of shoreline changes is expensive, time-consuming and labor-intensive. Instead, satellite imagery (Remote sensing technology) can be utilized as a substitute method to the field data collection, provided that time-series imagery is obtainable at the same location and freely downloadable using the Google Earth Engine archive. This study is mainly focused on shoreline change detection and geomorphological changes, Mirissa in southern coast of Sri Lanka. The 'CoastSat' software was employed to obtain the time-series of shoreline positions. According to the analysis of data, the beach was in three state: erosion, accretion, and steady state. Further, the most of transect locations indicate steady beach state and it is good for the development of tourism industry. In addition, the average horizontal shoreline difference ('CoastSat' and field measurement) was 7.95±1 m and that is in acceptable range. Accordingly, satellite images downloaded from the Google Earth Engine using 'CoastSat' can be used to analyze shoreline change detection very effectively with appropriate tidal correction when there is a lack of long-term field data in the area and it will be very useful for planning and evaluating coastal management strategies.*

Keywords: *Accretion, CoastSat, Erosion, Shoreline*

1. Introduction

The line of intersection of land and sea at a certain tidal height is measured as the 'shoreline'. An instantaneous coastline is defined as the position of the land-sea water boundary at a specific time (Gens, 2010). Based on the various conditions, different types of coastal boundaries such as vegetation line, wet-dry boundary, mean sea level (MSL), high tide line are also considered as shoreline (Boak and Turner, 2005; Gunasinghe et al., 2021; Ratnayake et al., 2019). Because coastlines are highly dynamic, detailed investigation of shoreline changes and maintenance of good coastal managing systems require continuous investigation and monitoring (Bouchahma and Yan, 2012; Gunasinghe et al., 2022). Nevertheless, continuous field data collection is expensive, time-consuming, and labor-intensive (Warnasuriya et al., 2018). To manage these difficulties, remote sensing (RS) technology is adapted to investigate long-term coastal changes and it has several advantages such as reduction of manual errors, cost-effectiveness, and temporal data acquisition (Gunasinghe et al., 2022; Specht et al., 2020).

Sri Lanka has a coastline of 1,620 kilometers around the country, with estuaries, sandy beaches, salt marshes, lagoons, coral reefs and dunes. Such an important coastal zone may be destroyed due to many reasons including dangerous storms, coastal erosion, and anthropogenic events, and investigation of shoreline changes offers scientific solutions and methods to develop coastal zones with protection. Coastal position changes in coastal regions of Sri Lanka are mainly controlled by monsoon seasonal changes (Amalan et al., 2018; Gunasinghe et al., 2019, 2021, 2022;

Gunasekara et al., 2020; Prabasara et al., 2021; Ratnayake et al., 2018, 2019). The coastal area focused on in this study (Mirissa, located on the southern coast) is wave-dominated (average significant wave height 1.12 m) and microtidal (tidal range 0.7 m) (Duong et al., 2017; Gunasinghe et al., 2022; Ranatunga et al., 2020; Ratnayake et al., 2013). Mirissa, a famous tourist destination of the island, is located about 129 km south of Colombo (Figure 1).

Figure 1. The study location

The main objectives of this study are to investigate shoreline changes using 'CoastSat' toolkit (the open-source and python-based) and to describe the coastal geomorphology at Mirissa. Further, such a scientific information is vital to maintain a proper coastal managing system in the area.

2. Methodology

In the present analysis, the open-source software 'CoastSat' toolkit was used to extract the coastlines relevant to the study area. 'CoastSat' is a Python-based program capable of obtaining shoreline positions (horizontal accuracy ~10 m) of any coastal region in the world using publicly available satellite images archived on Google Earth Engine (GEE) for more than 30 years (Vos et al., 2019a; Vos et al., 2019b).In Mirissa, WGS 84 coordinates of region of interest (ROI, the polygon) covering a 2 km long were entered into the 'CoastSat' software. The satellite mission was inserted as 'S2' (Sentinel-2, spatial resolution of 10 m), and the satellite image acquisition time length was expanded from 1 January 2016 to 1 May 2022. The 'CoastSat' retrieved 286 images and 65 images were selected for shoreline analysis after the pre-processing (cloud masking, panchromatic image sharpening and down-sampling) and classification process (sand, water, white-water, and other land features). The time gap between selected images was approximately 30 days and twelve shore-normal transects were defined by approximately equal distance (Figure 2) within a 2 km long coastline. After applying tidal corrections to the extracted shorelines at the location (converting instantaneous shoreline position into datum-based shoreline position, mean sea level (MSL)), the time-series of cross-shore distances along shore-normal transects were determined from landward to seaward and resultant data files were obtained as a MS-Excel *.csv format from the 'CoastSat' and timeseries of shoreline change along each transect was plotted on a graph for the analysis.The accuracy of the coastline extracted by 'CoastSat' was verified by comparison with coastal field survey data obtained through

Figure 2. Shore-normal transect locations

Global Navigation Satellite System (GNSS) technology (TOPCON GR5 GNSS receiver) and Sri Lanka Continuously Operating Reference Station Network (SLCORSnet) Correction (horizontal accuracy - 0.007 m). Accordingly, the average difference between the shoreline position obtained from 'CoastSat' and the field survey was calculated at the study location. Furthermore, the overall beach state at the Mirissa coastal zone was calculated at each transect location.

3. Results

A. Seasonal geomorphological changes

The shoreline variations at each transects based on the time is illustrated by Figure 3 and further, there are sixty-five shore-normal distances with respect to the mo monsoon seasonal variations. In general, the sand accretion is evident during the northeast monsoon season and sand erosion is evident during southwest monsoon season (Gunasinghe et al., 2021; Ratnayake et al., 2018, 2019). However, sand accretion and erosion process based on the monsoon seasonality in Mirissa is different than general process of sand accretion and erosion. The sand accretion is evident during southwest monsoon (03 May 2016), 1st inter-monsoon (27 April 2020), 2nd inter-monsoon (24 October 2020), and following general process that is during northeast monsoon (07 February 2017). Further, sand erosion is also evident during all monsoon seasons at the different times, and it is difficult to present common time duration for the sand erosion in the study area. Furthermore, there are no any significant variations of shorelines relevant to each transects.

B. Average horizontal difference of shoreline position ('CoastSat' and field observations)

The average shoreline difference of 'CoastSat' and field observation on 18 April 2022 was 7.95 ± 1 m at Mirissa coastal area. Therefore, it is suggested that the average value is in acceptable range.

C. Overall beach state

Based on the Table 1, the overall beach state can be categorized as erosion, accretion, and steady state. The values below 10 m (loss or gain), the beach state is considered as steady state. Further, first four transect locations are indicated steady beach state (Table 1). Furthermore, mean and standard deviation of shore-normal distances in each transects are presented on the Table 1.

4. Discussion

A. Seasonal geomorphological changes

Changes in shorelines depend on many factors such as existing shoreline shape, source and sink of sediment, strong storm and hydro-sediment dynamics, and longshore currents and cross-shore transport based on monsoonal changes (Deepika et al., 2014; Gunasinghe et al., 2021; Harris et al., 2020; Ratnayake et al., 2018; 2019).

Waves are propagated from southwest direction during southwest monsoon season in southern coast (Amarasekara et al., 2014) and therefore, the longshore currents move in an east-northeast direction in Mirissa. During the northeast monsoon season, waves propagate from northeast direction (Amarasekara et al., 2014) and longshore currents are towards west-southwest direction in Mirissa. Further, the sand accretion and erosion process in each transect locations is mainly controlled by longshore current direction and orientation of the coastline in Mirissa. Based on the location, and direction of the wave propagation, cross-shore transport is less effective for the coastal process (erosion/accretion).

B. Overall beach state

Based on the overall beach state, the steady state beach can be seen in many transect locations in Mirissa. It is suggested that the monsoon seasonality, wave propagation direction, orientation of the coastline, and local wind pattern are reasoned for the steady state beach in Mirissa. Therefore, Mirissa beach is most suitable for recreational activities and tourism industry. Further, sand accretion is

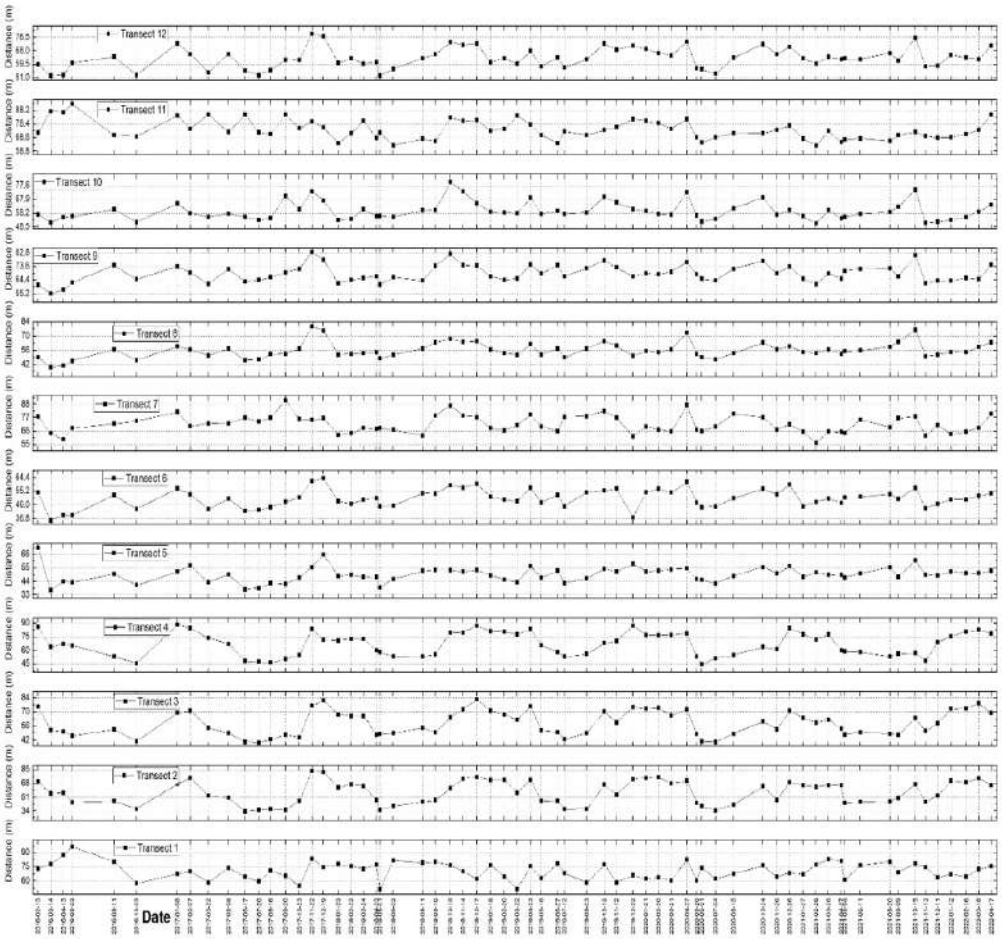

Figure 3. Transect based sholine variation

evident in many transect locations and it is a good reason for the development of the tourism industry

5. Conclusion

In this study, the 'CoastSat' toolkit was used to investigate shoreline changes in Mirissa coast. Accordingly, the following conclusions were reached.

1. If the long-term field measurements relevant to the shorelines are not available, the 'CoastSat' toolkit can be used with field verification as the best alternative.
2. The overall beach state in Mirissa shows more than 10m sand accretion and erosion based on the monsoon seasonality.
3. Sand erosion and accretion is occurred during all monsoon seasons (southwest, northeast, 1st inter-monsoon, and 2nd inter-monsoon).

Table 1. Overall beach state

Transect No.	Number of Shore lines Extracted	Time Frame	Distance between proceeding (OL) and succeeding (YG) Shorelines (OL-YG) m		Overall-Beach State	Mean (m)	Standard Deviation
			Gain	Loss			
Transect 1	65	2016 - 2022	02		Steady State	70.68	09.17
Transect 2	65	2016 - 2022		04	Steady State	56.89	14.29
Transect 3	65	2016 - 2022		06	Steady State	58.84	12.08
Transect 4	65	2016 - 2022		07	Steady State	67.00	12.67
Transect 5	65	2016 - 2022		19	Erosion	49.75	06.25
Transect 6	65	2016 - 2022		00	Steady State	50.53	06.13
Transect 7	65	2016 - 2022	02		Steady State	71.61	07.11
Transect 8	65	2016 - 2022	14		Accretion	55.94	07.74
Transect 9	65	2016 - 2022	13		Accretion	68.76	05.75
Transect 10	65	2016 - 2022	06		Steady State	59.78	06.43
Transect 11	65	2016 - 2022	12		Accretion	74.28	06.87
Transect 12	65	2016 - 2022	11		Accretion	63.51	06.46

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Acknowledgment

The authors gratefully acknowledge Syr. Pujitha Ranawaka and anonymous reviewers for their valuable comments and students of intake 36, spatial sciences for their assistance in completing field activities related to this research project.

The Effectiveness of Health & Safety Training and its Impact on Construction Workers' Attitudes in Sri Lanka

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Abstract*: Construction accidents happen due to defects on site environment or else defects on health and safety system. In the recent years, Sri Lankan construction industry experienced a considerable number of fatal and non-fatal accidents. Occupational health and safety training can apply as a precautionary action to reduce work site accidents. The construction workers attitude towards health and safety training is essential to make it more practical. The main objective of the study was to study the effect of occupational health and safety trainings and its impact on worker health and safety attitudes. Both qualitative and quantitative methods were applied to achieve the objectives. The data collected through questionnaires which was consist with closed-ended questions and five Likert scale questions and the semi-structured interviews. The degree of application on health and safety training was analysed through frequency analysis. Further, the relationship between health and safety training and workers attitude and the barriers on implementing health and safety training were analysed through correlation and regression analysis. Finally, the solutions to reduce work site accidents were analysed through content analysis. According to these analysis, results proved that there is a positive relationship between health and safety training and construction workers attitude in Sri Lanka. Conduct high-engaging health and safety trainings, conduct health and safety meetings and inspections, rewards and appreciations and managerial support were the results of the interviews to enhance the workers attitude on safety.*

Keywords: *Health & Safety Training, Construction worker, Attitude, Sri Lanka*

1. Introduction

Construction industry play a major role in today's world and it gives a biggest support to the economy of each and every country (Ofori, 2015). Construction is not only considered to be one among the foremost major industries in terms of its contribution to economic process (Alberto *et al.*, 2017). Therefore, before conducting a construction project we have to think of many areas like cost, time duration, capacity, environment, labour force, staff, safety etc. Among them, 'safety' or else 'the state which not being threatened by destruction or other undesirable consequences' is one of the main key area we should concern in a construction project (Risath, Sivatharsan and Thishanth, 2017). Sri Lanka is still in under developing country category where so many construction activities undergo and faced similar nature accidents can be happened. Fatal accidents and non-fatal accidents are main two types of construction accidents. Those accidents can be happen through fall from heights, struck-by or struck-against objects, when lifting and carrying, during machinery works, electrocution, elevator accidents, fire and explosion (Halwatura, 2012; Perera, Somachandra and Samarasiri, 2017).

In recent years Sri Lankan construction industry reported a larger number of fatalities and injury rate, which was ranked as the 3rd worst sector among other industries in Sri Lanka (Halwatura, 2012). Therefore the need of safety is really matters since it creates no obstacles in work. However, construction

accidents result in the loss of 500,000 man-days in each year which make a huge loss of productivity and other related matters (Dasandara and Dissanayake, 2021). Workers attitude on health and safety training can affect positively to reduce the worksite accidents. Main objective of this study is to study the effect of occupational health and safety training and its impact on worker health and safety attitudes. Furthermore, the main objective achieved through following sub-objectives;

[1] To identify the relationship between the occupational health and safety trainings and its influence on construction workers attitude

[2] To identify the issues regarding the implementing proper Health and Safety trainings

[3] To identify the practical solutions to reduce the work site accidents in Sri Lanka.

The construction workers, contractors, project manager and the client were the benefited parties in this research. Through this research, the construction industry will gain so many benefits like; invention of more techniques which can be applied for the Health and Safety training, it will increase the construction workers attitudes, it will help to deliver the project at correct time without any delay and it will help to decrease the cost which account due to the defects of the Health and Safety system.

2. Literature Review

A. Occupational Accidents

The worksite accidents are mostly happened due to immense use of sub-contractors, inaccurate record keeping of accidents, competitive tendering, less priority given for training and poor safety training etc. (Choi, Chan and Chan, 2012). That emphasis, poor safety training badly affect for the rate of construction accidents. The research study showed that when consider the years from 2004 to 2010, large number of fatal and non-fatal worksite accidents are happened from the unskilled labours in Sri Lanka (Halwatura, 2012). It indicates that the increase of occupational accidents can be seen in Sri Lanka as well.

B. Occupational Health and Safety Trainings

The systematic learning and the improvement of knowledge, skills and attitudes which required for the workers to perform competently and enhance performance in the job is defined as 'Training' (Clarke and Flitcroft, 2013; Mushayi, Deacon and Smallwood, 2018). That implies how much training is important for the workers which automatically improve the Knowledge, Skill and Attitudes and the performance.

Mainly there are two types of safety training that can be seen in the construction industry namely high engagement training and low engagement training (Robson *et al.*, 2012). Further it defines that lecture or information or video based methods were called low engagement trainings where simulation, behavioural modelling and hands on trainings were define as high engaging trainings. There is positive relationship between the safety risk awareness and highly engaged training (Namian *et al.*, 2016). Further it says, high engagement training gives a high level of safety risk awareness.

C. Hazard Identification

There are few steps need to be followed in safety management process, among them the very first step is hazard recognition (Namian *et al.*, 2016). Up to 42% of work site accidents are happened due to lack of hazard identification and assessment performance (Jeelani, 2016). There are several techniques and training programs to enhance the hazard identification by reducing occupational accidents (Jeelani, 2016; Namian *et al.*, 2016). Fall from heights, electrocution and exposure to harmful stuffs are the most reported hazards in Sri Lanka (Vitharana, Silva and Silva, 2015). According to a survey, it indicates that even minimum training is enough to identify the hazards and also it implies that thorough Occupational Health and Safety training is a must for hazard recognition since it influence the behaviour of the workers to adjust as per the situation arise (Perlman, Sacks and Barak, 2014).

D. Health and Safety Culture and Climate

A clear set of perception and expectations that construction workers have on safety in the organization is defined as safety climate (Risath, Sivatharsan and Thishanth, 2017)). Safety culture was expressed in safety attitudes, awareness and in safety behaviour (Clarke and Flitcroft, 2013). That implies in safety culture also can be seen in the workers safety attitudes also One of the main reason for the enhancement of safety culture in the organization and deduction of fatal and non-fatal accidents is due to involvement of the Occupational Health and Safety Training (Bahn and Barratt, 2014).

E. Health and Safety Signs and Symbols

Symbols and signs are specifically used for the purpose of improving Occupational Health and Safety Training awareness in construction sites (Mushayi, Deacon and Smallwood, 2018). Safety signs and symbols are defined as a method of providing information and also alerting the construction workers about the possible hazards that can be exposed in the work site (Amirhossein *et al.*, 2015). That illustrates Health and Safety signs and symbols help to improve the knowledge on workers regarding hazards and it is a better mechanism to communicate information without words. The signs and symbols which are designed graphically and colourfully along with naming those boards with all the three languages (Sinhala, Tamil and English), help to attract the attention of the construction workers and improve the safety attitude of them. According to this statement it simply shows that there is a positive relationship between Health and Safety signs and symbols and workers attitude.

F. Health and Safety Inspections

Health and Safety inspections plus actions were also important in Occupational Health and Safety related issues (Mushayi, Deacon and Smallwood, 2018). Furthermore states that, the Health and Safety inspections which are done as per a routine have a positive impact on occupational Health and Safety Training practices. It illustrates that there is a link between Health and Safety inspections and with the workers attitude. Previous study states that, safety experts believed that occupational accidents were can prevent through physical paths like fencing machinery and piloting Health and Safety inspections (Ghofranipour *et al.*, 2009).

G. Construction Workers' Attitude

The attitude and the behaviour of the construction workers is a huge element in jobsite safety, since most of the fatal and non-fatal accidents happen due to anxious actions they taken at the sites (Widaningsih, Susanti and Chandra, 2018). It concludes that the both positive and negative impact is solely depend upon the workers attitude. Construction workers' attitude is one of the main factor which is important in the construction sites (Othman, Shafiq and Nuruddin, 2018).

H. Barriers to Implement Health and Safety Training

Lack of managerial support is one of the significant barrier to implement health and safety measures after the Occupational Health and Safety Training has been conducted (Weinstock and Slatin, 2012; Dasandara and Dissanayake, 2021). This statement concludes that there are some more reasons where it directs to lack of managerial support. The language barrier was seen in Sri Lankan construction industry since the most of the construction workers have less education level which was not sufficient to understand Occupational Health and Safety Training and as a result they are reluctant to learn Health and Safety measures (Halwatura, 2012).

A previous research found that the workers were tend to work at an any risky situations due to low income level in Sri Lanka (Dasandara and Dissanayake, 2021). Furthermore it described that, when looking at the workers' income levels in both instances, these workers earn low amount and live in low- income households with many dependents where faced numerous financial difficulties in daily lives and automatically driven them to work at any risks to earn more and more money.

3. Methodology

The target of this study is to identify the effectiveness of health and safety training and the way of it is impact on workers attitude in the Sri Lankan construction industry. There are two types of variable can be seen in this research known as dependent variable and independent variables as shown in the Figure 1, Conceptual framework.

A. Conceptual Framework

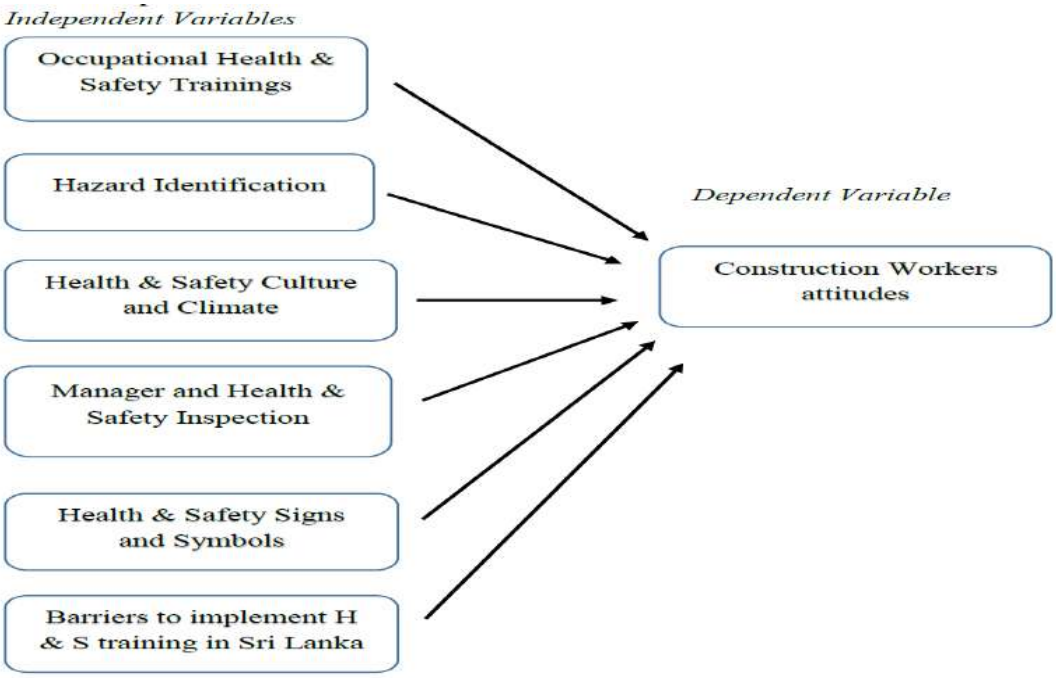

Figure 1: Conceptual Framework

B. Hypothesis

H_{A0} - There is a relationship between Occupational Accidents and the Construction workers attitudes

H_{A1} - There is no relationship between Occupational Accidents and the Construction workers attitudes

H_{B0} - There is a relationship between Occupational Health and Safety Trainings and the Construction workers attitudes

H_{B1} - There is no relationship between Occupational Health and Safety Trainings and the Construction workers attitudes

H_{C0} - There is a relationship between Hazard Identification and the Construction workers attitudes

H_{C1}- There is no relationship between Hazard Identification and the Construction workers attitudes

H_{D0} - There is a relationship between Health and Safety Culture and Climate and the Construction workers attitudes

H_{D1} - There is no relationship between Health and Safety Culture and Climate and the Construction workers attitudes

H_{E0}- There is a relationship between Health and Safety Signs and Symbols and the Construction workers attitudes

H_{E1} - There is no relationship between Health and Safety Signs and Symbols and the Construction workers attitudes

H_{F0} - There is a relationship between Health and Safety Inspection and the Construction workers attitudes

H_{F1} - There is no relationship between Health and Safety Inspection and the Construction workers attitudes

H_{G0} -There is a relationship between Barriers to implement Health and safety trainings and the Construction workers attitudes

H_{G1}-There is no relationship between Barriers to implement Health and safety trainings and the Construction workers attitudes

C. Data Collection

Data collection is important to obtain the final outcome of the research properly. There are two types of data collection methods as namely; primary data collection and secondary data collection method. Both the methods were applied for the research, primary data collection method was used since there were objectives need to be fulfilled through semi structured interviews and also the data which were found already by another researchers' also used for this research which means secondary data collection. The sample was taken only from the Colombo District since most of the development projects in different levels are mostly located in that district. Around five ongoing constructions projects were selected for the data collection task which were having different grades in construction that may help to collect data from different levels of construction workers.

In analysing the data, correlation analysis method was used to identify whether there is relationship between the safety trainings and the construction workers attitude. Regression analysis and the relative important index method was applied to identify the issues regarding the implementing proper Health and Safety trainings since the impact of each variable was essential. Lastly, content analysis was applied to analysis the data taken from the semi structured interviews.

D. Reliability of the Questionnaire

Reliability test used for the questionnaires which are validated using Cronbach alpha coefficient measure before the project objectives could be assessed (Clarke and Flitcroft, 2013). Further it says that the accuracy and the reliability is increased when the Cronbach's Alpha coefficient of reliability is closer to one. But there is a cut-off point. That is 0.7. The result should be more than 0.7 to make the result more realistic. The overall reliability of the questionnaire was resulted as 0.976.

Table 1: Correlation Results

Variable	Pearson Value
Occupational accidents	0.910
Hazard identification	0.876
Health and Safety culture and climate	0.873
Health and Safety inspections	0.934
Health and Safety signs and symbols	0.883
Barriers to implement Occupational Health and Safety training in Sri Lanka	0.922

4. Results

A. The relationship between the occupational health and safety trainings and construction workers attitude

The correlation analysis was used to figure out the result of relationship between occupational health and safety training and construction workers attitude. The coefficient value was 0.864 where it means have a positive correlation between the dependent and independent variables. The remaining all the independent variables (occupational accidents, hazard identification, Health and Safety culture and climate, Health and Safety inspections,

Health and Safety signs and symbols and barriers to implement.)

B. Barriers to implement Occupational Health and Safety training in Sri Lanka

The Regression Analysis and Relative Important Index were used to figure out the barriers to implement occupational health and safety in Sri Lanka. The overall regression was resulted as 0.977 while barriers to implement occupational health and safety in Sri Lanka showed as 0.273. It concluded that there was an impact on construction workers attitude through this independent variable and the significance value was 0.002 which proved that it statistically significant.

According to the Relative Important Index value, the average amount was 0.720 and it was ranked in 3rd place. The result prove that all the three barriers namely, 'Lack of managerial support', 'Language barrier' and 'Risk taking behaviour' were relatively important and it affect on construction workers attitude.

C. Solutions to reduce work site accidents through enhancing workers attitude

Occupational accidents are one of the major factor that should be mitigated as much as possible. Therefore, taking precautionary actions is highly appreciated in such occasions. Since the research study is targeted Occupational Health and Safety training and the workers attitude, therefore project manager and safety officer were the people who targeted for the interviews. The age range facing accidents mostly and the reason, the current safety practices conducted to reduce occupational accidents, opinion of investing money for safety training and solutions to reduce work site accidents were the key areas focused under semi structured interviews.

The age range facing construction related accidents mostly and the reason

The interview results shows that mainly the age below 18 and age between 18– 25 have high frequency on facing construction site accidents. For an example, the safety officer from project A said that, "every day we conduct safety meetings at the site and instruct how to work safely at site but unfortunately most of the young generation age below 25, do not adhere and follow the safety guidance properly."

Table 2: Project Details

Project Name	Grade of the Contractor	Project duration	Location
A	CS1	17 months	Colombo 03
B	C1	18 months	Colombo 08
C	CS2	21 months	Colombo 02
D	C7	12 months	Colombo 03
E	C1	16 months	Colombo 03

Another opinion was point out by a project manager from project C told that, "the young generation mostly prefer to participate for risky works and unfortunately face severe accidents." It concludes that the risk taking behaviour can be seen in the younger generation when compared it with elderly labours.

When considering above research findings, almost all the interviews concludes that the younger generation face accidents when compared to the older generation and as for the reasons; thought of young energetic power, risk taking behaviour and poverty.

The current safety practices conducted to reduce occupational accidents

This was the second point which asked in the interview from the respondents. Since safety practices improve the degree of safety by

reducing accidents that can happened at the construction sites.

One of the safety officer from Project D said that "our company conduct safety inspections and meetings in daily basis, conducting training programs and confirm the site safety always." This opinion was come up with all the five projects as the main safety practices they follow up at the site. The project manager from Project E told that, "Conducting safety meetings, safety inspections, providing Personal Protective Equipments, use of safety signs and symbols and site clean are the safety practices conduct in our project." Apart from the other opinions, this respondent expand the idea by adding some more safety practices like use of safety signs and symbols and keep the site clean.

When considering above research findings, almost all the interviews mainly point out some safety practices like safety inspections and meetings, use of safety signs and symbols, use of Personal Protective Equipment and keeping the site clean may help to reduce occupational accidents.

Opinion on investing money for safety training

Safety training cannot be done easily, it spent both time and money. Therefore, allocating money for a training program should a deep concern since a construction project strictly concern on budget.

The safety officer from project C mentioned that, "that is the best solution to reduce work site accidents is proper safety training program, therefore investing money for such thing benefited in long term." Where the almost same idea was provided by other respondents. But the Project manager from project D said that, "investing money on safety training is a waste of money since most of the labours did not follow the guidance provided by the safety training properly." It illustrates that there are people whom with different perspectives not seen the positive side of the safety training.

When considering above research findings, it concludes that investing money on safety training was not a waste and it is a huge invest for the future since it reduces the occupational accidents and save that money.

Solutions to reduce construction work site accidents in Sri Lanka

Whereas solutions on reducing the occupational accidents in construction was very practical on nowadays, that was the last question asked at the interview. The participants gave different answers as per their perspective. The safety officers from project A, C and E stated that, "giving rewards for the labours who work safely, providing induction training, providing proper Personal Protective Equipment, establishing safety sign and symbols and conducting safety meetings in daily basis are the solutions to reduce work site accidents." Apart from these suggestions the project manager from project D said that, "introducing proper safety guideline by the government and inspect the project by the government officers and also increase the level of education the labours can enter into the industry will help to reduce the construction occupational accidents in Sri Lanka."

However, all the opinions and suggestions mentioned in the above may help to reduce the accidents in Sri Lanka at a considerable level.

5. Discussion & Conclusion

As discussed briefly in previous sections it concluded that construction industry greatly affect for the economic development of the country. The research study determined that a suitable and proper Health and Safety training is essential to achieve the required knowledge and skills to carry out a task. Further, Health and Safety training helps to transfer the knowledge to reduce occupational accidents, identify the hazards and change the workers attitude. Therefore, health and safety training ought to be beneficial in transforming construction employees' beliefs and attitudes, and as a result, the way they act safely at work.

The research study determined that a suitable and proper safety training is essential to achieve the required knowledge related to carry out a task safely.

The research study concludes that language barrier, lack of managerial support and risk taking behaviour affect on construction

employees' attitudes regarding implementation of safety training. Mitigating those barriers is essential. Therefore as solutions the research study identified some precautions through conducting semi structured interviews, providing proper Personal Protective Equipment's, establishing safety sign and symbols and conducting safety meetings in daily basis, introducing proper safety guideline by the government and inspect the project by the government officers and also increase the level of education the labours. These measures would assist to reduce occupational accidents.
According to the research findings providing well-structured and high engaging training for the construction employees' periodically, correctly expressing their values recruiting only the new employees' who can adopt and adhere to those values, awarding some rewards and appreciations to the employees' who work safely at site, conducting Health and Safety inspections and meetings on daily basis and displaying safety signs and symbols which are fully readable are the recommendations to enhance the construction workers attitude.

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Acknowledgement

I would like to gratefully acknowledge all the participants of the questionnaire survey for their valuable comments and views and for the participants of the semi structured interviews. Further, I would like to acknowledge Faculty of Built Environment and Spatial Sciences and for my supervisor for the inspiration and encouragement.

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The Impact of Cost Overrun Factors on the Project Performance in the Construction Industry of Sri Lanka

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Abstract: *The construction sector is an extremely vital business for the sake of the economic growth of the nation. However, this sector has been suffering significant issues by the inability to finish projects within allowed cost and cost overrun effects on the total project performances. Hence, this study determines to identify the impact of cost overrun factors on the performance in the construction industry of Sri Lanka. As an outcome, the findings of this study give recommendations and solutions to cost overrun factors that affect the performance of a project in Sri Lanka's construction sector. The aims of this research were attained utilizing qualitative and quantitative data acquired through a comprehensive questionnaire survey and semi-structured interviews concurrently. The sum of circulated questionnaires was 50 and the number of responses was 90%. A detailed literature survey was carried out to establish the significant cost overrun factors that affect the project performance. Correlation & regression analysis done with the use of SPSS software to analyse the collected data. The interviewed questions were assessed through the content analysis. The findings of this study explain the cost overruns that have a major effect on project performance. Finally, solutions such as shifting to digitalization, selecting the best construction management team and employees, properly tracking and monitoring progress, developing employee skills and maintaining a sustainable supply chain were found to be effective in overcoming the cost overrun factors that have an impact on the performance of Sri Lankan construction industry.*

Keywords: *Cost overrun, Project performance, Construction cost, Construction industry*

1. Introduction

The construction industry forms a critical portion of a country's economic development. It included a highly complex process with broad connections to hundreds of upstream and downstream sectors (Oladinrin, Adeniyi and Udi, 2014). The rise of the construction sector contributes to the Gross Domestic Product (GDP) and the employment of all countries and the construction produces a multiplier impact on other industries such as manufacturing sector, professional services, and financial services. (Teknologi, Dingin and Modifikasi, 2015). Sri Lanka's construction industry is a vital part of the economy and has played a key role in the country's growth (Cooray et al., 2019). Sri Lankan construction industry has contributed approximately 6.8% to the GDP (Annual Report 2018, Central Bank of Sri Lanka). The success of a construction project is decided by its performance, which is measured in terms of on-time completion, cost control, quality assurance, and client satisfaction (Hanagodimath, Rajashekarswamy and Parate, 2016). When a building project is finished on time, on budget and according to plan and the satisfaction of all stakeholders, it is called proper achievement. In terms of functionality, the lack of claims and legal procedures for contractors, as well as "fitness for purpose" for occupants, have been castoff to assess project success (Takim and Akintoye, 2002).

All across the life cycle of a project, the cost is the most important considerations. The difference between the cost at completion and that initially anticipated, known as cost overrun, may be considered as one of the major significant criteria indicating the

accomplishment of projects. Even though it demonstrated its consequence, it is common to see building projects fail to complete within the budgeted timeframe. (Hiroshan and Hadiwattege, 2014). Cost overrun is a common occurrence connected with the majority of the building projects in Sri Lanka. This tendency is observed in the emerging nations, where these overruns often surpass 100 % of the initial project cost (Wijekoon and Attanayake, 2012).

This study is discussed about the impact of cost overrun factors on the project performance in the construction industry of Sri Lanka. The performance of construction projects in the worldwide construction sector is influenced by a variety of cost overrun elements. However, the scope of this study is confined to cost overrun factors in the Sri Lankan construction sector. Moreover, research data is collected based on only building constructions in Sri Lanka.

2. Literature Review

A. Construction Project Performance

The word project arises in the organization where the project completion is controlled by quality, cost, and time usually termed "triple constraint." Even though the project is regarded as necessary by the stakeholders, all the team members engaged in the project management should examine all the three triple constraints known as the "iron triangle" or “golden triangle” (Hassan and Adeleke, 2019).

Figure 1: Triple Constraints

Source: (Teknologi, Dingin and Modifikasi, 2015)

B. Construction Cost Overruns

Cost overrun is described as the variation between actual and budgeted costs. Cost overrun is also often called "cost escalation," "cost increase," or "budget overrun." A cost overrun is calculated by dividing the alteration in contract amount by the initial contract awarded value (Subramani et al., 2011). Appropriate cost management methods should be utilized to prevent cost overruns, which is not a simple operation. In identifying cost overrun factors that cause the project performance, it is not only adequate to discover them but also essential to determine what produces them and neutralize them before it impacts the relevant construction organizations (Senouci, Ismail and Eldin 2016).

D. Causes For Cost Overrun

Cost overruns in construction can occur for a variety of causes, depending on the project. Cost overruns may be divided into numerous categories to make them easier to analyse and provide better mitigation methods. Chan and Park (2005) investigated that it is clear that both internal and external factors of the company environment are significant drivers to cost overruns.

Slow decision making, poor timeline management, increases in material/machine prices, poor contract management, poor design/delay in providing design, rework due to incorrect work, land acquisition issues, incorrect estimation/estimation method, and the long time between design and time of bidding/tendering were all identified as significant causes of cost overruns (Subramani, 2014). According to the research (Hiroshan and Hadiwattege, 2014) Materials costs, project scale, project planning, and size of the project were regarded as the most relevant cost variables. Further, elements were classified into five major groups. Building parties associated variables, financial considerations, construction item-related issues, environmental considerations, and political factors. Abusafiya and Suliman (2017) The final findings revealed that numerous design

changes, construction faults, and timetable delays were the most common causes of cost overruns in Bahrain's construction sector. Inadequate planning and scheduling, fluctuating material prices, inadequate fund facility by the client, wrong cost projections, interruptions in payment by the client, financial issues by the client, extra works, poor financial control on site, interruptions in decision making, and recurrent design changes are among the leading reasons of project cost overrun (Akram et al., 2017).

Karunakaran et al., (2018) show that potential cost overrun causes were classified into seven categories: project-related, contract-related, client-related, contractor-related, consultant-related, labour-related, and external-related variables. Ramabhadran (2018) classified cost overruns into two types: internal and external. External factors are more challenging to regulate than internal ones, and it also has a low occurrence rate. He discovered that only internal factors were significantly affecting the cost overrun.

According to (Hiroshan and Hadiwattege, 2014; Teknologi, Dingin and Modifikasi, 2015) categorized cost overrun factors into five main categories. Such as financial factors, management factors, construction material related factors, governmental and environmental factors.

D. Mitigation measures for cost overruns

Throughout the implementation of a project, project management and record keeping processes become essential. Managers are required to be well prepared to implement the project, with appropriate attention to the quality of work, but within the specified cost and limitations. Cost management may be accomplished by choosing the appropriate personnel for the correct task, the right equipment and tools for the excellent work and the excellent quality of materials, in the correct amounts from the correct source, just at the correct price and delivered at the right time (Al-Jibouri, 2003). (Williams and Gong, 2014) state that the majority of the potential factors that contribute to more enormous cost overruns can be identified during the bidding stage using the indicators provided in the bidding document. Premalal, Mudalige and Malkanthi (2016) state that experts in the building business are needed to have hypothetical knowledge on cost management approaches. The adoption of suitable project cost management apparatuses is a necessity in today's construction business.

Most past researches conduct to identify cost overrun factors in the industry. There were relatively few studies that explored the influence of cost overruns on overall project performance. In this study identifying the impact of cost overrun factors on the project performance in the construction industry through considering building projects in Sri Lanka and to give solutions to mitigate cost overrun factors that directly affect the project performance.

3. Research Methodology

The research study is targeted to identify the impact of cost overrun on project performance in the construction industry Sri Lanka. To assess the impact of cost reduction, a diverse group of professionals connected to the Sri Lankan construction sector will be surveyed. The study was thoroughly examined using a questionnaire survey and interviews with relevant authorities. Combining qualitative and quantitative methodologies is highly valued since it provides a holistic picture of the research field and enhances the study.

A. Data Collection Methods

A web based detailed questionnaire (Google forms) was circulated among professional groups in construction industry. Questionnaires were distributed among professionals in order to obtain suitable responses to the questionnaire & different viewpoints were ranked accordingly to the "Likert Scale". A total number of questionnaires distributed was 50 (selected by simple random sampling), & the response rate was 90% including from18 Quantity Surveyors, 13 Engineers, 08 Technical officers and 06

Project Managers. Semi-structured interviews with open ended questions are allow for a broad range of topics to be discussed. A purposive sample was selected for the semi-structured interviews since the objective is to select the participants who have better knowledge & industry experience in the area of research study. A total number of interviews conducted were 10 including 03 Quantity Surveyors, 03 Engineers, 02 Technical officers and 02 Project Managers.

B. Conceptual Framework

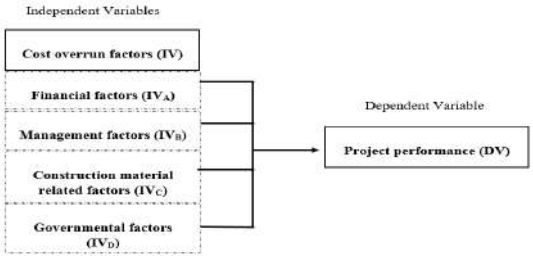

Figure 2: Conceptual framework

D. Data Analysis Methods

Primary data has been evaluated using quantitative approaches and secondary data has been studied using a content analysis. Statistical study allowed to discover the correlations between the researched factors linked to cost overrun & their influence on project performance. This is an excellent approach for multivariable analysis. The relationship is hypothesized at the beginning & the statistical analyses were done appropriately. The study was done with the use of SPSS program which provides a comprehensive range of formulas, statistical methods.

Presentation was in the forms tables were auto created by the SPSS program itself. Most of the data transformed in to information. A cording scheme employed at the SPSS program is comparable to the codes given on variables.

4. Research Findings

The general information of respondents including their profession & experience in the industry were assessed because based on the perspective of different people the answers to the questions may vary due to their thinking capacity, knowledge & based on the industry experience. The degrees of responses are illustrated in Figure 3.

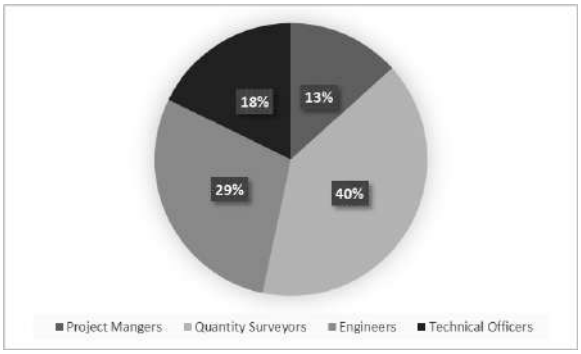

Figure 3: Respondents Details

A. Correlation Analysis

Correlation analysis done to identify the relationship between developed independent variables (IV) & the dependent variable (DV). Pearson correlation coefficient is used to check the relationship & analysed through SPSS software. Each independent variables were tested with the dependent variable. Positive correlation represents, when one variable increase the other variable also increase & the negative correlation represents decrease of both.

Table 1: Correlation Analysis (SPSS Software generated)

Correlations						
		AFFC	AMFC	ACFC	AGFC	ACFP
AFFC	Pearson Correlation	1	.868**	.867**	.745**	.827**
	Sig. (2-tailed)		<.001	<.001	<.001	<.001
	N	45	45	45	45	45
AMFC	Pearson Correlation	.868**	1	.883**	.745**	.839**
	Sig. (2-tailed)	<.001		<.001	<.001	<.001
	N	45	45	45	45	45
ACFC	Pearson Correlation	.867**	.883**	1	.717**	.867**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001
	N	45	45	45	45	45
AGFC	Pearson Correlation	.745**	.745**	.717**	1	.807**
	Sig. (2-tailed)	<.001	<.001	<.001		<.001
	N	45	45	45	45	45
ACFP	Pearson Correlation	.827**	.839**	.867**	.807**	1
	Sig. (2-tailed)	<.001	<.001	<.001	<.001	
	N	45	45	45	45	45
**. Correlation is significant at the 0.01 level (2-tailed).						

Financial factors (AFFC), Management factors (AMFC), Construction items related factors (ACFC) and Governmental factors (AGFC) has gained less than 0.001 significant value over the project performance and it is proven that there is a strong relationship between financial factors and project performance. The correlation values are 0.827, 0.839, 0.867 & 0.807 respectively. Which suggests there is a substantial and positive relationship between these factors.

B. Regression Analysis

Regression analysis done to identify the impact of developed 4 different variables on the dependent variable. This makes all the independent variables comparable & standardized.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.100	.325		.309	.759
	AFFC	.077	.129	.090	.600	.552
	AMFC	.119	.152	.124	.783	.438
	ACFC	.483	.169	.442	2.855	.007
	AGFC	.320	.100	.330	3.208	.003
a. Dependent Variable: ACFP						

Table 2: Regression Analysis (SPSS Software generated)

The beta value of 0.077 shows that project performance in the Sri Lankan construction sector is impacted by financial related cost overrun factors. There is a 7.7% variance of construction projects performance is affected by when regarding the financial related cost overrun factors. And according to the outcomes, this is the lowest impacted factor.

The highest impact is shown by the construction materials related cost overrun factors. The beta value of 0.483 shows that project performance in the Sri Lankan construction sector is impacted by construction materials related cost overrun factors. There is a 48.3% variance of construction projects performance is affected by when regarding construction materials related cost overrun factors.

The next highest impact is shown by government related cost overrun factors. The beta value of 0.320 shows that project performance in the Sri Lankan construction sector is impacted by government related cost overrun factors. There is a positive relation. This means there is a 32% variance of construction projects performance is affected by when regarding government related cost overrun factors.

Management related cost overrun factors have a beta value of 0.119. It shows that project performance in the Sri Lankan construction sector is impacted by management related cost overrun factors. There is a positive relation. This means there is an 11.9% variance of construction projects performance is affected by when regarding management related cost overrun factors.

C. Content Analysis

1. Barriers Regarding Causes of Cost Overrun on the Project Performance

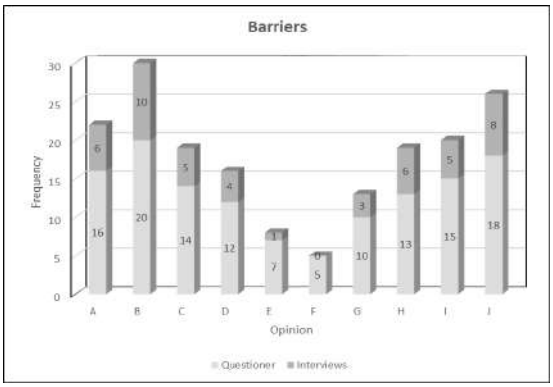

Figure 4: Identified Barriers

According to the comments of the professionals, approximately ten barriers were identified. As illustrated in the above bar chart highest frequency is obtained by 'Traditional practice' (opinion B), 83.3% frequency obtain out of total responses. The second most mentioned barrier is 'Lack of awareness in new technology' (opinion J), 72.2% frequency obtain out of total responses. The third highest frequency is obtained by opinion A; 'Limited resources availability', 61.1% frequency obtain out of total responses. 'Government rules and regulations', (opinion I) obtained 55.6% frequency, 'Unethical practice by management', (opinion C) and 'less competent staff members' (opinion H) obtained 52.89% frequency out of total responses. Fluctuation of economy (opinion D), In-efficiency of construction (opinion G), Climatic changes (opinion E) and Poor cost data bases (opinion F) obtained 44.4%, 36.1%, 22.2% and 13.6% respectively.

2. Solutions to Mitigate the Cost Overrun Factors that Directly Affect the Project Performance

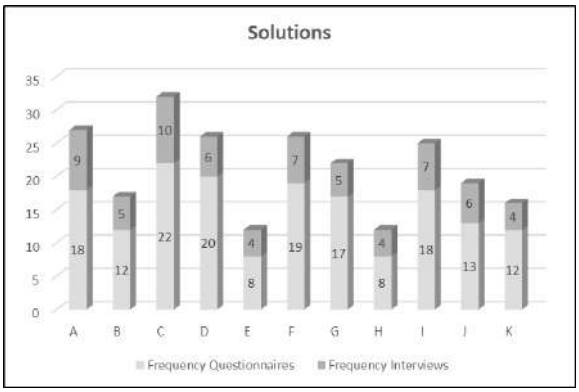

Figure 5: Identified Solutions

According to the replies of the specialists, generally eleven Solutions have been identified to mitigate the cost overrun problems that directly impact the project performance. As illustrated in the above bar chart highest frequency is obtained by 'Shifts to digitalization" (Opinion C), 88.9% frequency obtain out of total responses. Selecting the best construction management team and employees (opinion A) was the second most common mitigation method and it displays 75% of responses. The next highest frequency shows by Proper tracking and monitoring progress (opinion D) and Keep a sustainable supply chain (opinion F). These two factors show an equal frequency percentage of 72.2%. Development of skills of employees (opinion I) obtained 69.4% frequency. Establish material wastage management systems (opinion G) obtained 61.1% frequency out of total responses. Proper value engineering in the earliest stage of the project (opinion J), Implement proper communication plan (opinion B), Review and assess contractual terms and conditions (opinion K), Keep to the planned scope (opinion E) and Accurate future predictions on economy and industry (opinion H) obtained 52.8%, 47.2%, 44.4%, 33.3% and 33.3% respectively.

5. Conclusion And Recommendations

A. Conclusion

The major persistence of this study was to examine the influence of cost overrun elements on the project performance in the construction sector of Sri Lanka. Through the findings of the regression analysis, it was further demonstrated evident that there is an influence of cost overrun elements on the project performance in the construction sector of Sri Lanka. The second purpose of this exploration was to investigate the association between cost overrun variables and project performance in the construction sector as per the conceptual framework. Clear positive relationships were demonstrated between independent variables and dependent variable which satisfies the H1 (Alternative Factor). Through a comprehensive literature review, the purpose of this study was realized. The main cost overrun factors in the construction industry of Sri Lanka were identified.

Traditional practice in the modern building sector. Despite that, Lack of understanding of new technology, limited resources availability, government rules and regulations, unethical behaviour by management and less competent staff members; have been listed as the next highest frequent barriers regarding causes of cost overrun on the project performance. The most crucial solutions stated by the professionals moved to digitalization, pick best construction management team and staff, appropriate monitoring and monitor progress, retain sustainable supply chain, development of skills of employees and implement material waste control systems.

B. Recommendations

Nowadays traditional practice is one of the core problems that can be seen in the construction industry in Sri Lanka. For that, it is recommended to shift traditional practice to digitalization. Another important factor is lack of resources and wastage. So it is recommended to have proper resource management in construction. And also needed to reallocate resources if uncover a project costing more supplementary than planned. But it can formulate for that circumstance by analysing resources ahead, and deploying them where they'll be greatest successful.

The employees' and professionals' knowledge about modern construction techniques and procedures is vital for the accomplishment of project performance. Therefore, suitable training, Continuous Process Development (CPD) programs and course work concerning the application of modern techniques and methods should be organized for professionals and employees. The greatest strategy to avoid cost overrun is to prepare a risk management strategy before implementing a project. The supplementary detailed and precise estimations, the more likely to remain within budget. There are dangers, but they may be accounted for with a comprehensive risk management strategy. When preparing for any project, must analyse completely conceivable possibilities, including past data, interviews and experience. The real-time monitoring method is appropriate for following the progress of a project as it occurs, not after the fact. Before difficulties become problems that lurk to send the project off-track and over-budget they may be handled. The real-time monitoring approaches examine not only the progress of the project, but also the workload of the team, anticipated and real completion deadlines, project slippage, and other factors. So this leads to overcoming cost overruns in the project and delivering the project to success.

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Acknowledgment

I would like to give my heartfelt appreciation to Dr. Sanjaya Jayasooriya. His contribution towards my research was significantly supported to pursue the correct path. In addition, I would like to thank with respect all the lecturers of my university for the amazing advises and inspirations supplied by them. The last tribute and admiration are left for my dear parents who always sat next to me in pushing me to concentrate on my best.

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Challenges Allied to the Effectiveness of the Environmental ImpactAssessment in the Construction Industry of Sri Lanka

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Abstract: *Environmental Impact Assessment is a structured program for evaluating and inspecting environmental factors, in order to support and aid the decision-making or the planning stage of a development process. Basically, this information is used to observe the change that cause to the environment due to the development process and advice the most effective and reasonable methods to reduce the impact to the environment. Considering the last decade Sri Lanka has been positive towards development and towards the Construction industry. Nevertheless, there are numerous environmental concerns that should be addressed due to these developments. EIA procedure emphasizes the possible environmental impacts and methods to reduce these impacts. This study elaborates on the Challenges allied to the Effectiveness of the Environmental Impact Assessment in the Construction Industry of Sri Lanka. Theimpacts of five main challenges are discussed in this study and also study will provide an insight about the current EIA procedure implemented in Sri Lanka. Both quantitative and qualitative approaches are used to collect data, and these collected data were presented using both numerical formats by regression analysis and descriptive formats by content analysis. The findings inthe study reveal that the challenges discussed in this cause have a significant impact towards the effectiveness of the EIA procedure. The paper concludes with recommendations or strategies to overcome these Challenges.*

Keywords: *Environmental Impact Assessment, Challenges, Strategies, Construction Industry*

1. Introduction

The Construction industry of Sri Lanka is a prominent industry that assists the development of the country. It contributes 7% to the Gross National Income of the country. The construction industry plays a key role whenit comes to employment by contributing a potential 6-10%to the countries total labour force. The report on Economic and Social Statistics in Sri Lanka 2019prepared by the Central Bank of Sri Lanka identified 17 industries that directly contribute to the National Economy out of which the Construction Industry is Ranked 1(Wijesekara, 2020). Since the elimination of terrorism from the country which lasted nearly 30 years, Sri Lanka has taken a huge leap forward when it comes to construction. For an Example Colombo Port City, Hambantota Harbour and The Southern Expressway are some of the major developments taken place during the past two decades. Even though these developments attract foreign investments, increase the living standard of peopleand link Sri Lanka to the modern world there are some negative impacts from these developments mainly to the Environment. These Environmental issues are caused due to Construction finally generate the interest and concept of sustainable Construction, Where new legislation and laws are introduced in order to influence Construction projects and reduce the impact on the Environment. Environmental Impact Assessment is a good example for such legislations.

Principle 17 of the Rio Declaration on

Environment and Development (1992) refers to EIA as a national instrument which "shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment". EIA procedure was introduced by USA in 1969 and then it was extended and introduced throughout the world. EIA was introduced to Sri Lanka in 1988 through the National Environment Act and it acts as an effective tool that integrates Environmental consideration into different development projects in Sri Lanka. But Sri Lanka is faced with many constraints when instituting EIA arrangements. There are many factors that affect the effectiveness of the EIA procedure in developing countries and these challenges must be avoided in order to create and increase the Sustainability of a construction project. Therefore the main aim of this study is to identify the challenges that areallied to the effectiveness of Environmental Impact Assessment in the Construction Industry of Sri Lanka and to suggest strategies in order to design construction projects in harmony with the Environment.

2. Literature Review

A. Environmental Impact Assessment

According to United Nations Environment Programme publication on "Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach" by Abaza, Bisset and Sadler (2004)states that Environmental Impact Assessment is a structured program for evaluating and inspecting environmental factors, in order to support and aid thedecision making or the planning stage of a development process. The Review of Implementation of the Rio Principles (2011) defined Environmental ImpactAssessments (EIA) as a decision-making process and assessment that provides a systematic, accountable evaluation of the potential environmental threats if the proposed development takes place.

B. Effective Environmental Impact Assessment

Most of the studies that are related to Effective Environment Impact Assessment propose components or pillars that an effective EIA should possess. according Leu, Williams and Bark (1996)) an Effective EnvironmentImpact Assessment should contain "Environmental policies, Regulations & Guidelines, Environmental administrative framework, EIA procedure, Role of actors involved, Status of EIA reports, EIA compliance monitoring and enforcement, EIA implementation in Practice, Implementation of Strategic Environmental Assessment (SEA) and International interactions". Out of nine components seven are domestic components and two are international components. Mentioned pillars were the base of identifying the challenges discussed in this study.

C. Challenges to effective Environmental ImpactAssessment

Problems in ensuring adequate public participation According to Zubair (2001), the limited period on commenting about the development project is notsufficient. Because most of the complex projects need more time for public hearing. And most of the general society is not aware of Environment Impact Assessment.The second issue is about the language barrier because most of the EIA reports are printed in English. ThereforeEIA report must interpret and printed in a convenientlanguage.

D. Inadequate technical and managerial resources toimplement EIA

The EIA process merely relies on the judgement of the EIA consultant. But the practitioners have few drawbacks when performing the EIA procedure. According to this study project proponent can influence the EIA consultant to create a report in favour of the development process. The unethical behaviour of EIA practitioners imposesa negative impact on the EIA procedure (Zubair, 2001) *Inefficient EIA implementing and monitoring techniques* Glasson, Therivel and Chadwick (2005) point out developing counties as less interest in EIA implementation,

Because of limited number of EIA institutions and technical capabilities. At a primary level, effective EIA implementation and monitoring depends on the influential level of political commitment, financial support, public trust and participation, convenient environmental policy framework, proper institutional arrangements.

E. Challenges in enforcing Laws for Environmental ImpactAssessment

There is a need for legal enforceability but there are some loopholes by which project proponents circumvent EIA. Some developers bypass the EIA procedures and implementation using these loopholes (Zubair, 2001). Sosovele (2011) conduct a research on how the EIA process has become effective with a focus on accountability in the implementation of the law. This study has compared the differences and effectiveness of the EIA procedure after the EIA laws are implemented.

F. Less transparent Environment Impact Assessment procedure

Zubair (2001) this study on EIA procedure in Sri Lanka, accordingly transparency in the EIA process is vested on the prepared EIA report, but in order to prepare a transparent EIA, accessible Environmental data should be available. Lack of environmental data creates a short circuit process.

3. Methodology

The main aim of this research is to identify the Challengesallied to the effectiveness of Environmental Impact Assessment in the Construction Industry of Sri Lanka. To understand the main aim a mixed method of quantitative and qualitative methods are highly appreciated. As a Quantitative approach Regression Analysis has been conducted and as an qualitative approach Content Analysis has been used because it gives a comprehensive picture about this study.

A. Conceptual Framework

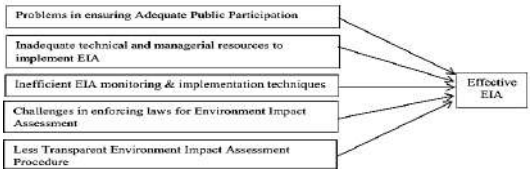

Figure 1: Conceptual Framework

Leu, Williams and Bark (1996) as mentioned 7 pilliars that an effective EIA should posses based on those pillars, challenges for an effective EIA has been pick out for this study. The above conceptual frame work reflects it in a scienticfic manner

B. Data Collection Methods

A structured questionnaire is distributed among 50Construction professionals and EIA consultants, and in order to gain an expert point of view about this study several open-end face to face interviews are conducted with 10 EIA consultants

C. Data Analysis Methods

Table 1: Data Analysis Methods

Objectives	Data Collection	Data Analysis Technique
To identify the impact of challenges that affects the Environmental Impact Assessment procedure, in the context of the Sri Lankan Construction Industry.	Questionnaire	Regression Analysis
To understand the effectiveness of the current EIA implementation mechanism in Sri Lanka	Questionnaire /Structured Interview	Content Analysis
To identify the strategies that should be taken in order to increase the effectiveness of the Environmental Impact Assessment	Structured Interview	Content Analysis

4. Results and Discussion

This chapter addresses and analyses the findings of this study conducted under the topic "Challenges allied to the effectiveness of the Environmental Impact Assessment in the Construction Industry of Sri Lanka". Accordingly, a questionnaire was distributed among 50 EIA consultants and Construction professionals with significant knowledge about Challenges that affect the current EIA implementation mechanism and the questionnaire is used to analyse the main objective of this study. Based on the below pie chart 40% of the respondents are Engineers, 26% of the respondents are EIA consultants, 22% of the respondents are Quantity surveyors, 8% of the respondents

are Architects and finally 4% of the respondents are Project Managers

regression analysis are tested and elaborated below.

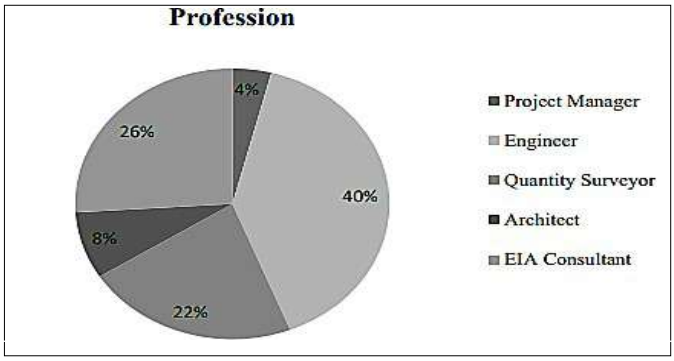

Figure 2: Profession Experience in the construction industry and building

A. Attainment of Main Objective

The main objective of this study is to identify the challenges that affect the Environmental Impact Assessment procedure, in the context of the Sri Lankan Construction Industry. in order to gain an general view about this challenges question was included in questionnaire to identify perception of respondents, out of 50 respondents 44% Strongly agrees and 42%agrees to the fact Problems in ensuring adequate public participation will affect effectiveness of the EIA , 34% Strongly agrees and 44% agrees to the Inadequate technical and managerial resources to implement EIA will affect effectiveness of the EIA, 24% Strongly agrees and 52% agrees to fact Inefficient EIA implementing and monitoring techniques will affect effectiveness of the EIA, 34% Strongly agrees and 30% agrees to the fact Challenges in enforcing laws for Environment Impact Assessment will affect effectiveness of the EIA and 30% Strongly agrees and 44% agrees s to the fact Less transparent Environmental Impact Assessment procedure will affect effectiveness of the EIA . These percentages clearly signify that the above challenges will cause an impact on the EIA procedure therefore in order to identify the level of impact a correlation analysis and a

B. Correlation Analysis

Correlation is tested to emphasize the relationship between the independent variable and the dependent variable.

The relationship between the dependent and independent variables illustrate using the Significance value (p) which,P< 0.05- the dependent variable has a relationship with the independent variable

P> 0.05- the dependent variable has no relationship with the independent variable projects involved gives an insight about the particular respondent ,Based on the questionnaire 30% the of the respondents are with 15-20 years of experience followed.

Table 2: Correlations

Correlations							
		AVGA	AVGB	AVGC	AVGD	AVGE	AVGF
AVGA	Pearson Correlation	1	.589**	.548**	.478**	.502**	-.526**
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
	N	50	50	50	50	50	50
AVGB	Pearson Correlation	.589**	1	.550**	.438**	.493**	-.554**
	Sig. (2-tailed)	0.000		0.000	0.001	0.000	0.000
	N	50	50	50	50	50	50
AVGC	Pearson Correlation	.548**	.550**	1	.553**	.281*	-.365**
	Sig. (2-tailed)	0.000	0.000		0.000	0.048	0.009
	N	50	50	50	50	50	50
AVGD	Pearson Correlation	.478**	.438**	.553**	1	.621**	-.398**
	Sig. (2-tailed)	0.000	0.001	0.000		0.000	0.004
	N	50	50	50	50	50	50
AVGE	Pearson Correlation	.502**	.493**	.281*	.621**	1	-.578**
	Sig. (2-tailed)	0.000	0.000	0.048	0.000		0.000
	N	50	50	50	50	50	50
AVGF	Pearson Correlation	-.526**	-.554**	-.365**	-.398**	-.578**	1
	Sig. (2-tailed)	0.000	0.000	0.009	0.004	0.000	
	N	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Where;

AVGA- Average of independent variable "Problems inensuring Adequate Public Participation"

AVGB- Average of independent variable "Inadequatetechnical and managerial resources to implement EIA" AVGC- Average of independent variable "Inefficient EIA monitoring and implementation techniques"

AVGD- Average of independent variable "Challenges inenforcing laws for Environment Impact Assessment" AVGE- Average of independent variable" LessTransparent Environment Impact Assessment Procedure"

AVGF- Average of dependent variable" Effectiveness ofEnvironmental Impact Assessment"

The above table represents the relationship between the independent variables (Problems in ensuring adequate public participation, Inadequate technical and managerial resources to implement EIA, Inefficient EIA monitoring and implementation techniques, Challenges in enforcing laws for Environmental Impact Assessment and Less transparent Environmental Impact Assessment procedure) and the dependent variable effectiveness of EIA. According to the above table, all the independent variables shows a negative and moderately strong relationship and a significant values less than 0.05 which means the alternative hypothesis cannot be rejected. Therefore it confirms that there is a relationship between the dependent variable and the independent variable.

C. Regression Analysis

Regression Analysis is conducted to identify the impactof the Challenges that are allied to the effectiveness of Environmental Impact Assessment in the Construction Industry of Sri Lanka. This makes all the independent variables comparable & standardized.

Table 3: Regression Analysis

Coefficients*						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	4.597	0.538		8.537	0.000
	AVGA	-0.183	0.151	-0.186	-1.210	0.233
	AVGB	-0.230	0.139	-0.254	-1.654	0.105
	AVGC	-0.033	0.095	-0.055	-0.346	0.731
	AVGD	0.056	0.124	0.075	0.454	0.652
	AVGE	-0.278	0.114	-0.391	-2.439	0.019
a. Dependent Variable: AVGF						

Considering the above table regression model can beexplained as follows.

$Y = \alpha - \beta 1x1 + \beta 2x2 + \beta 3x3 + \beta 4x4 + \beta 5x5 + Std.E$

Y=4.59-(AVGA*-0.183+AVGB*-0.230+AVGC*-0.033+AVGD*+0.56+AVGE*-0.278) + Std.E

The table shows a negative impact when considering the

Beta value for the first independent variable Problems in ensuring Adequate Public Participation as -0.183. More elaborately it states that effective Environmental Impact

The Beta value of inadequate technical and managerial resources to implement EIA is -0.230. More elaborately it states that effective Environmental Impact Assessment can be achieved by reducing challenges regarding inadequate technical and managerial resources to implement EIA by 23%. And also it shows a negative relationship.

The Beta value of Inefficient EIA monitoring and implementation techniques is -0.033. More elaborately it states that effective Environmental Impact Assessment can be achieved by reducing challenges regarding Inefficient EIA monitoring and implementation techniques by 0.03%. And also it shows a negative relationship.

The Beta value of Challenges in enforcing laws for Environment Impact Assessment is 0.056. More elaborately it states that effective Environmental Impact Assessment can be achieved by reducing Challenges in enforcing laws for Environment Impact Assessment by 0.03%. And it shows a positive relationship.

The Beta value of a less transparent EIA procedure is -

0.278. More elaborately it states that effective Environmental Impact Assessment can be achieved by reducing challenges regarding less transparent EIA procedure by 27.8%. And also it shows a negative relationship.

Generally considering above mention Numerical values it is clear that these mentioned challenges will cause a significant impact on the effectiveness of the Environmental Impact Assessment.

Content Analysis is used to analysis the second and third sub-objective which was to understand the effectiveness of the current EIA implementation mechanism in Sri Lanka and to identify the steps that should be taken in order to increase Effectiveness of the Environmental Impact Assessment.

D. Attainment of Sub-objective1.

The second sub-objective of this study is to understand the effectiveness of the current EIA implementation procedure in Sri Lanka. For that expert opinion from semi-structured interviews and some questions of the questionnaire were used to gather data. Before understanding the current effectiveness let's discuss about general overview on EIA implementation.

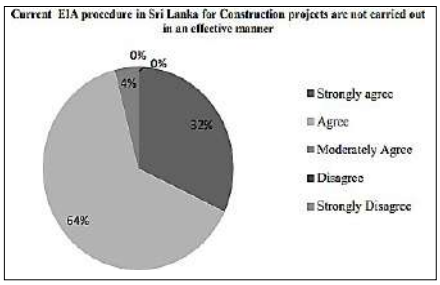

Figure 3: Respondents Perception

This is the perception of the respondents when it comes tothe statement in the questionnaire "Current EIA procedure in Sri Lanka for Construction projects are not carried out in an effective manner". The chart signifies that 32% strongly agree and 64% agree to this statement, thereforeit is clear that the current EIA mechanism is implemented with many shortcomings. In order to elaborate more on this several experts have discussed certain shortcoming of the current EIA implementation these shortcoming are discussed and analysis under the following section Policies and Acts related to EIA and the EIA process inSri Lanka

1. *Policies and Acts related to EIA*

Fauna and Flora Act; According to the EIA experts interviewed for this study EIA process under Fauna and Flora protection ordinance is the most effective procedure of all three Acts

but it is implemented very rarely but the all the instances where the Environmental Impact Assessment is conducted under section 9A of Fauna and Flora protection ordinance is up to a Satisfactory level butit is conducted very rarely therefore the expected effectiveness cannot achieved.

Coast Conservation Act; Considering the Experts' point ofview most of them implies that the EIA procedure under Coast Conservation Act has several shortcomings. For example under provisions of section 16, the EIA process is not mandatory it is but it is 35 discretionary therefore it will directly affect the transparency of the project and it is not effective and not very satisfactory.

National Environmental Act; Most EIA experts interviewed during this particular study emphasize several shortcomings of this act such as if a given project is rejected then the project proponent can appeal against the decision, but if a project is approved and the people who made comments are not satisfied with the decision, they (people who made comments) have no right of appeal therefore it is lopsided procedure implemented under the National Environment Act. The next shortcoming or the deficiency in the EIA process is that when a project is approved and then it is change during the construction phase there is no quick mechanism to undo the wrongdoing and to take necessary action against the project proponent. The third shortcoming that most EIA experts stated is that even though there is an EIA process and IEE Process there is no clear demarcation for what projects should procedure with an IEE process and what project should procedure with EIA, therefore there is scope of manipulation in order to bypass the public participation procedure and get an unscrupulous approval.

2. *EIA process in Sri Lanka*

Screening; Most of the expertise responded that the screening process conducted in Sri Lanka is satisfactory

Environmental Scoping; According to most EIA experts are missing areas related to the EIA which have not been identified and covered by the TOR (Terms of Reference). Even though the EIA consultant warns the client that certain aspects are not covered by the TOR, the client will suggest the EIA consultant to undergo the scoping process according to the TOR because by including more new items to the scoping process is an additional cost to the Client.

EIA Report Preparation; Most of the EIA Experts interviewed emphasize time duration allocated to prepare an EIA report is not sufficient. Basically the project proponents (client) will request to faster the report preparation process in order to get early approvals and start the construction phase this factor will also affect the standard of the EIA Report. Other than above mention shortcoming EIA experts interviewed mention several shortcomings such as Some EIA reports include irrelevant information confusing the reviewing bodies and the public and making it cumbersome, the translation to the Sinhala language from the English language is furthermore horrendous.

Public Participation & Evaluation of the Report; considering the responses to the questionnaire and theinterviews the current public participation is an ignored component. There are several NGOs and Environmentactivists who speak up against Environmental destruction but most of them involve only in some interested projects because it helps to increase their fame and the attention towards them. Even some projects Project Proponents (client) advice EIA consultants to ignore the Public Participation because it will create chaos during the planning stage.

Decision Making; According to most EIA experts this is a controversial area, considering government projects there is a significant influence to the CEA and the Project Approving Agency to approve the particular project at anycost, because most of the projects are funded by using International loans therefore the government will influence to prepare

necessary approvals quickly by giving less priority to the environment.

Compliance Monitoring; considering the responses via Semi-Structured interviews, this stage is the most ineffective and less likely implemented. Mainly because there is no proper implementing and monitoring procedure to check whether allocated mitigation measuresare implemented or not and the budget allocated for the monitoring process is not sufficient or the allocated budget is not used for the implementing or compliance monitoring.

A. Attainment of Sub-objective 2.

The next objective of this study is to identify the strategies that should be taken in order to increase the effectiveness of the Environmental Impact Assessment. These strategies are categorized under the following topics.

1. *Ensuring Adequate Public Participation;* to overcome these Difficulties interviewed experts mentioned several strategies such as Increase the accessibility of EIA reportsto the public, Involve the public during EIA decision making, Reviewing and implementation and compliance monitoring.
2. *Provision of adequate technical and managerial resources to implement EIA;* upgrade human resources outside the government, introducing regular EIA training programs for responsible EIA actors will upgrade the knowledge about EIA.
3. *Efficient EIA Implementing and Monitoring Techniques;*Allocating a considerable amount of the construction budget in order to implement compliance monitoring, implementing a formal EIA compliance monitoring program carried out by the core environmental agency and competent authorities, formal EIA compliance implementing and monitoring program carried out by the core environmental agency and competent authorities must be included to the NEA because it increase the formality of the Monitoring process.
4. *Enforcing laws for Environment Impact Assessment;* The NEA and the Coast Conservation Act must be amended to make it a more inclusive process and to make it a more efficient and effective process, there should be a clear demarcation between what projects needed an EIA and what projects needed an IEE, Then the Coast Conservation Act should be amalgamated with the National Environment Act but not to be mutually exclusive as it is in the present and Finally the right of appeal should be given to both parties.
5. *Transparent Environment Impact AssessmentProcedure;* EIA experts suggest by decreasing the third party involvement will increase the effectiveness of the EIA process, increase publicity of EIA decisions and results will increase public participation and the next strategy is to the standardized time allocated for the EIA procedure.

5. Conclusion

The main objective of this study is to identify the impact of the challenges that affect the effectiveness of the EIA procedure in the construction industry of Sri Lanka, the results of the regression analysis confirms that by reducing the mentioned challenges (Problems in ensuring Adequate Public Participation by 18%, Inadequate technical and managerial resources to implement EIA by 23%, reducing challenges regarding to Inefficient EIA monitoring and implementation techniques by 0.03%, Challenges in enforcing laws for Environment Impact Assessment by 0.056% and reducing challenges regarding to less transparent EIA procedure by 27.8%) will increase

The next objectiveof this study is to identify the effectiveness of the current EIA implementation mechanism in Sri Lanka, this includes the Acts and Policies that enforce EIA in Sri Lanka and EIA process implemented in Sri Lanka, according to the experts there are several loopholes in some Acts and Polices which have been discussed. but yetthese Acts and policies are sufficient to implement an effective EIA procedure.When it comes to the EIA process there are several shortcomings in each stage, therefore current EIA mechanism

implemented in Sri Lanka is questionable.

The final objective is to identify the strategies toovercome the five main challenges mention in this study, accordingly, some experts (EIA consultants) suggest certain strategies that should initiate in order to overcome these challenges. The data is gained through semi-structured interviews was analysed through content analysis.

6. Recommendation

The study covered five main challenges allied to the effectiveness of the Environmental Impact Assessment in the construction industry of Sri Lanka. Therefore the following recommendations will assist in enhancing the effectiveness of the EIA procedure. The first recommendation is to implement a Formal mechanism for appeals and dispute settlement related to EIA recommended to involve independent and competent review bodies in EIA programs and strategy will decentralize the power of the central Environmental Authority, the next recommendation is to Increase public participation throughout the EIA and also by increasing the awareness of the public to participate in the process at the initial stage. Regular EIA training Programs organized/coordinated by the main environmental establishments for responsible officials will increase the knowledge among EIA officials which will be effective during the monitoring and implementation process, by establishing an EIA tracking system and a centraldatabase for EIA reports will assist the monitoring stage. The next recommendation is to standardize the EIA procedure, by imposing a proper consultancy registration criteria and initiating annual excellence awards for good EIA practice by consultants and proponents will encourage the project proponents to implement an effective EIA. The considering the findings of this study the final and recommendation most important recommendation is to create a formal Implementation and monitoring mechanism by involving judicial agencies and EIA experts, because the monitoring mechanism is an important component of the EIA process which proves the effectiveness of the whole EIA process.Therefore these are some of the Recommendations suggested to overcome challenges allied to the effectiveness of the Environmental Impact Assessment in the construction industry of Sri Lanka.

Finally study is limited to five main challenges therefore recommended to identify more challenges other than above mentioned five. Identification of strategies to overcome the mentioned challenges is a sub objective of this study therefore the experts recommend to conduct a research mainly focusing on these strategies how they willaffect the effectiveness of the EIA procedure. SEA Strategic Environmental Assessment is implemented around the world and also in Sri Lanka especially for large-scale projects therefore it is recommended toconduct a study based on SEA implementation in Sri Lanka. Another recommendation is to consider a single development or an infrastructure project and evaluate the shortcomings of the EIA process implemented particular project using this study as a based article, which willassist to a deep evaluation about Environmental Impact Assessment.

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Acknowledgment

I would like to offer my sincere gratitude to my supervisor Lt Col (Rtd) TC Kathriarachchi for guiding methroughout the period of this study and the Faculty of Built Environment and Spatial Sciences of General Sir John Kotelawala Defence University for the inspiration and guidance to the betterment of this research.

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Analyse Factors Affecting the Delay in Building Construction Projects in Sri Lanka; Through the Interaction of the Project Team

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Abstract*: Constructions are undergoing with an unfavourable situation with their cost overruns due to the delay issues and are exposed into the risk because of the inappropriate identification and minimizing of the factors. Fulfilling this gap, the research has been undergone to analyse factors affecting the delay in building construction projects in Sri Lanka; through the interaction of the project team with an adequate understanding on the practical solutions for minimizing. The study has used a mixed approach of qualitative and quantitative techniques for the identification of factors, review of literature was undergone. To assess the factors affecting for delays, questionnaire was distributed among 40 professionals in Sri Lanka and with the analysis under the Relative Important Index (RII) and it was identified that client related factors, contractor related factors, consultant related factors and other related factors and assessment of the factors affecting to the building construction industry. The significant factors of building construction delays were identified as poor communication and coordination, delay in obtaining approvals from government regulated bodies and delays in subcontractor activities, inexpedient scheduling and project planning, inefficient contractor work and unexpected subsurface conditions and unforeseen circumstance. The study identified that contractor related category had the highest affect to the delays of construction industry in Sri Lanka. To identify the practical solutions for minimizing, interviews were conducted by selecting 10 professionals with more than 10 years of experience as the sample. Concerning more on the effective performance of the key stakeholders under a better management system is recommended in minimizing the arising delay problems which will help to ameliorate the performance of the industry.*

Keywords: *Delays, Building Construction, Sri Lanka*

1. Introduction

Delay is the number one challenge facing the construction industry (Cülfik et al., 2014). Delays happen in almost every construction project and it is regarded to be a recreating problem in the construction sector (Gardezi et al., 2014). It is undergone within an extremely common occurring factor affecting the complete of construction projects within the approved budget, time and cost achieving its quality specifications. Due to this uncertainty, most development construction projects are facing many problems in achieving the objectives with a successful completion by fulfilling the scope of the project (Sha et al., 2017).

Among those problems, the considerable uncertainty and risk in the building projects is higher than in other industries. Construction processes and methods are also subject to unprecedented events and conditions, in addition to the complicated and time-consuming designs. As a result, the construction sector has been facing considerable issues, and impact risk management has emerged as a leading issue (Gardezi et al., 2014).

Delay occurs that whenever a project is not completed by the agreed-upon delivery of a project due to factors involving the contractor,

client, client's consultant, or others. Delays are stealthy, resulting in time overrun and cost overruns, litigation, disputes, and complete project abandonment (Afshari et al., 2011).

Many building projects have been plagued by major issues, preventing them from being completed on time. Furthermore, when new tools, equipment, technology, and innovation become available, building projects get more challenging. Delays are frequently caused by inadequate project planning of numerous components (Haq et al., 2017). Main focus of this paper is to analyse factors affecting the delay in building construction projects in Sri Lanka; through the interaction of the project team.

2. Literature Review

There are numerous reasons for delays, as each building project seems to have its own unique characteristics and surroundings. Hence, many researchers have endeavoured to recognize the highly important factors in the delay of construction projects. For decades, researchers have done several studies on construction project delays, with researchers identifying various causes and combinations of factors that contribute to delays. The literature reviewed indicates different factor classifications (Muhwezi et al., 2014). In this study, time overrun factor group into four main categories of client-related factors, contractor-related factors, consultant-related factors and others-related factors.

A. Client related delay factors

Several studies have identified client related delay factors to cause schedule delays. As per Aladayleh, (2020); Arantes & Ferreira, (2020) both examined that suspension of work, owner delay in paying for finished work, nature of project tendering and awarding, impractical project duration, ineffective delay charges, and client involvement having greatest effects to delays.

According to State, (2019); Wang et al., (2018) both concluded that corruption tendencies, occasional work suspension due to cash flow limitations, and changes in material types and specifications throughout construction, of client in construction projects were ranked.

In separate study, Kesavan, (2015, 2017) both identified the factors of delay in progress payments, variation orders and changes of scope of work by owner during construction, delay throughout the decision-making process, suspension of work by client, delay throughout the decision-making process, slowness in certifying shop drawings and sample materials, delay in reviewing and approving design documents, poor coordination and communication, and problems among joint ownership of the as causes of delay during Sri Lankan construction process.

According to Gunduz et al., (2015); Sha et al., (2017) both conducted client inexperience in building projects, a lack of skilled representatives, and inaccurate information provided by the client during the project feasibility study are the factors that cause the most delays. Unclear and uncapable drawings, client inexperience in building projects, a lack of skilled representatives, and inaccurate information provided by the client during the project feasibility study are the factors that cause the most delays for the client and other stakeholders (Aziz & Abdel-Hakam, 2016).

B. Contractor related delay factors

Several studies have identified contractor related delay factors to cause schedule delays. In a separate study, Kesavan, (2015, 2017) both examined the factors of difficulties in project financing, conflicts in subcontractors schedules during project execution, conflicts among contractor and other stakeholders, delays in sub-contractors task, poor coordination and communication, supervision and rework due to mistakes throughout construction, inadequate project planning and scheduling, delays in site mobilization, implementation of unsuitable construction, insufficient contractor's work, sudden changes of subcontractors and poor qualification of the contractor's technical staff as effects of time overruns during construction process in Sri Lanka.

As per Muhwezi et al., (2014) observed the major factors on delays are improper

construction methods, inaccurate time and cost estimating, poor site management and supervision, inept project team, inadequate contractor experience, subcontractor turn-over unreliable subcontractor, and obsolete technology are all major contributors to this category of delay factors.

Alzara et al., (2016); Mydin et al., (2014) examined the contractor's related delay in construction projects poor contractor competence, delay in preparation of shop drawings and material samples inadequacy of contractor qualifications, construction errors and defective work were ranked highly.

There are a variety of other causes that might cause delays in the project, which can be classified into three categories:

- Materials
- Equipment
- Manpower

In separate study, Kesavan, (2015, 2017) both examined the factors of changes in material types and specifications during construction due to a shortage of construction materials on the market, late delivery of materials, damage to selected materials when they are sorely needed, delays in manufacturing unique building materials, and delayed procurement of materials for Sri Lankan construction projects are all indications of delays in material delivery.

Gunduz et al., (2015); Sha et al., (2017) both observed the factors that material related imported of construction materials and unreliable suppliers were critical.

In separate study, Kesavan, (2015, 2017) both examined the factors of equipment breakdowns on a frequently, a scarcity of equipment, lack of high-technology mechanical equipment, low equipment productivity and efficiency, and a lack of equipment operator experience were the causes of the equipment related delays.

According to Gunduz et al., (2015); Sha et al., (2017) both observed that shortage of equipment part, slow mobilization of equipment, unsuitable equipment, equipment allocation issue and equipment allocation problem were the major causes equipment related delays.

In a separate study, Kesavan, (2015, 2017) both concluded the factors of work permits for workers, labour shortages, low labour productivity, and personal conflicts among workers the highest impact in Sri Lankan context.

According to Gunduz et al., (2015); Sha et al., (2017) both using factors analysis conducted that slow labour mobilization, supply of labour, strike, absenteeism, and poor morale and motivation are the leading reasons of labour-related difficulties under contractor related section.

C. Consultant related delay factors

Several studies have identified consultant related delay factors to cause schedule delays. In separate study, Kesavan, (2015, 2017) both identified the factors of inadequate experience of the consultant in the construction project, discrepancies and faults in design documents, inadequate and unclear information in drawings, and poor communication and coordination with other parties as the main causes under the consultant related delay category.

As per Muhwezi et al., (2014); Sha et al., (2017) is concluded that delay in, inadequate site investigation, conflicts between consultants, insufficient estimation of initial contract duration, delays in obtaining interim payment certificates, delays in examining and approving design changes, delays in executing testing and inspection, contract clauses that are unfavourable, and an unclear definition of "Substantial Completion" had greatest impact for the time overruns.

As per the Alzara et al., (2016); Marzouk & El-Rasas, (2014) as inaccurate site investigation, quality assurance/control, a delay in progress payments, an incorrect project feasibility assessment, a delay in site delivery, a lack of skilled representatives, an inability for the contractor to finish ahead of schedule, and the owner suspending work examined that having greatest effects to consultant related delays.

According to J. Gardezi et al., (2013); Mydin et al., (2014) identified the causes of factors contract modifications, change orders,

slowness in decisions making, financial problem and lack of experience as key consultant related factors.

Gardezi et al., (2013) identified that design related delays inadequate data collection and survey prior to design, design changes made by the owner or his agent throughout construction, errors and delays in producing design specifications, design mistakes made by designers, lack of experience of design team in building projects, design engineer's misunderstanding of the owner's requirements improper usage of advanced engineering design software and unclear and insufficient details in drawings are factors that contribute to delays under consultant related category.

D. Other related delay factors

Several studies have identified other related delay factors to cause schedule delays. In separate study, Kesavan, (2015, 2017) both stated that as the major courses of external delays, according to the factors of effects of unexpected subsurface conditions and unforeseen ground conditions, delays in getting approvals from municipalities, traffic control and restriction at the job site, accident during building projects, delays in performing final inspection and certification by a third party, changes in government laws and regulations, delays in providing services from utilities, and weather condition effect on construction activities.

As per the Muhwezi et al., (2014); Sha et al., (2017) both identified that unexpected geological condition and regional stability, inflation/price fluctuations, neighbour issues, war, conflict, strike, riot, and the public enemy as key contributors to delays. According to Alzara et al., (2016); Mydin et al., (2014) both revealed that poor site conditions, delay in manufacturing building material, transportation delay a scarcity of materials on the market, tender system, a lack of tools and equipment on the market the most important factor in this category. In separate study, J. Gardezi et al., (2013); Muhwezi et al., (2014) both examined that global financial crisis, issues with neighbours, natural disasters, delay site clearance as key causes under this category. According to Muhwezi et al., (2014) identified that environmental and social factors, escalation of local material prices, unreliable suppliers, legal disputes among project participants, shortage of construction materials, delay in getting approvals from the local authority, ineffectual delay penalties, and poor communication between the parties as key causes as a delay. Rising raw material prices can significantly affect a construction project but they are beyond the client's and contractor's control. These external factors can lead to conflicts or disputes between the construction stakeholders. Moreover, increasing the production cost and duration (Olawale, 2002).

3. Methodology

The goal of this study is to discover out what are the causes of delays in building construction projects in Sri Lanka. To properly meet research objectives, the study used a mixed approach of qualitative and quantitative techniques. Using a mixed approach will enhance the reliability, quality, and accuracy of the findings of the study, rather than using a single method because of the capability to avoid the lapses that could occur due to use of a single technique either qualitatively or quantitatively separately (Amaratunga et al., 2002).

Literature review was used to identify the factors and qualitative and quantitative methods were followed using the questionnaire survey and interviews with the identified client, contractor, consultant and other related factors respectively. The outcomes of the questionnaire survey were subjected to the analysis techniques, relative important index analysis and content analysis.

Sample of 40 professionals was randomly selected to send the questionnaire. Out of the sample used, 35 number of respondents were responded with their responses and five were not responded. Considering the number of respondents as a percentage, 87.5% can be taken from the sample showing that it is sufficient for the analysis to confirm the

satisfactory representation of the research population.

Purposive sampling was used as the sampling technique to select the sample of 10 respondents form the professionals currently working construction industry in the Sri Lankan as the population of the interview. Selection was done based on their in the construction industry experience.

The following formula was used in analysing the severity of the factors using the RII analysis.

$$RII = \frac{\sum_{i=1}^{5} wixi}{A * \sum_{i=1}^{5} xi}$$

Equation 1: Relative Importance Index

Source: (Muhwezi et al., 2014)

Table 2 - Client related category

Factors	Code	Frequency					RII	Rank
		SA	A	N	D	SD		
Client Related Factors								
The owner issues change orders and changes the scope of work.	C1RF1	8	22	5			0.817143	2
Delay in progress payments	C1RF2	4	26	5			0.794286	3
Late in revising and approving design documents	C1RF3	12	18	4	1		0.834286	1
Tendering issues	C1RF4	5	23	7			0.788571	4

4. Analysis And Discussion

Relative Important Index techniques were used to determine the most significant causes of construction project delays in Sri Lanka with a view to performing quantitative analysis. Identification was done by prioritizing factors ranging from the highest to the lowest.

Further the analysis was evaluated with the group basis by giving a classification-based rating taking the average of each category separately. The questions used were Likert Scale questions and the data was obtained under five scale in according to the degree of the severity.

Table 1: Level of Agreement and allocated Weight

Level of agreement	Allocated weight
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Strongly disagree	1

wi = Weight allocated for the ith factor or strategy (i= 1, 2, 3, 4, 5)

xi = Number of respondents in each factor

A = Highest weight allocated (i.e. - 5 in this)

The client related factors have been relatively important with the cause of delay on building construction projects. With the RII analysis, the highest late in revising and approving design documentation was ranking first with RII value of 0.834. The most significant factor affecting construction delays is the need for design documents as a direction to the project, which acts as a permit for the contractor not to carry out construction without permission and not to waste money on unnecessary site works. The owner issues change orders and changes the scope of work was identified as the second important factor with RII value of 0.817. Frequent variation orders and changes of scope of work can extend the works on the site and affect the whole project schedule so that the project cannot be completed on time.

The analysis of the contractor related factors under the factors affecting for delays of building

Table 3- Contractor related category

Factors	Code	Frequency					RII	Rank
		SA	A	N	D	SD		
Contractor Related Factors								
Delays in the work of subcontractor	C2RF1	15	16	2	2		0.851429	1
During construction, supervision and rework are requied due to errors	C2RF2	8	22	5			0.817143	7
Project planning and scheduling are ineffective	C2RF3	10	23	2			0.845714	2
Difficulties in financing project	C2RF4	6	29				0.834286	4
Ineffective contractor's work	C2RF5	13	17	5			0.845714	2
Frequent change of sub-contractors	C2RF6	8	20	7			0.805714	8
The contractor's technical staff is poorly qualified	C2RF7	12	18	4	1		0.834286	4
Delay delivery and change in material	C2RF8	9	23	3			0.834286	4
Personal conflict and shortage of labours	C2RF9	5	21	9			0.777143	10
Breakdowns and shortage of Equipment	C2RF10	5	23	7			0.788571	9

construction projects. Delays in sub-contractor's work has obtained the highest rank with RII of 0.851. Project planning and scheduling are ineffective and ineffective contractor's work were identified as the second important factors. In addition, contractors' select the contractor's technical staff is poorly qualified as the lows contributing to delays on construction industry through all of the contractors' related factors and the consultants prefer the site mobilization delay as the minimum point among the factors. The quality of the subcontractor's work is highly dependent on speeding up construction, otherwise it could delay the construction project. Also, the contractor's inadequate work not only takes time but also costs more.

Table 4- Consultant related category

Factors	Code	Frequency					RII	Rank
		SA	A	N	D	SD		
Consultant Related Factors								
Major changes in the scope of work are being approved slowly	C3RF1	8	23	4			0.822857	1
Inadequate experience of consultant	C3RF2	7	22	3	2	1	0.782857	5
Errors and delays in the creation of design documents	C3RF3	8	17	5	4	1	0.754286	7
Drawings with unclear and insufficient details	C3RF4	13	12	8	2		0.805714	2
Inadequate data collection and surveying prior to design	C3RF5	10	15	8	2		0.788571	4
Use of advanced engineering design software is inefficient	C3RF6	12	11	9	2	1	0.777143	6
Delay in preparing interim payment certificates	C3RF7	13	12	9		1	0.805714	2

Considering the factors generating with the actions of the consultant, major changes in the scope of work are being approved slowly has obtained the first with RII value of 0.822. This issue directly affects the scope of work of the contractors, which affects the continuous performance according to the agreed contract. With that, the contractor may have to deal with delay problem. Non-performance with accordance with SBD 2 document and the time it takes to prepare interim payment certificates were identified as the second important factors. This has been identified as a serious issue affecting the cash flow of the contractor. When payment is delayed, the contractor will not be able to execute the work due to improper flow of cashflow, which will cause severe delays to the contractor.

Table 5: Other related category

Factors	Code	Frequency					RII	Rank
		SA	A	N	D	SD		
Client related factors affected to the delay on building construction projects	DV1	7	25	3			0.822857	2
Contractor related factors affected to delay on building construction projects	DV2	10	21	4			0.834286	1
Consultant related factors affected to delay on building construction projects	DV3	12	16	4	3		0.811429	4
Other related factors affected to delay on building construction projects	DV4	10	18	7			0.817143	3

Table 6: Category based rank

Factors	Code	Frequency					RII	Rank
		SA	A	N	D	SD		
Other Related Factors								
Unexpected subsurface conditions and unforeseen circumstance	ORF1	13	17	5			0.845714	3
Delay in obtaining approvals from government regulated bodies	ORF2	18	12	2	3		0.857143	2
Weather condition effect on construction activities	ORF3	14	13	8			0.834286	4
Traffic control and restriction at job site	ORF4	3	21	9	2		0.742857	7
Accident during construction	ORF5	5	18	8	4		0.737143	8
Changes in government regulations and laws	ORF6	4	26	5			0.794286	6
Conflicts with other parties	ORF7	9	22	4			0.828571	5
Poor communication and coordination	ORF8	14	20	1			0.874286	1

There are eight other related factors that contributed to the delays in grading based on relative important index. The main impact on construction projects is poor communication and coordination. Effective communication and coordination are very important to the success of good team activities that can indirectly give success to the construction project. The second and third factors are the delay in obtaining approval from government regulatory agencies and unforeseen ground conditions and unforeseen circumstances. Substantial surface and ground conditions can be considered as essential other related factor influencing the delay. If the ground condition is unstable, it will be impossible to start the foundation work as there may be settlements in the future. Furthermore, construction activities can be influenced due to weather impact protection considerations such as floods.

To analyse the impact of the factors categorically, category-based rank was obtained by taking an average RII of the factors under each category. With the analysis it was identified that the category on contractor related factors was obtain the first rank with an RII of 0.811. Therefore, as a whole, it can be summarized that the contractor related factors have influenced severely on the delay of building construction projects compared to the other categories. Further, the category of client related factors was ranked second place with RII of 0.823. Client has become of the major source of causing delays mainly due to the variations due to changing requirements, payments delays, and lack of experience within the industry on the procedures to be undertaken.

5. Conclusion

The primary objective of the research was to assess the severity of the factors affecting for delays of building construction projects in Sri Lanka with an adequate understanding of practical solutions to minimize delays as a general objective of research. From the literature review, the theoretical aspects and the past research findings under the state of construction industry in the present context, standards of construction industry in developing countries and Sri Lanka, prevailing procurement systems on procuring construction contracts, factors to be considered under the traditional procurement, construction time and time overruns, impact of delay issues, factors affecting for the delays of the client related, contractor related consultant related and other related, minimizing the impact of delay and identification of the research gap were explained.

In order to bridge the gap identified by solving the research problem, standard techniques of data collection, especially literature survey, questionnaire survey and interviews were used. A literature survey was conducted to identify factors contributing to the delay. Then a descriptive questionnaire survey was then conducted to assess the identified factors for delays in building construction projects. Finally,

a semi-structural interview was conducted to determine the most relevant practical solutions to mitigate the highly influential factors identified in the construction sector in Sri Lanka.

6. Recommendations

To minimize delay problems faced by building construction projects, the primary stakeholders have the major responsibility and following factors can be recommended as guidelines towards the key stakeholders as the guidelines in minimizing the affecting factors for the delays.

A. Towards the client

- Minimize changes, variations during construction to avoid or minimize delays.
- Pay contractors progress payments on time, which weakens the contractor's ability to finance their work.
- Speed up design review and approval.
- Amending bidding documents including clauses, airing, drawing and specifications will be useful to avoid disputes within the contract.
- The qualifications of the bidders to execute the project should be considered strictly without relying on the lowest bidder to execute the project.

B. Towards the contractor

- Improving the knowledge and skills of the technical staff.
- Manage financial resources using progress payments and plan cash flow.
- Planning and scheduling work from the beginning of the project and during the work.
- Improve site management and monitoring to ensure timely completion of work.

C. Towards the consultant

- Avoid delaying the review and approval of design documents.
- Build the skills and knowledge of the technical staff.
- Improving coordination and communication between parties.

The project performance is enhanced by the key stakeholders recognizing their responsibilities and their proper integration, enabling the project to properly integrate with external stakeholders even in the external environment. Furthermore, the parties should always be concerned about the other parties when there is a delay issue to prevent or minimize the impact that the steps, they have taken to reduce the risk may adversely affect the other party. Therefore, it is very important to balance the responsibilities between the parties to minimize the problems of delays in building construction projects. Cooperation between parties with adequate mutual understanding will improve project perspectives while minimizing the financial instability faced by the parties and will also be important for improving the economic condition of the Sri Lanka.

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Abbreviations and Specific Symbols

RII - Relative Important Index

Acknowledgment

I would like to thank to Dr. Sanjaya Jayasuriya and Ms. Nethmi Kawmadi, for their valuable supervision throughout my research from beginning to end and the construction professionals for their immense support given for me by contributing their valuable time and opinions by participating for the interviews.

Finally, I would like to give my heartiest gratitude for Department of Quantity Surveying Faculty of Built Environment and Spatial Sciences, General Sir John Kotelawala Defence University.

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Foreign funding construction projects in Sri Lanka: review challenges on Technology Transfer with the local stakeholders

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Abstract: *Technology is an integral part of construction and domain factor with cost. Most of modern materials, plant, equipment and services are innovated by developed countries and their aim is to transfer them by one way through funding facilities to other countries. Sri Lankan government pleases to obtain foreign funded in order to develop most of infrastructure and buildings in order to cater for economic growth and living standard which would answer somewhat on socio-economic issues in the present conditions. One of the positive outcomes on foreign funding is the technology transfer. The study aims to define the potential impact on that and assessing them could cater for best decision to do in future endurances. The direct population was stakeholders who are in construction projects and selected sampling (experts) was by snowball technique. The Quantitative and qualitative methods were applied for data collection in the mode of questionnaire and semi-structured interview. The SPSS computer software applied in order to check validation of data and to give reliability of findings. The content analysis had been used for synthesis evaluation.*

The literature review shows positive effects as well as potential negative effects on foreign technology transfer on other countries as well. The outcome of findings reveal that arrival of modern goods, latest methods of execution, sophisticated computer software modeling and simulating, innovative management procedures as positive impact. The lack of development in supported industry (example, e-commerce in legal trade) and upgrading is required on education on theory and training which derive a negative impact on technology transfer. Finally, the recommendations have been put forward to minimize the potential negative impact areas and identify more opportunities cost on positive impact areas on stakeholders' future projects.

Keywords: *Technology Transfer, impact assessment, economy growth, foreign funding, BIM*

1. Introduction

The construction is one of the most important sectors of the economy in any country which creates employments, adding fixed assets in the like of new buildings and infrastructure projects (Khaertdinova, Maliashova and Gadelshina, 2021) which largely depend on investment activities. A developing countries can receive foreign investment through with the basis of aid/grant or borrowing funds in order to enhance socio-economic of the particular society (Golini and Landoni, 2014). Other than this Ijirshar, Godoo and Joseph (2016) shown that construction projects through foreign involvement would facilitate not only a financial assistance but also technical assistance to the local construction team including training, good project management and decision making techniques as well.

Araujo, Alenc, and Mota (2017) stated that foreign finding projects have several unique and uncontroversial features, such as the uniqueness and multidisciplinary nature of the goods and services provided, temporary nature of the undertakings, long life cycles, cost and

quality restrictions, adherence to project management standards, use of advanced tools and techniques, involvement of several stakeholders, provision of community services, cultural differences, and resource scarcity are highlighted as significant circumstance.

With beginning of post-war period, the government of Sri Lanka had planned to proceed construction revolution with the help of foreign donors by US $ 1.5 – 2 billion a year on road and rail development, power production, port facilities, and water and sanitation in order to achieve a per capita income of US $ 4,000 by 2016 and reduce poverty and unemployment (Delgoda, 2014). Currently, the contribution of foreign contractors is very high in Sri Lanka. With this situation the process of technology transfer can be increased, and it causes to increase the potential impacts that can happen through the foreign funded projects.

Accordingly, this paper focuses on: (1) discuss how technology transfer on foreign funded projects in developing countries and impacts to the society; (2) identify level of both positive and negative impact on Sri Lankan construction industry and how effect to the stakeholders; and (3) propose suggestions on how and what mitigation action on negative impact and which positive impact would enhance on future funded projects to gain for stakeholders. Having said that this research helps to influential stakeholders to address correctly on decision making when foreign funding project in Sri Lanka.

2. Literature Review

According to Hobbes (2014) and Ika (2015), International Development projects have to facilitate economic growth and poverty reduction through not-for-profit, humanitarian, and socioeconomic objectives. Amarasinghe and Rebert (2018) highlighted that foreign finance is provided to Sri Lanka through traditional donors, non-traditional donors, quasi-governmental organizations (export credit agencies), and sovereign bond sales. The European Union, the USA, Japan, and international development banks are the traditional donors while the donors that have recently become global financial powers are the non-traditional donors. The literature review has been carried out under the traditional donor funded projects. According to the selected past research documents, the following significant criteria were chosen for further studies.

A. Technology Transfer

Technology Transfer can define as the most valuable concept among world to develop the socio-economic states of a country. Technology can transfer through various ways, among countries, among organizations and more. Luna (2012) defined Technology Transfer as "process of movement of technology from one entity to another" The Technology Transfer process is used by an organization to develop organization's technology and other related capabilities with the productivity economic concept.

B. Technology Transfer and Construction Industry

In order for a technological transfer to be very successful in construction, certain criteria must be met. Specialists have introduced products (Industrial House Building solution by Uusitalo and Lavikka, 2020), processes, and knowledge as the basic scientific criteria to be completed (Rameezdeen, Menah and Amaratunga, 2005). In addition, people and culture have recently been introduced as another criterion (Chatterji, 2005). The question that arises here is whether these criteria can be met in the construction industry. Takim, Nawawi and Omar (2015) identified number of barriers to implement on technology transfer as cultural differences, language barriers, social valves, and different objectives.

C. The Technologies that transfer through the Construction Technology Transfer

Construction technology is one of the fastest growing and developing technology in the

world today. Overseas contractors supported in spreading this technology vastly. Globalization and innovation are two mediums that can have a major impact on this rapid growth. Because of this, a new update of technology can be seen tomorrow. According to Anderson and Schaan (2001), construction technology can be discussed in five parts. These same technologies are also being exchanged to some extent through foreign contractors. Therefore, construction technologies exchanged through foreign contractors can be shared in the same way.

In terms of Communication related construction Technology Transfer, this category includes technologies such as emails, digital photography for progress reporting, office to site video links, company computer network related technologies (Anderson and Schaan, 2001) The use of such technology will greatly benefit the construction industry as well as minimize unnecessary project costs. Due to the current corona disaster, these technologies will greatly help to reduce human consumption and keep the project going as usual.

On-site Plant and Equipment related construction Technology Transfer includes such as laser guided equipment, automated systems and programmable machines, Global Positioning Systems related technologies (Anderson and Schaan, 2001). In the case of this, these are used for survey related work (setting out), levelling purposes. Advantages of these technologies include increased productivity, improved safety, shorter workweeks for labour and as disadvantages include possibility to workers becoming slaves to automated machines, human error in the management of these technologies will somehow endanger civilization.

In terms of Material related Technology Transfer, this category includes using high performance concrete, composite materials, recycled plastic components related technologies (Anderson and Schaan, 2001). High performance concrete refers to the types of concrete that are manufactured to achieve high performance through strength or other desired properties. In the case of composite material, for example, fiber reinforced polymer. Advanced systems related Technology Transfer includes remote sensing and monitoring systems, pre-assembled systems, deconstruction and reuse systems (Anderson and Schaan, 2001). The remote sensing and monitoring systems include such as real time safety monitoring systems, laser scanning systems, and drone technology. In the case of pre-assembled systems, this refers to the design of a system outside the construction project site, bringing it to the project site and assembling and using it (Anderson and Schaan, 2001). Various systems like formwork (Muhammad, 2020) and concrete batching plants can be introduced for this.

Design related Technology Transfer includes such as computer aided designs, modelling and simulation technologies, electronic exchange of computer aided design files (Anderson and Schaan, 2001). Computer aided designs are the use of computer systems to design, modify, analyse, and optimize a design. In terms of modelling and simulating related technologies, modelling is called "the process of producing a representation of the construction and the working of some system of interest" and simulating is called "imitation of the operation of a model of the system". The other type of technology is electronic exchange of computer aided design files. Those exchanging technologies can take as feature recognition tool, non-Parametric modelling method.

D. Foreign Contractors' Construction Technology Transfer on Sri Lankan Construction Industry

Sri Lankan contractors' weaknesses and impact of globalization can take as the most influenceable aspects for foreign contactors' technology transfer. Sri Lanka is a small island surrounded by the Indian Ocean and has a population of around 22 million. Sri Lanka annually allocates more than Rs. 100 billion to the construction sector. Contractors are a major contributor to the Sri Lankan construction industry. Sri Lanka currently has main

Contractors ranging from CS2 to C9 and the number of contractors in all sectors is over two thousand five hundred. Oke, Aghimien and Adedoyin (2018) say there is a small amount of opportunity and strength for local contractors in developing countries, but many threats and vulnerabilities exist compared to developed countries. Their weaknesses include poor technology applications, poor research and development, low financial and organizational capabilities, and inexperienced expertise. Their threats include low technical innovations and unfavorable government policies. Such threats and vulnerabilities are common to Sri Lanka as well as a barrier to large-scale construction as well as the development of their companies. This situation can only be expected to increase due to the volatile economic situation and political instability in the country.

Globalization has been a hot topic not only in recent times but also in the recent past. Yeates (2002) states that globalization is "the term that has been given to a range of economic, technological, cultural and political forces and processes that are said to have collectively produced the characteristic conditions of contemporary life". Over time, the needs and requirements of each human division became more complex and needed to outperform the other. Due to the complexity of these projects for developing countries, the problematic conditions prevailing within the country and the weaknesses of the local contractors mentioned above, foreign contractors have to be imported to carry out these constructions.

E. Potential positive effects of construction technology transfer through foreign contractors on Sri Lankan construction industry

According to Iroegbu (2017), technology transfer to developing countries can enhance the manufacturing process and increase productivity and efficiency in the country. Construction industry is a major part of a country and that means if there is an overall productivity improvement of a country it directly means that there is also a productivity improvement in their construction industry. According to Piva (2003), Technology catching-up is a another one of positive impact of Technology Transfer which helps to enter to the large-scale construction projects within relevant areas. Other one can take as it gives ability to export construction services to overseas countries (Bandara, 2014). This can be confirmed by the fact that Sri Lankan contractors are currently exporting their services to foreign countries. Domestic contractors have been providing their services in states such as the Maldives and Qatar. Next one is that is causes to improve the status of domestic construction firms. Devapriya and Ganesan (2002) states that construction Technology Transfer helps to improve the construction firm's future business. If it can improve the future businesses, then it automatically develops the status of construction firms. Those can take as the potential positive impacts of Technology Transfer on developing countries through the foreign contractors.

F. Potential negative effects of construction technology transfer through foreign contractors on Sri Lankan construction industry

Technology transfer can have a positive as well as a negative impact on the Sri Lankan construction industry. There is clear evidence that there are many Indian and Chinese contractors in Sri Lanka today and that they have a large manpower and machineries (Perera *et al.*, 2021). There is some connection between them and the local construction technology exchange because they bring new construction technologies to the country. Thus, they contribute many local constructions and their attendance in local sector is high. They also intervene in projects where local contractors can participate alone. This reduces the number of projects that local contractors must participate and creates a lot of competition among them for other remaining small projects at present there is a certain

decline in the skills of the people employed in the construction industry.

Technological acquisitions through the exchange of technology make it possible to overcome the situation. With the convenience of technology the need for human labour will drop to a very low level. Furthermore, there may be some tendency in the future, for job losses in the construction industry due to the transfer of construction technology. The transfer of technology in the construction industry can have a negative impact on the composition of jobs as well as the wages of those employed (Asia and Pacific, 2018).

Currently, robotic technology is increasingly being used for manual labour, and the use of multifunctional automation machines is gaining momentum Inequality in income distribution is a major problem in many developing countries today (Dabla-norris and Kochhar, 2015). This disparity in revenue distribution through technology transfer across a particular sector may increase in the future (Muzammil *et al.*, 2018). This is like the situation in the construction industry as a whole. The salaries of people who can handle new construction technologies have the potential to skyrocket, while the salaries of other relief workers could be drastically reduced. As a result, there is a risk of revenue sharing through the technology transfer associated with the construction industry.

Finally past research represented that construction technology transfer as a key benefit can gain through the foreign counterparts and this investigation investigated about the potential impacts that can happen through them.

3. Research Methodology

The aim of this paper was to conduct an in-depth study on consequence of foreign funding projects into the local construction industry (primary stakeholders) including secondary stakeholders who are in associated fields. The required information had to be obtained from professionals who had knowledge and experience on direct or supported on foreign funded projects. Bricki and Green (2007) found that the qualitative research approach is best for collecting opinions and facts from people based on their experience and behavior. However, this research design with mix approach both with qualitative and quantitative method. In order to identify the level of degree of the impact a questionnaire was distributed by using the stratified sampling technique to choose the sample for detailed questionnaire and the purposive sampling technique was used to obtain the semi-structured interview-related samples. The data obtained from the detailed questionnaire were analysed using a variety of techniques. At first step, the alignment of the effects of the data had been analyzed using the Relative Importance Index (RII) methodology and the analysis of Yes / No type problems using percentages. Secondly, use the SPSS software and results were represented through the tables and Pie charts. Finally, use content analysis for analyse the interviews outcome and listed and highlighted for applicable audience reference.

4. Result and Discussion

Below analyses flow according to the data gathered through the detailed questionnaire. Planned samples from professionals were: Ten Project Managers; Twenty Site Engineers; Ten Quantity Surveyors; and only five Architects and this brings the total number of respondents to forty-five. But forty-two questionnaires were received before the due date and the remaining three were not received by the researcher. Examining the forty-two questionnaires collected, one of them was incomplete.

Reliability Statistics

Cronbach's Alpha	N of Items
.819	21

Figure.1: Reliability Statistics

According to SPSS software, Cronbach's Alpha value is 0.819.Iit proved that internal consistency is good, and the research tool is reliable and will give credible results.

Based on questionnaire, the following technological factors were identified and listed as per prioritization and highly impactable construction technologies which can come to Sri Lanka through foreign contractors.

Table 1: RII of Construction Technologies

	CODE	RII
On-Site Plant and Equipment related construction Technology Transfer		
Laser guided equipment related technologies	ON1	0.6634
Automated systems and Programmable machines related Technologies	ON2	0.8975
Global positioning systems related technologies	ON3	0.6292
Advanced Systems related construction Technology Transfer		
Remote sensing and monitoring systems related technologies	AS1	0.7463
Deconstruction and Reuse systems related technologies	AS2	0.6146
Pre-assembled systems related technologies	AS3	0.6000
Design related construction Technology Transfer		
Computer Aided Design related technologies	DT1	0.8487
Modelling and simulating related technologies	DT2	0.9414
Electronic exchange of CAD files related technologies	DT3	0.6780
Communication related construction Technology Transfer		
E-mail related technologies	CT1	0.5365
Digital photography for progress reporting related technologies	CT2	0.5902
Office-to-site video links related technologies	CT3	0.6634
Company computer network related technologies	CT4	0.5170
Material and Systems related construction Technology Transfer		
High performance concrete related technologies	MS1	0.7024
Composite materials related technologies	MS2	0.5902
Recycled plastic components related technologies	MS3	0.5024

Average: $\frac{\sum_{i=0}^{n} Xi}{n}$

Equation 1: Average Equation

Source: (Kar, 2010)

$\sum_{i=0}^{n} Xi$ = X1 + X2 + X3 + … + Xn

n = Total number of terms

Average of RII $= \frac{RII1 + RII2 + ...+ RII16}{16}$

= 0.6701

The table above shows the potential impact of technologies that can be transferred from foreign contractors into Sri Lanka based on data obtained from the knowledge, experience, and vision of construction professionals. Most impactable technologies are ranked through the RII values of each technologies and only selected the technologies had RII value more than average RII value, as the highly impactable technologies Most impactable technology can take as the Modelling and simulating related Technologies and second one is the Automated systems and Programmable machines related Technologies and others are Computer Aided Design related technologies, Remote sensing and monitoring systems related technologies, High performance concrete related

technologies, electronic exchange of CAD files related technologies respectively.

The content analyses were conducted, according to the data gathered through the semi structured interviews. There were three categories of stakeholders selected as: project owners; project advisors including design and cost consultants; and contractors which was interviewed three professionals from each group.

The influential stakeholders are the project owners and according to their primary data collection the following results were generated. All most all foreign funded projects were imposed with none negotiated provisions and backwardly benefited to them, i.e. materials are to be purchased from same country; management teams and heavy equipment from same party as well as forcing to appoint a principal contractor. All interviewees satisfied on technology transfer received to the country in their level and appreciate about receiving of modern materials, plant and equipment. Their special concern given that losing of tax component on imported materials and equipment due to granting of tax concessions as per agreed provisions in the building contract which can be treated as negative impact to the local industry. Further added that foreign contractors tend to import excess quantities on materials and equipment through tax concessions for their other projects. The next negative impact was that rejection of imported materials and equipment due to local designer's comment in order to maintain the Sri Lankan codes and standards which becoming waste and uneconomical to return to the originate place.

The outcome related to second category was local consultants and they were very pleased about participation to foreign funding projects because they would able to receive latest modern technology applications where rich countries to apply at present time in order to enhancing modern knowledge during same consultation application. They confirmed that latest project delivery approach by on Building Information Model (BIM) based strategy which serve long term value of asset information from earliest concept to demolition during a project life cycle. As per their view this application able to alignment with client asset management strategy which serve about long range business goals and further said that information is digitalizing by computer base automated software application and arrange common data platform to share and use by authorized stakeholders and generating data and handling by non-proprietary data server. They were keen on adaptation to the BIM project delivery method as individual parties' involvement through their own sophisticated computer application (ex. Architect by 3D model AutoCAD design; engineers by Revit; and cost consultant to apply by CostX and the like).

The interviewees who were from contractors' party also given positive comments on participation of foreign funded projects. Their main concern was how to handle the procurement (bidding) practices through e-commerce as demanded by the project owners. One interviewee was estimating manager from reputed construction organization and given his experience on 'e-practicing' on bidding with his team and express that main barrier to adopt to the system was lack of training on his system (combing design information to the value calculation by way of sophisticated computer software packages). Second interviewee was Contractor's project manager and informed that most of project administration was under the prolog computerized system and occurred to adopt it sooner to continue progress of works. And also, modern developed building components were part of the work to execute and special training was demanded by the service provider from the funded country and therefore special programme to adopt selected technical staff in order to educate them. Another point was that building services operational manual was not in common language and translator was appointed to cater the situation. Thirdly, interviewed the manager on purchasing department on another construction organization and given his experience on his department contribution on foreign funded project in Maldives where project execution was by Sri Lankan contractor. Solution taken to that project was an adopting

by ERP (Enterprise Resource Planning) system by way of procurement of materials, goods, plant and equipment. He pointed out that electronic application is not fully supported in legal principles currently exist and authentication of transaction is jape dice from unauthorized parties.

In the industry now right time is to transfer gained their knowledge to local projects in Sri Lankan context. All contractors' representatives raised that allowing capital on adopting those system are costly and government has to involve on policy decision and action plan to implement on it.

According to experts' given findings, there were significant suggestions to improve transferring of technology to the country and also highlighted importance about how to reduce those negative effect as well to address in this report.

5. Conclusion and Recommendations

The aim of this paper was to identify construction technologies that have the greatest impact on the Sri Lankan construction industry through possible foreign contractors' technology transfer through participants. In addition, it explores the potential positive and negative effects of technology transfer on local construction industry through one of sub-objective and explores possible ways of mitigating the potential negative impact of technology transfer on future Sri Lankan construction industry.

Conclusion was set out based on recommendations given through the industry experts that can be described as follows. The participated local construction organizations were gained extensive benefits through modernly developed materials on building constructions (mainly in finishes and building services plant and equipment). It facilitates to identify environmental friendly and cost benefited goods based on life cycle cost application rather than using traditional goods on decays. Challenges were on: special training sessions were on technical staff to carry out maintenance of permanent system; appointment of language translators to prepare operational and maintenance manual including other reports; adopting electronic base bidding process; application of BIM practices with new software programmes. There are negative impact create as well: monopoly of trading where only few contractor's would benefited new system and not distributing to the other local competitors; the cost of spare parts would be costly on future due to the fixing of special system; shutdown period can occur at any time and overhauling events to consider on maintenance; construction organization to spend additional capital cost to adopt new systems to the existing process; maintain on software license in long run basis. There are many opportunities creates in the field of computer software programmes and need more training centers to facilitate the requirement. Specially, the development of legal principles on e-commerce is to a prime action to be taken.

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Sustainable Tourism in Hikkaduwa; Evaluations of Sustainability Parameters & Design Recommendations

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Abstract*: This research intends to identify the factors that influence tourism industry of Hikkaduwa coastal area and to give an overall architectural guideline to implement resulting in sustainable tourism. At present, rapid and unsustainable development of Hikkaduwa area have caused different kinds of environmental, economic and social issues. Many of those cases have been identified and studied on coastal tourism, sustainable parameters and existing regulations that related to architectural or urban planning to give out solutions. Based on these studies, a case study was done for identifying the special characteristics of Hikkaduwa for modifying and adjusting the parameters that are fitting for Hikkaduwa. While following these parameters, the study has proposed a suitable design guideline for overall Hikkaduwa study area. These proposed parameters and guidelines are supportive to the existing regulations and these architectural solutions have been implementing the criteria for sustainable development automatically. Therefore, the study has been given proper contribution for achieving the sustainable development and creating a sustainable tourism city.*

Keywords: *Sustainable Development, Design Guidelines and Parameters, Coastal Tourism*

1. Introduction

Inheriting a tropical climate and accessing the glamorous beach front and coral reefs, Hikkaduwa is known as one of the most famous tourist destinations of Sri Lanka. Yet, the Urban Development Authority (2019) states that this tempting destination has now dropped even below Rumassala and Unawatuna when compared. Through observations, one dominant reason for this devolution has been noticed as the development of its built environment being abysmally out of order and control.

Tourism industry has been identified as one of the best foreign income sectors in the world with 83% of the world's largest employment generating industry and the world's fastest growing business (Cossio, 2016). It is a globally accepted sustainable development process. Therefore, the World Tourism Council's report (1993) states that protection of the environment is a moral responsibility of the tourism industry.

Yet at present any parameters of sustainable tourism industry adopted by foreign nations to overcome the impact of collapsing tourism cannot be embraced as it is to Hikkaduwa city whose context is much disparate to the contexts of other regions. Hence, it is evident that a fresh set of parameters have to be developed within the context of Hikkaduwa, which will subsequently lead to sustainable tourism industry growth in the area. Thus, the major motivation of this study is to evaluate the collapse in the tourism industry of Hikkaduwa city and eventually to introduce appropriate guidelines and convenient recommendations in order to flourish a sustainable tourism industry within the Hikkaduwa coral city.

A. Problem identified

Due to the rapid development with tourism, Hikkaduwa has grown without any development plans causing degradation of coral reefs, disruption of coastal water high-quality, rush congestion and excessive exploitation of ecological benefits (Hoon, 1997).

Therefore, the lengthy-time period survival and excellent of such assets is threatened through declining tourism in Hikkaduwa area. Furthermore, buildings have been constructed with insufficient street allocation (Ministry of Sustainable Development, 2018) and it has been noted that unplanned boom of Hikkaduwa has caused unsuitable coordination and discipline where foreign travellers are affected with infected seashores, traffic noise and many more severe issues in the region. Thus, at present Hikkaduwa suffers from over improvement and useful resource degradation. The problem identified was even though a number of activities have been prescribed to triumph over these challenges, only much little has been performed. Because of these issues and cases this research will fill in the gap by finding the solutions/methods with appropriate parameters.

B. Need of study

Tourists who come to Sri Lanka mainly attracts to the coastal region and experience sea foods, beach huts, beach parties, scuba diving, snorkelling, sun bathing and relaxation. For tourist satisfactions, 5 crucial parameters have been identified as beach type, safety, facilities, water quality, litter and scenery.

Therefore, this research tries to emphasize the need of sustainable tourism development to Hikkaduwa under major sections of social, ecological and economic significance. Hence ultimately this will aid with introducing appropriate design guidelines and recommendations that will assist urban planning and future development of the city.

C. Research aim & objectives

The aim of this research is to evaluate and identify parameters of sustainable tourism and assist the applicability for Hikkaduwa while proposing design guidelines to make Hikkaduwa a sustainable tourist city.

The aim will be fulfilled by following objectives,

- To understand the concept of sustainable tourism and its application in Sri Lanka and Hikkaduwa area
- To evaluate and identify parameters of sustainable tourism in accord with local guidelines
- To assess application and to propose guidelines for sustainable tourism to Hikkaduwa

D. Scope & limitations

Though Sri Lanka is home to many coastal cities with tourism, the scope of the study only Hikkaduwa city with recreational tourism is selected within the costal belt area and surrounding. Uniqueness of each beach and time allocated are ministrations to the study.

E. Literature review

Literature review focus on main two areas sustainable tourism and design guidelines. The first review on main ideas and criteria of sustainable tourism. And second review on what and how the design guidelines implementing the costal tourism.

F. Tourism industry at Hikkaduwa

Beach tourism or costal tourism defined as 'a travel for recreational, leisure or business purposes specifically on beaches. The tourists who come they like sea breeze and salt water. They want a clear blue vision of the ocean' (Cano and Prentice, 1998). And according to Jentoft and Knol (2014), today the Coastal areas are still the main tourist destinations.

Hikkaduwa is placed in the Galle District, 95km south of the capital of Colombo - emerging as one of the tourist destinations. It is one of the main vacationer destinations in Sri Lanka with appealing seaside and coral reefs. It affords completely unique underwater surroundings

within the presence of coral reefs, aquatic creatures and marine flora. The shallow ocean ground within the coral reef is very stunning with diverse shapes in the backdrop of underwater plants and aquatic organisms (Rajasuriya, 1995). he natural beauty of Hikkaduwa makes it an ideal place for nature lovers including coral for snorkelers, waves for surfers and white pristine beaches for those who wants to enjoy the sun and the sand. The reason for such attraction on Hikkaduwa has noted as the natural environment including corals and the related activities by tourists (Orrin H. Pilkey, 2011). Hikkaduwa is also home to Sri Lanka's first Marine Sanctuary which was established in 1979 to protect the fringe coral reef which extends along the beach front and provides Hikkaduwa with a remarkable natural tourist attraction. Also, Hikkaduwa and the nearby area which offers major attraction points and activities that includes beach, surfing, diving, snorkelling, fishing, ecotourism, bird watching, and wildlife viewing (Rajasuriya, 1995).

Also, Hikkaduwa boasts of an abundance of industries and jobs compared to other tourist areas in Sri Lanka (Orrin H. Pilkey, 2011). According to the Hikkaduwa Grama Niladhari Report (2006), out of 4440 employees in the private sector, about 60% are employed in tourism industry. A similar proportion of 4055 self-employed persons are also employed in tourism through major sources of industry associated with tourism.

In the present, Hikkaduwa has exceptionally urbanized with significant improvement alongside the Galle road (A2) for a distance of approximately 8km by all commercial, governmental, and tourism activities on sides, while residential, agricultural and sports related built environment is established on eastward from the Galle avenue (USAID SCOTIA-SL, 2007). Although the tourism industry succeeded until 90's, now it is in a situation of conflict due to unplanned and uncontrolled development (Joseph, 2009). The government recognized the potential of tourism development in Sri Lanka and continued with

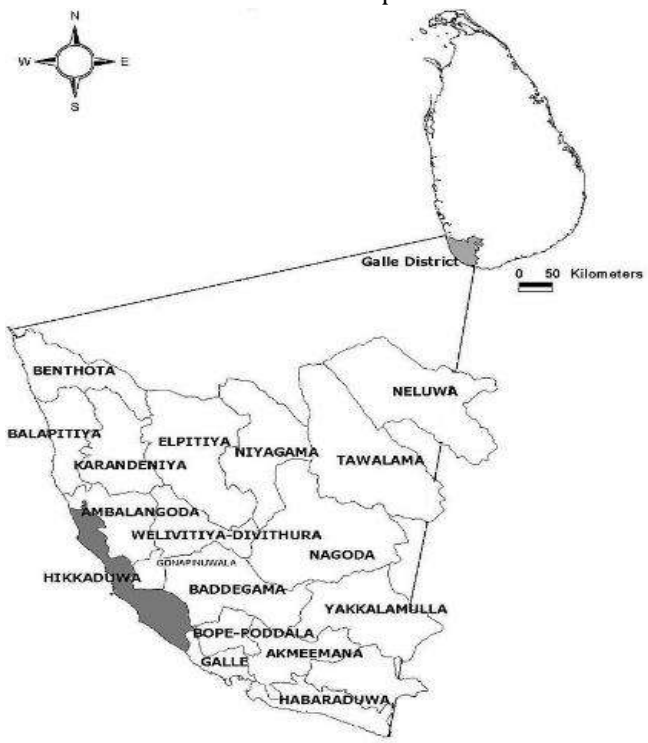

Figure 1. Hikkaduwa context
Source: Department of Town & Country Planning

their attempts to promote tourism only as a means of expanding economic activities (Fernando, 2012).

Figure 2. Tourist attractions & types in Hikkaduwa
Source: author

1. Sustainability & sustainable tourism

According to Grant (2020) 'sustainability' is defined as 'meeting the needs of the present without compromising the ability of future generations to meet their needs. It is composed of three pillars: economic, environmental, and social—also known informally as profits, planet, and people'. 'You matter' (2020) has stated that sustainability can be defined as 'the processes and actions through which humankind avoids the depletion of natural resources to keep an ecological balance so that society's quality of life doesn't decrease'. Similarly, Kuhlman and Farrington (2010) Sustainability is not just environmentalism. Embedded in most definitions of sustainability we also find concerns for social equity and economic development'.

Sustainable tourism is a tourism development with balancing the environmental, economic, socio – cultural aspects. Also, it has taken a major role of environmental preservation by minimally impacting nature and local culture for the future while providing for employment, increasing and produce incomes (World Tourism Organization,1990).

"The United Nations World Tourism Organization defines sustainable tourism as tourism that meets the needs of present tourists and host regions while protecting and enhancing opportunity for the future. The objective of sustainable tourism is to retain the economic and social advantages of tourism development while reducing or mitigating any undesirable impacts on the natural, historic, cultural or social environment. This is achieved by balancing the needs of tourists with those of the destination." (UNWTO, 2020).

The aim of sustainability brings many meanings which include earnings redistribution, ecosystem preservation, first-class of life, the system of natural and human environment, and the redistribution of energy (UN, 2013). However, these Sri Lankan communities are excellent in keeping up with increasing plans for a sustainable boom. Recognizing the issues first, Sri Lankan people provide the maximum achievable solutions (UNWTO, 1999).

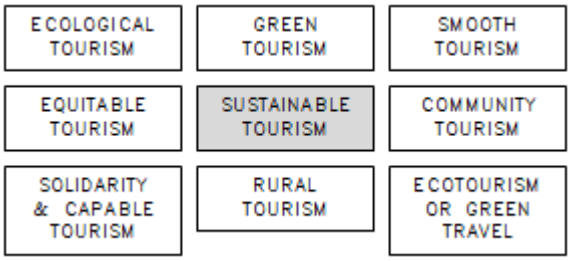

Figure 3. Types of sustainable tourism
Source: author

Coastal regions are transitional regions among the land and sea characterized by biodiversity and they consist of the richest and most fragile ecosystems in the world, like mangroves or coral reefs. Additionally, amongst all unique components of the planet, coastal regions are those which is often visited by tourists and in lots of coastal region's tourism offers the maximum essential financial works (Cossio, 2016).

Figure 4. Major assets of coastal region
Source: author

Figure 5. Examples for sustainable tourism area
Source: author

2. Parameters of sustainable tourism

In considering sustainability development parameters, it is important to analyse different types of sustainability approaches that cause changes at Hikkaduwa (Kiper, 2013). Also, Gebhard, Meyer and Roth (2009) has mentioned the criteria to be considered in sustainability (Gebhard, Meyer and Roth, 2009).

2. Methodology and Experimental Design

Sustainable coastal tourism does not have a specific formula. According to State (2009), after gaining the involvement of stakeholders who are interested in local growth, sustainable coastal tourism strategy and an action plan can be established through the steps shown in Figure 8. The study methodology framework consists of 3 main phases.

Phase A – Site Survey
Phase B – Analysis
Phase C – Proposal of guidelines

At phase A, the study area will be understood

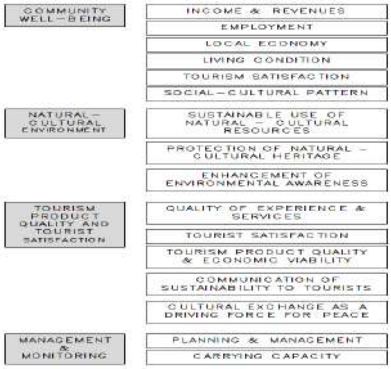

Figure 6. Parameters of Sustainability
Source: adapted from Gebhard, Meyer and Roth, 2009

and evaluated for its prevailing conditions and complications through observations. At phase B, concepts which studied in the literature review will be adopted to the case studies. Finally, at phase C, sustainable parameters of

Hikkaduwa will be identified using the obtained data and thereafter focus on creating and developing the guidelines and recommendations that should be adopted when introducing a sustainable tourism industry to the region.

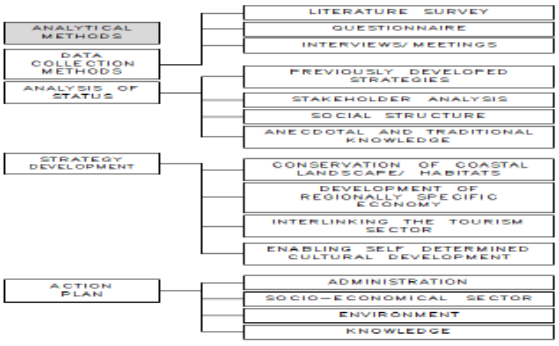

Figure 7. Methodology Framework, Source: author

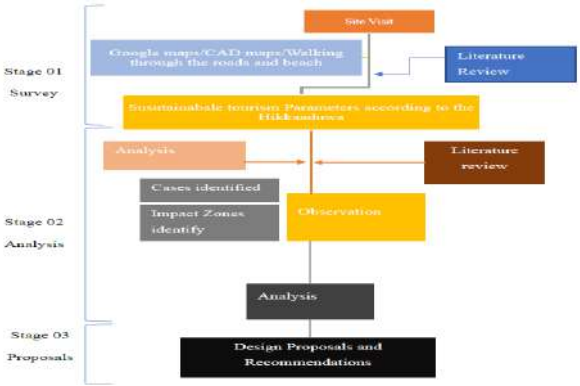

Figure 8. Steps for establishing a strategy & action plan, Source: adopted from Satta (2009)

Figure 9. Hikkaduwa tourism zoning map
Source: author

Study Area

The coastal tourism parameters were identified through the literature review and accordingly the application of those parameters tallied with the process of identifying following matters to promote tourism in the coastal area of Hikkaduwa.

- Places with high tourism attraction/promotion
- Developments within the past years
- Changes happened after Tsunami where the impact can be evidently observed

Table 1. Defining the study area

	Tourism Zone I	Tourism Zone II
Boundaries	Hikkaduwa Transfer building to Thiranagama	Hikkaduwa town to Thiranagama
Observations	Satisfying development in accord with sustainable principles	Area between Kumarakanda and Thiranagama is adapting to tourism industry
Characteristics	* Less traffic * Walkable spaces on either road sides * Maintained green spaces * Parking facilities * Visual access to the beach & sea * Maintained a character to the potential of the area	* Traffic conjunction * No visual access to the beach & sea * Lesser walkable spaces on roadsides * Polluted environment * Facades do not comply with the character of the area

Source: author

Both of these areas have regulations that is implemented by the UDA. It was noted that

there was no any specification rules, regulation or guidelines for these two zones for implementing or developing the sustainable tourism. Therefore, this study has a major potential to create specific guidelines to achieve the sustainable tourism. The research design is to gather more information through field surveys to identify details of the character of the building. Thereafter go through the existing studies of sustainable tourism to discuss those characters complying with sustainable criteria to propose the layout design guideline plan for the study area hoping to continuously promote sustainable tourism within the coastal area. Therefore, the process of identifying the sustainable parameters of Hikkaduwa zoned area to be done by focusing on the high tourist density places, hotels, restaurants and other specific buildings to implement the proposed guidelines as per said in the objectives of the study.

Field survey

The field visits were made to Hikkaduwa to study the area to find the characteristics of the connection between urban planning and architecture. Also focus was given to the existing rules and regulations that are already imposed by the UDA to come up with the proposal or guidelines to the study area for implementation. The following UDA regulations should be adhered in evaluating the existing conditions of the area.

- Maintaining Road Width
- Road Frontage
- Entrance to the Site
- Height Restrictions
- Building Lines
- Boundary Walls
- Beach Side Reservations
- Other Special Reservations

Moreover, the study extends on to old and new buildings within the area as case studies in order to identify and comply with facade development and its need to be included in the proposing guidelines through identified parameters. Therefore, through the identification of those said parameters will aid in creating the guidelines which will bring out the criticality of views within a walker's range in the town area. Thus, the focus will be in showing case studies with implemented of such process - where needed guidelines and recommendations can be bought forward.

Analysis of the case studies

Under a span of 5 days, the field survey was done in the said tourism zones l and ll. In each case study, sustainable parameters were tried to identify and potential to implement new parameters as well. A summary of said parametric characters of each case study is given as a details analysis.

These findings will be later analysed into produce a layout plan for the study area.

1) Tourism Zone l:

Table 2. Observations of case studies of Zone l

Place	Observations
Riff Hotel 	* An infill with a vivid contrasting appearance * Planting landscape on front * Lack of boundary walls
Hotel Cottage 	* Open facade building * Visual & physical connection to the beach and sea * Building consist of 5 storeys * Building language against the Hikkaduwa character
Avendra garden 	* Modern building with views to the sea through the building * Front without any boundary - won't disturb pedestrians * Attractive elevations
Refresh restaurant	* One of the oldest buildings * Good maintenance

 	* Consists of green spaces * Either side of the public accessible alleyway are food stalls * Temporary structure with thatched roofs * Comparatively high green cover * Dining space and an observation platform to the sea * Sign board disturbs the pedestrians
Ancient building 	* Open space on one side * Can be renovated as an open or garden restaurant or as an alleyway accessing the beach
Abandoned building with alleyway 	* Act as a publicly accessible alleyway * Parking requirement can be provided easily

Source: author

Table 3. Identified parametric characters within Zone ll

		Riff Hotel	Hotel Cottage	Avendra Garden	Refresh restaurant
1	Alleyways				√
2	Parking slots		√		
3	View to the sea	√	√	√	
4	Building form				T
5	Building height		5		√
6	Building structure				P
7	Boundary walls	x	x	x	
8	Facades		O		
9	Sign boards				√
10	Double walls				

Source: author

2) Proposed master plan for Zone l:

It is an essential concept for the Hikkaduwa area for a long period of time. But unauthorized construction of buildings had made this situation more difficult. Yet with the accreditation of CCCRM, those buildings can be demolished with prioritizing the requirement of a sustainable tourism city.

The area between the Coral Garden Hotel and the Co-operative building is the most suitable plot to be considered as beach park since it already provides the main access and act as an entrance to the beach. Within the area between Bansai Hotel and Coral Garden Hotel, all the buildings can be removed and re-establish them in accord with the concept of a sustainable tourism city. Developing this area as a beach park would solve all the prevailing problems related to environment and society. Also, gradually by attracting tourists it will enhance the economic benefits as well. When the identified parameters are set in an organized way within, the city will become a sustainable city effortlessly.

Figure 10. Proposed Beach Park, Source: author

Same as the Zone l, the study was conducted through observation in Zone ll as well and the detailed analysis of the selected buildings are given above. The summary of each zone is then given according the chosen sustainable parameters on the existing condition to get a whole idea on the existing built environment in both zones.

In the study, the building forms were categorized as temporary (T) and compatible (C), building structure categorized as renovated (R), preserved (P), and facades were categorized as green (G), unsuitable (U) and open (O).

3) Tourism Zone ll:

Table 4. Observations of case studies of Zone ll

Place	Observations
Bansai Hotel 	* Renovated building * View of sea through the building * Not exceeding 2 storeys * Green double wall with creepers to the 1st floor
Coral Sand Hotel 	* Unpleasant facade towards the road site disturbing pedestrians * A/C machines, sewage pipes and pumps installed to the roadside. * * Building a double wall can solve the issue
Mandala Hotel 	* Green facade with protective tree covers & creepers * Attractive side walls instead of sign boards * Visual & physical access to the sea through the building * Parking
Citrus Hotel 	* Parking and view of the sea through the centre of the hotel * provided green spaces * presence of boundary walls and an acceptable height
Abandoned building near the co-operative building 	* Unpleasant appearance overall * Can be developed as a rest house for the tourists

Source: author

Table 5. Identified parametric characters within Zone ll

		Bansai Hotel	Coral Sand Hotel	Mandala Hotel	Citrus Hotel
1	Alleyways				
2	Parking slots	√	x	√	√
3	View to the sea	√	x	√	√
4	Building form	C		C	
5	Building height	2	2		
6	Building structure	R	R		
7	Boundary walls	x	√	x	√
8	Facades	G	U	G	
9	Sign boards	x		x	
10	Double walls	√			

Source: author

The whole study looked after 11 buildings in both zones - 6 in zone l and 5 in Zone ll and thereafter 10 alleyways that were observed throughout the coast line in both good and bad pedestrian and walkability experience to both locals and tourists (see Figure 13).

4) Proposed master plan for Zone ll:

When considering about the master plan for the Zone ll, the main element stands out is the existing main entrance t to the Hikkaduwa beach. At present both local and foreign tourists use the premises, but the path has become congested with vehicle parking and having the path in middle of 2 busy shops.

Figure 11. Existing entrance to the Hikkaduwa beach, author

With the DWCMDO supporting through the social upbringing, his alleyway to be developed as an attractive point with properly functioned amenities with provided bathing places on the either side as well.

Figure 12. Existing entrance to Hikkaduwa beach, Source: author

Buildings should be re-established with green facades to be introduced instead of dark and narrow ones and should adhere the spacing requirements from the road as well as the beach. Having demolished the unnecessary elements in the built environment, new built environment can be oriented without any other existing errors.

3. Results , Discussion and Conclusion

From the above field survey analysis, parameters that are suitable for the Hikkaduwa context have been identified which are to be used in the sustainable tourism contributing through architecture.

G. Parameters for Hikkaduwa

5) Alleyways:

When considering the alleyways that were identified in the Zone l, they were not up to standards and had poor connection to the beach through the facades of the built environment.

Figure 13. Types of alleyways observed, Source: author

Some were blocked by temporary and outward structures with disturbing views along the way. Thus, it can be proposed to clean up those alleyways and provide separate spaces for those said structures and make room on the either side creating a welcoming ambience to enter and have an impression that won't hesitate local and foreign tourists. In Zone ll, most identified were dark alleyways as a result of cantilevered structure from near buildings. Those can be demolished under regulations and can improve the alleyway to be pleasing to the eye with comfortability to walk-in.

6) Parking slots:

Mainly this matter for commercial and mixed-use buildings as well as in common spaces. People are expecting the requirement thus, can be catered through removing boundary walls or modify them accordingly. Also, it is a crucial point to be implemented in a master plan level in planning.

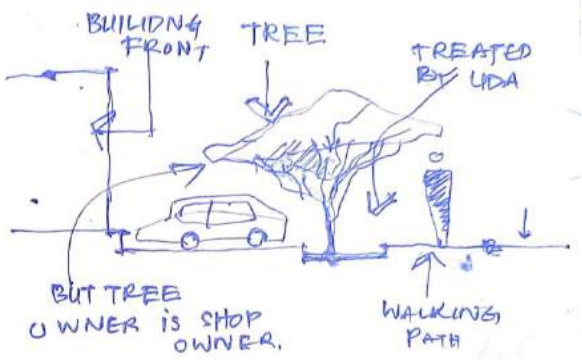

Figure 14. Proposed parking slots
Source: author

7) Views:

At present construction of buildings in the beach side have caused to block the scenic view of the sea for the people or pedestrians. Wind path from the sea is also blocked by the said buildings and prevent the wind from entering inside the land. Thus, it can be proposed that those said buildings could be converted or reconstructed allowing views of the beach and sea through the building as can give access physically through a connected bridge or preparation of a side as an alleyway. For the above suggestion, there are standard dimensions and planning to be adhered to.

8) Building form & structure:

It was noted that there are many numbers of temporary structures within the study area. Both sustainable and well-functioning structure and unpleasant abandoned structures were found. These abandoned structures can be renovated and use with sustainable functional requirements where other better ones can be facilitated with other needed requirements such as parking. Other compacted building types that have been built along either sides of the road causing many problems as well. They can be identified as small shops which does not even have the minimum requirement of floor space and stalls that have been divided from a larger floor space. Some of these are built in alleyways blocking the path, thus they should be removed as they are unauthorized structures. When considering about building heights, at present many sea side buildings can be categorized as tall buildings, but they should be not allowed to go that high and should impose regulations regarding height restrictions as wind should be allowed to flow to the land side, thus buildings in the coastal line should not exceed the height of the mangrove tree level.

9) Building development and function:

In Zone ll, it was identified that most of the buildings are renovated and currently functioning as restaurants. Yet there are some houses to be found among commercial built areas which results in scatter effect where there is no proper zoning has been done. Also, old buildings which were found in the area which carries the Hikkaduwa character should be highlighted and renovated preserving the language for tourist development. Also, within these built areas, public activities should be catered improving walkability through alleyways.

10) Boundary walls:

Construction of a boundary wall can be considered as a disturbance in the perspective of improving walkability for pedestrians. Even though many sea side hotels and restaurants plan to view the beach and the sea through their

building, boundary walls make the effort useless. Thus, boundary walls should be demarcations with permeable surfaces with a restricted maximum height of 3ft.

At present sign boards and hoardings have become a disturbance for the improvement of walkability for pedestrians as hotels' and restaurants' name boards have been placed up to the pedestrian line. This can be considered as

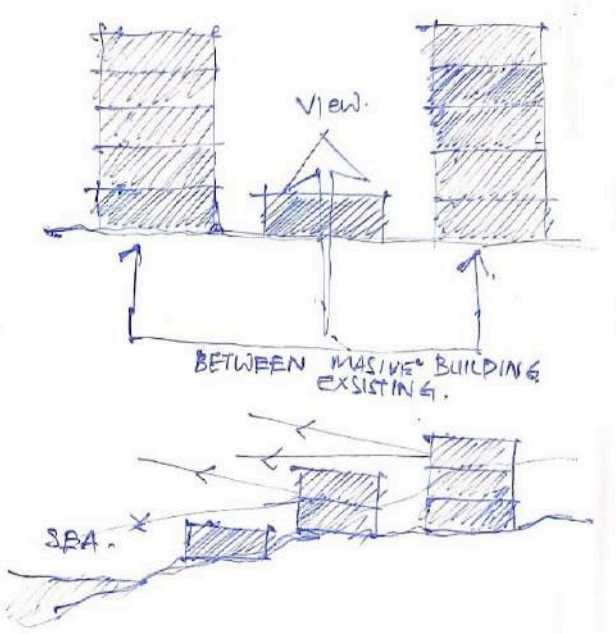

Figure 15. Proposed building height restrictions
Source: author

11) Facades:

The main reason for a building's facade to be a darker one is due to the materials that is used. Also designing facades that are not compatible with the Hikkaduwa language can be considered as a violation of urban planning principles. Thus, they should give the impression of ingenious characteristics. Other unpleasant facades in abandoned buildings should also to be renovated with the building to function to uplift tourism industry. Thus, the most suitable solution would be creating green facades. If the landowners hesitate due to maintaining costs, that can be facilitated by the Town Council or the Divisional Secretariat where they will plant trees, water and maintain them. This is successful tactic that it used to uplift tourism industry through economically sustainable environment.

12) Sign boards/hoardings:

an obstructing element to tourists when roaming around the city and would lead to hesitation. Mainly it is major issue at night, since tourists like night tours. Thus, regulations should be imposed with standard lengths and sized for hoardings representing uniqueness of Hikkaduwa.

13) Double walls:

It can be considered as an architectural element which adds value to both street side and coastal side while increasing building's security and efficiency. Also, it provides solutions to thermal comfort, dusty winds and act as a climatic responsive and sustainable unit. The wind from the sea side will be controlled and as well as will gain the attention of the pedestrians of the road side.

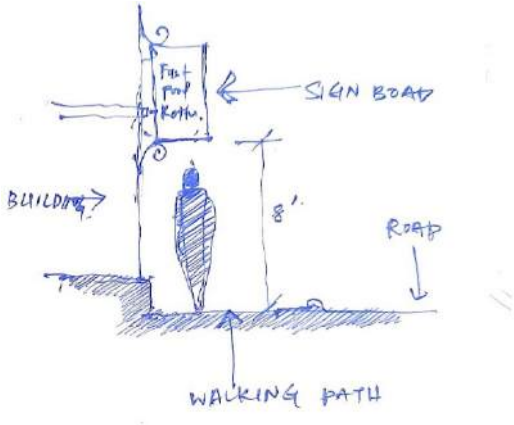

Figure 16. Proposed signboard/hoarding regulations, author

All of these above-mentioned parametric characters that found from the field survey had based through the architectural view that should be implemented for sustainable tourism in Hikkaduwa area. Through those sustainable criteria of environment, social and economic factors, architectural parametric strategies can be fulfilled. Hence, it will create and improve the quality of life of the area with social interactions. Then these factors altogether will pave the way for automatically environmental-social-economic sustainability

Proposed layout Plans

The field survey study had given an idea of what to considered as design guidelines with the said parameters. Comparing with the existing rules and regulations, parameters were implemented as design guidelines to the proposed layout

plan. As the main parametric feature, creating alleyways on the existing coastal belt have to be done as much as possible in development

Figure 17. Proposed alleyways
Source: author

strategies as a sustain mechanism. Where an alleyway cannot be created, an openable ground level is another alternative to the matter.

The following figure shows the proposed guideline layout plan for the creating alleyways. They have more potential to creating the new alleyways with connecting sea side and its views.

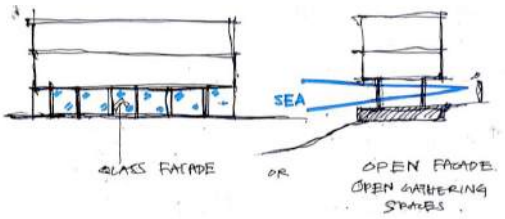

Figure 18. Proposed open ground floor
Source: author

The section shows the proposed design guidelines to be implemented tot eh sea side of the Hikkaduwa area. It is clear how the buildings get the wind and the view through height restrictions and considerations on implementing pedestrian path's walkability with green paths and facades.

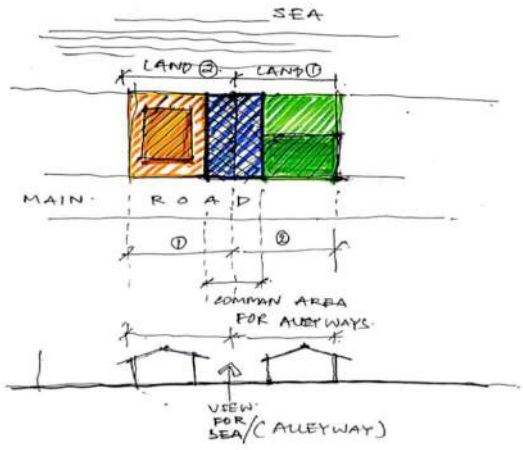

Figure 19. Proposed alleyway plan
Source: author

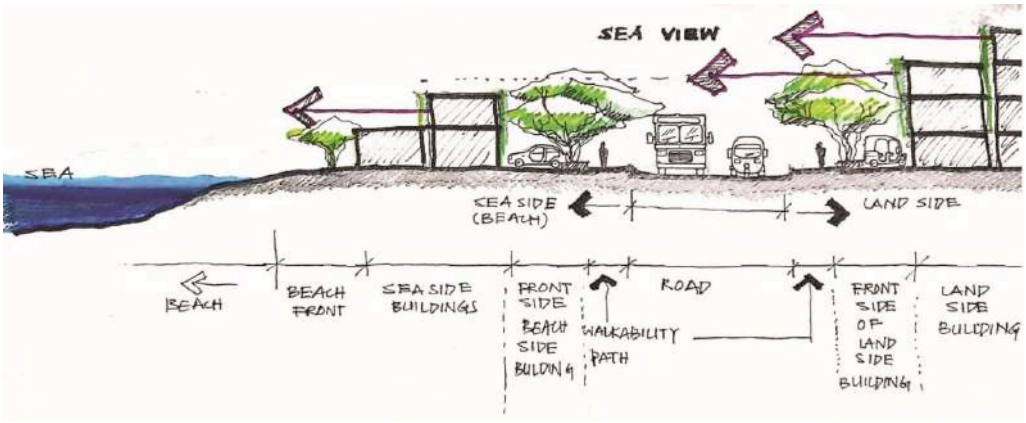

Figure 20. Proposed design considerations for the sea side
Source: author

They The proposed layout plan shows the considerations for a typical beach side along with green developments, improved connectivity and walkability. Thus, those cover all the main sustainable parametric criteria to be implemented for sustainable tourism in Hikkaduwa. Thus, following should be considered as notable factors in making design guidelines.

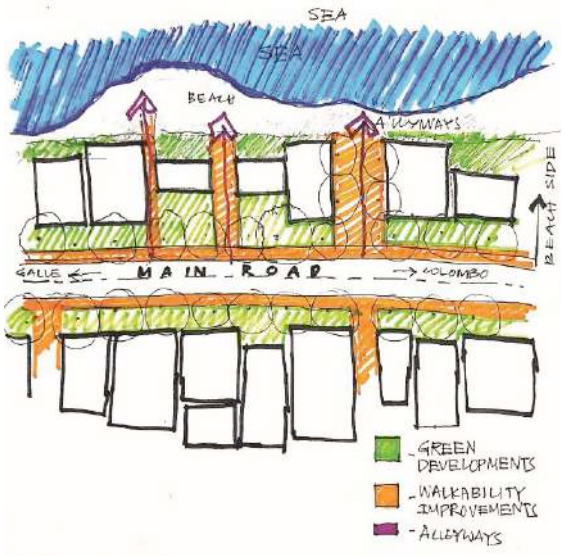

Figure 21. Proposed alleyway design considerations with improved walkability

- Spaces to build alleyways
- Spaces to create parking slots
- Areas that have and not been exposed to the sea
- Building functions on the sea side or overlooking the beach
- Location of old buildings to be renovated
- Buildings to give the scenery of the sea to pedestrians as well
- Attraction of tourists and simultaneously reducing the traffic conjunction

Through such action, it will bring on improvement of tourism zone I to sustainability with existing potentials and tourism zone II have to re-establish in sustainable manner with implementing parameters with guidelines. For that course, the guidelines and recommendations are of huge assist within the process affecting on the identified area creating a solution to the identified problem. Here, the advantage in identifying zone categorization within the Hikkaduwa town area is laying interest and knowledge on the small areas and architectural features which are neglected or missed during the process of catering a highly developing project. Thus, this study brings an overall idea regarding the process of making Hikkaduwa a sustainable tourism city as a whole.

Conclusion

The Hikkaduwa is known for its tourism, especially beach tourism; each year being the centre of attention for a long time with the increasing demands for such tourism opportunities. Hikkaduwa including the tourism industry has been developing rapidly completely ignoring the development guidelines & social, environmental & economic impacts. Due to this reason, the Hikkaduwa Town has covered up with non-permitted buildings which would cause poor walkability &

pedestrian accessibility, blockage of views which would cause in less gathering areas and also resulted in less appalling built environment with unpleasant facades & building envelopes. Overall, this affects the urban planning process including vehicular parking and accessibility. Due to these causes Hikkaduwa town is gradually becoming unpleasant for tourist attraction which would cause lesser tourism and would gradually become unsustainable as a town. Considering these factors, concerned authorities have been come up with regulations, Urban plans or master plan developments to develop the Hikkaduwa town and the tourism industry. Yet, there is a huge gap between those development plans and the problems that have been created due to the existing contextual situation. These development plans only focused on certain areas including the existing regulations separated under specific areas. This has caused the issue of not having an overall guideline for Hikkaduwa town for tourism and sustainable development.

Therefore, as a solution to this issue, based on the existing studies and the regulations a proposal has been made by this study considering the factors that should identify as characteristics for the Hikkaduwa town development and made parameters including design guidelines accordingly for application of the overall Hikkaduwa tourism area. Hence, after defining the study area, a field survey was done with a case study which lead to identification of specific sustainable characteristics where they were studied on how to develop those as architectural solutions to achieve environmental, economic and social sustainability. Thereafter, those identified characteristics were improved as parameters which were used for design guidelines and layout plans to be implemented for the overall Hikkaduwa area. It was identified that the addition/implementation of proper alleyways, fulfilling the parking requirement, establishing openable ground floors which consist with good views through the building, creating proper façade with green development as the potential of bringing about improved sustainable tourism factors in Hikkaduwa. Thus, it was proved that to the above-mentioned issue, architectural solutions can be given with parameters and guidelines to follow and maintain as a starting point of the Hikkaduwa coastal area to become a “Sustainable coastal tourism city”.

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Abbreviations and Specific Symbols

UDA- Urban Development Authority

CCCRM - Coast Conservation & Coastal Resource Management

CMC- United States

DWCMDO- Department of Wildlife Conservation Marine Department Office

Author Biographies

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Contribution of green buildings towards achieving sustainability: A perspective of LEED-certified buildings in Sri Lanka

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Abstract*: Recently, the focus on green buildings has fore fronted in countries. However, in the context of Sri Lanka, the number of green-certified buildings seems to be still at a minimal level and the focus is solely on the energy efficiency features. Although green buildings are meant to be sustainable, the level of incorporation of sustainable features and their contribution to sustainability is questionable. Therefore, the current study aims to examine the extent of incorporation of sustainable features in green-certified buildings in Sri Lanka. A review was conducted into the USGBC database and the profile of green-certified buildings in Sri Lanka was examined to identify the extent of green certification in Sri Lankan buildings and their level of achievement of sustainable features. The reasons for the level of achievement of those sustainable features were then identified by interviewing professionals who engaged in green buildings. Accordingly, the selected buildings have over 80% of achievement in terms of water efficiency and sustainable sites, while other design features, such as energy and atmosphere, indoor environmental quality, and material and resources are below 50% achievement. Further, energy and atmosphere, and indoor environmental quality features require alternatives with higher initial cost, early commitment, and an integrated design process. Most of the time, energy and indoor environmental quality features seem easy to achieve, but often turn out to be far more complicated, and thus less feasible, than anticipated. Knowing sustainability achievement of features would enable green building investors to select the most appropriate features for a given construction.*

Keywords: *Green Building, LEED Certification, Sustainable Features, Sustainable Development, Sri Lanka*

1. Introduction

The construction industry has a significant impact on economic, environmental, and social development all over the world (Nahmens, 2009). With the growing global interest in sustainability, the concept of green building construction has come to the forefront of the construction industry in Sri Lanka (Abidin, 2010). However, as studies highlighted, there are some challenges for a developing country like Sri Lanka when leading towards sustainable construction. For example, Bombugala and Atputharajah (2010) concluded that the construction cost of green buildings is about 20 to 25% higher than that of traditional buildings. Further, Waidyasekara and Fernando (2012) indicated that green building investors primarily focus on minimising construction costs and failing to consider the economic performance throughout the life cycle. Further, Waidyasekara & Fernando (2012), stated that there is a great requirement to promote the construction of green buildings in Sri Lanka with the rapid growth of the construction industry. Green buildings incorporate various sustainable features under major focus areas such as sustainable sites, management, energy efficiency, water efficiency, materials and resources, indoor environmental quality (IEQ), health, etc. (Fowler & Rauch, 2006). Though green buildings provide sustainable features in many aspects, a visible limitation of the past studies is that the findings on the implication of

sustainable features on green buildings were mostly limited to energy efficiency technologies. Therefore it is more important to identify the contribution of each sustainable feature to promote the green building concept with the green certification.

Table 1: Summary of Points Allocation as per LEED NC Version 3.0 and GREENSL®

Sustainability Feature	Points Allocated	
	LEED BD+C NC v3 (2009)	GREENSL®
Energy and Atmosphere	35	21
Sustainable Sites	26	25
Indoor Environmental Quality	15	21
Materials and Resources	14	21
Water Efficiency	10	14
Innovation and Design	6	4
Regional Priority	4	-
Management	-	4
Social and Cultural Awareness	-	3
Total	**110**	**113**

To this end, the current study aims to examine the extent of green certification in Sri Lankan buildings and their level of achievement of sustainable features with the justifications for those achievements. It is expected that the outcome of this study would enable potential green investors to make informed decisions with sound knowledge of sustainable features. This would further enhance the sustainable performance of buildings and promote sustainable development.

2. Literature Review

Green Building Council Sri Lanka (GBCSL) was launched in 2009 and is a non-profit organisation that is devoted to encouraging the adoption of green building practices thereby developing a sustainable building industry in Sri Lanka and has introduced a green rating system. GBCSL came into existence because of an emerging trend toward applying greener concepts to the built environment. Thus, the green building concept is new to the Sri Lankan context and it is introduced to many industries as they are searching for more energy-efficient buildings for their usage (Green Building Council Sri Lanka, 2010). Green buildings represent the next phase of buildings however, the reality is that most of the buildings in Sri Lanka are not green. LEED has been active in Sri Lanka, even before the GREENSL® rating was introduced by the GBCSL in 2010. For example, the first LEED certification in Sri Lanka was issued in 2008 (Bombugala & Atputharajah, 2010). Fowler and Rauch (2006) highlighted that LEED® is the dominant and most widely used rating system around the world. To date, LEED encompasses more than 72,500 LEED building projects in over 150 countries and territories. Moreover, GREENSL® rated building has an equivalent efficiency as a LEED-rated building (Green Building Council Sri Lanka, 2015). Table 1 provides the summary of point allocation of LEED BD+C NC (V3) and GREENSL® for the sustainable features.

As shown in Table 1, energy and atmosphere are top ranked in LEED BD+C NC (v3) rating system and the sustainable sites feature is a close second, whereas, the sustainable site is identified as the most important sustainable feature in the Sri Lankan context and associated with higher points in the GREENSL® rating system. Management and social and cultural awareness are specific sustainable features of the GREENSL® rating system while regional priority feature is excluded from the GREENSL® rating system. However, the sustainability criteria in each common sustainable feature seem to be similar between the two rating systems.

3. Research Methodology

The main objective of the study is to examine the profile of green buildings in Sri Lanka, their sustainability level achieved through the incorporation of sustainability features, and the reasons for the level of achievement of those features. The required data were collected through documentary reviews of the USGBC directory and semi-structured interviews with professionals who engaged from the green building initiation project to operation and maintenance (O & M) activities of the selected green buildings. Initially, a search into the USGBC directory was carried out to identify the extent of green certification in Sri Lankan buildings and their level of achievement of sustainable features. In the Sri Lankan context, the LEED and the GREENSL are widely used rating systems. Amongst, the study is limited to LEED-certified buildings due to the lack of comprehensive data available in the case of GREENSL-certified buildings. As per the updated UGBC directory, altogether ninety-seven (97) buildings have been registered under LEED certification in Sri Lanka as of 2020 as per Table 2. Of them, fifty-four (54) buildings were awarded LEED certification in Sri Lanka. The majority of green-certified buildings (25 out of 54) are industrial manufacturing facilities, while office buildings were the second most certified type with 9 out of 54 buildings. Among the LEED-certified buildings, the profile of the green buildings was further reviewed based on the rating system, rating version, certified level, and certified year to ascertain the status of the green buildings. In the Sri Lankan context, green-certified buildings were registered under five (5) categories and 5 different rating versions. Amongst, the majority of buildings have been certified under LEED BD+C: NC version LEED -2009, hence, analysis was conducted for the LEED BD+C: NC (v3 - 2009) industrial and office buildings in Sri Lanka. The LEED BD+C: NC (v3 -2009) includes 08 (out of 25) industrial buildings and 07 ((out of 09) office buildings registered.

Table 2: Profile of Participants

	Position	Profession	Experience (Years)	Involvement in the Project
I01	Maintenance Engineer	Mechanical Engineer	1-10	Construction, O & M
I02	Manager Maintenance	Mechanical Engineer	1-10	Construction, O & M
I03	O&M Manager	Mechanical Engineer	11-20	O & M
I04	Maintenance Engineer	Mechanical Engineer	1-10	O & M

Subsequently, semi-structured interviews were used to identify the reasons for the level of achievement of sustainable features of LEED BD+C New Construction buildings. Table 3 presents the profile of the interviewees. The data collected through document analysis were subjected to descriptive statistics. Manual content analysis was used to capture the interviewees' views on the reasons for the level of achievement of sustainability.

4. Results and Discussion

Eight (8) industrial manufacturing buildings and six (6) office buildings certified under LEED BD+C: New Construction (v3 - LEED 2009) were considered to analyse the implication of sustainable features in the achievement of green certification.

A. Level of Achievement of Sustainable Features

The points achieved to each sustainability criteria of certified industrial and office buildings were analysed and the average point achievement was considered to identify the significance of sustainable features in the Sri Lankan LEED-certified buildings. Table 4

presents the possible points allocated for each sustainable feature, average achieved points, and the percentage of achieved points from the possible points of each feature. As shown in Table 4, the average points achievement of selected green-certified office and industrial buildings indicate that regional priority, and water efficiency features have achieved over 90% of the possible points. The sustainability level of the sustainable site and innovation feature exists between 65% - 80%. Though office buildings achieve a 54% of sustainability level in energy and atmosphere features, industrial buildings account for only 44%. The remaining features: Indoor environmental quality and material and resources have achieved a sustainability level between 40% to 50%.

Table 3: Profile of LEED-certified buildings in Sri Lanka as at 2020

Certified green spaces	Industrial manufacturing	Office	Loading	Warehouse and distribution	Multi-family residence	Retail	Higher education	Datacentre	Laboratory	Public assembly	Others	Total
No. of registered buildings	40	18	18	5	3	3	3	2	2	1	1	97
No. of certified buildings	25	9	8	3	1	3	2	1	2	-	-	54
No. of uncertified buildings	15	9	10	2	2	-	1	1	-	1	1	43

B. *Reasons for Level of Achievement of Sustainable Features*

The interviewees were presented with the findings of a comparative analysis of points allocated and achieved and asked to comment on the reasons for the level of achievement of sustainability in terms of each sustainability feature. Reasons for the achievement level of each sustainable feature were sought and analysed separately under each feature and then a summary of all the reasons is presented.

a. Water Efficiency

As discussed previously in the preliminary analysis, the certified industrial buildings have achieved a 100% of sustainability level while office buildings achieved 90% in terms of water efficiency. Water efficiency consists of three criteria as water-efficient landscaping, innovative wastewater technologies, and water use reduction. All, of the interviewees (I01-I04), agreed that organisations are willing to invest in water efficiency since the building owners are required to pay for utility costs over the life cycle of the building. According to interviewees, high-efficiency irrigation using reclaimed water (water supplied to the site by the local water district) can be designed at a minimal cost. Adding to that, the interviewee (I02) stated that the native plants which are suited to the local rainwater levels reduce the additional water consumption. On a similar note, the interviewee (I01) explained that "natural drainage such as grass paving and planted stormwater retention areas were used to reduce stormwater run-off from the site at a less cost". Considering the innovative wastewater technologies, interviewees stated that sewage treatment plants (STPs) are available in many green building sites. Interviewee (I03) indicated that they used the treated water for gardening and flushing purposes, while Interviewee (I02) stated that the treated water discharged to a waterway in an environmentally friendly manner. Although implementing a STP incurs a considerable cost, both interviewees agreed that the building owners often invest in STPs due to their familiarity with the technology engaged with STP. The last criterion of water use reduction is acquired by installing water-efficient plumbing fixtures. The Interviewee (I04) stated that when achieving the points for water use reduction, feasibility in

implementation is the main concern rather than the cost. I04 further noticed that "*our building has installed low flow fixtures for toilets and urinals and dual plumbing which serve the recycled water from STP for flushing purposes*". From a similar point of view the Interviewee (I01) explained that "*the waterless urinals are engaged with a technology that is unfamiliar to the technical staff; however, there is no cost impact*". Therefore, it is obvious that green industrial and office buildings achieve the highest sustainability in water efficiency through low-cost, feasible, and familiar (no modern technology) alternatives of water efficiency strategies and technologies.

b. Sustainable Sites

According to the preliminary analysis, on average the percentage achievement of sustainability level is 76% and 75% in terms of the sustainable site by industrial and office buildings, respectively. According to interviewees (I01-I04), more than 50% of the points can be achieved by fulfilling the requirements of development density and community connectivity, and alternative transportation since, this feature allocates more points for those criteria. The Interviewee (I04) explained that "*providing provision for bike racks and changing rooms are inexpensive to achieve with low design impact therefore we have targeted this point from the start*". Similarly, Interviewee (I01) stated that "*low emitting and fuel-efficient vehicles with electric refueling stations can be added almost any time during design and construction*". Therefore, all the interviewees (I01-I04) have agreed that over 50% of the sustainability level can easily be added to the building by making minimal design changes that require low cost and design impact. Interviewee (I03) added that they have achieved the points for site development – protecting or restoring habitat by planting native species and the heat island effect was achieved by changing the colour of concrete paving and adding shade elements at a relatively low cost. According to the interviewee (I01), other points which can be achieved with a low cost and design impact are maximising the open space and designing and constructing the building in a location near wetlands or natural ponds.

c. Innovation in Design

The innovation in design feature in LEED BD+C NC certification is designed to allow projects to earn points for items that may not fall into any other designated point. According to the interviewees (I01 and I04), most of the projects have achieved 60 to 70% of the points allocated for this feature by pursuing low-cost innovation points and hiring a LEED-accredited professional for green building projects.

d. Indoor Environmental Quality

As identified previously, the IEQ feature includes 15
single points. According to the interviewees (I01, I02, and I03), the first point: is outdoor air delivery monitoring, usually achieved by installing CO_2 and airflow measurement equipment and feeding the information to the heating, ventilating, and air conditioning (HVAC) system and building automation system (BAS). Knowledge of modern technologies and incorporating these strategies into the building is the key requirement to achieve this point. Further, the Interviewee (I01) stated that "*it is all about sensing, monitoring and controlling the outdoor air intake flow*". Similarly, all the interviewees (I01-I04) agreed that modern technology, as well as the strong commitment of the members of the green project, is necessary to achieve the second point: which is increased ventilation. The next two points are the construction indoor air quality (IAQ) management plan during construction and before occupancy. As the Interviewee (I03) opined, the IAQ management plan during construction is relatively difficult to achieve because this point requires significant coordination and management on the contractor's part.

Table 4: Significance of sustainable features in terms of points allocation

	Sustainable Feature	Allocated points	Level of achievement			
			Industrial		Office	
			Average points achieved	Average %	Average points achieved	Average %
Sustainable Site	Site selection	1	0.750	75%	0.800	80%
	Development density and community connectivity	5	3.125	63%	5.000	100%
	Brownfield redevelopment	1	0.000	0%	0.000	0%
	Alternative transportation - public transportation access	6	5.250	88%	6.000	100%
	Alternative transportation - bicycle storage and changing rooms	1	1.000	100%	0.500	50%
	Alternative transportation - low emitting and fuel-efficient vehicles	3	3.000	100%	3.000	100%
	Alternative transportation - parking capacity	2	2.000	100%	2.000	100%
	Site development - protect or restore habitat	1	0.500	50%	0.000	0%
	Site development - maximize open space	1	0.750	75%	0.000	0%
	Stormwater design - quantity control	1	0.375	38%	0.000	0%
	Stormwater design - quality control	1	1.000	100%	0.250	25%
	Heat island effect - non-roof	1	1.000	100%	1.000	100%
	Heat island effect - roof	1	0.875	88%	1.000	100%
	Light pollution reduction	1	0.250	25%	0.000	0%
	Total Received points	**26**	**19.875**	**76%**	**19.550**	**75%**
Water efficiency	Water-efficient landscaping - no potable water uses or no irrigation	4	4.000	100%	3.000	75%
	Innovative wastewater technologies	2	2.000	100%	2.000	100%
	Water use reduction	4	4.000	100%	4.000	100%
	Total received points	**10**	**10.000**	**100%**	**9.000**	**90%**
Energy and atmosphere	Optimize energy performance	19	9.500	50%	9.250	49%
	On-site renewable energy	7	0.875	13%	3.250	46%
	Enhanced commissioning	2	1.250	63%	1.500	75%
	Enhanced refrigerant management	2	0.000	0%	2.000	100%
	Measurement and verification	3	2.625	88%	2.250	75%
	Green power	2	1.000	50%	0.500	25%
	Total received points	**35**	**15.250**	**44%**	**18.750**	**54%**
Material and resources	Building reuse - maintain existing walls, floors, and roof	3	0.750	25%	0.750	25%
	Building reuse - maintain interior non-structural elements	1	0.000	0%	0.000	0%
	Construction waste management	2	2.000	100%	1.500	75%
	Materials reuse	2	0.125	6%	0.000	0%
	Recycled content	2	1.000	50%	0.750	38%
	Regional materials	2	2.000	100%	2.000	100%
	Rapidly renewable materials	1	0.000	0%	0.250	25%
	Certified wood	1	0.000	0%	0.000	0%
	Total received points	**14**	**5.875**	**42%**	**5.250**	**38%**
Indoor environment quality	Outdoor air delivery monitoring	1	0.125	13%	0.500	50%
	Increased ventilation	1	0.625	63%	0.250	25%
	Construction IAQ management plan - during construction	1	0.750	75%	0.750	75%
	Construction IAQ management plan - before occupancy	1	0.375	38%	0.500	50%
	Low-emitting materials - adhesives and sealants	1	0.875	88%	0.750	75%
	Low-emitting materials - paints and coatings	1	1.000	100%	1.000	100%
	Low-emitting materials - flooring systems	1	0.5	50%	0.750	75%
	Low-emitting materials - composite wood and agrifiber products	1	0.000	0%	0.750	75%
	Indoor chemical and pollutant source control	1	0.000	0%	0.000	0%
	Controllability of systems - lighting	1	0.375	38%	0.250	25%
	Controllability of systems - thermal comfort	1	0.000	0%	0.250	25%
	Thermal comfort - design	1	0.25	25%	0.500	50%
	Thermal comfort - verification	1	0.25	25%	0.500	50%
	Daylight and views - daylight	1	0.875	88%	0.000	0%
	Daylight and views - views	1	0.875	88%	0.000	0%
	Total received points	**15**	**6.875**	**46%**	**6.750**	**45%**
Innovation	Innovation in design	5	3.125	63%	3.500	70%
	LEED Accredited Professional	1	1.000	100%	0.750	75%
	Total received points	**6**	**4.125**	**69%**	**4.250**	**71%**
Regional priority	Regional priority	4	4.000	100%	4.000	100%
	Total received points	**4**	**4.000**	**100%**	**4.000**	**100%**

He further stated, "*The cost to achieve this point is low, however, the contractor's bid can be very significant. Due to the reason that the construction must be planned and scheduled with well-trained members, it is ensured that all the criteria are met*". Considering the IAQ

plan before occupancy, the interviewee (I01) opined that achieving this point depends on the climate condition. In dry areas, a two-week flush-out with outdoor air is quite feasible, while in wet climates where there is high humidity, the mould could grow on the interior of the building. Both interviewees (I01 and I02) agreed that it is easy to achieve low emitting materials points where local or regional regulations already established the use of low emitting materials. Similarly, the next point: indoor chemical and pollutant source control can often be met with low cost and controllability of the system. Lighting could be achieved by integrating occupant controls for lighting and task lighting at a low cost. The controllability of the system: which is the thermal comfort often achieved by incorporating operable windows with a low direct cost premium. However, there is a significant added cost when combined with a traditional air conditioning system with extra controls, zones, and ductwork. According to the interviewee (I01), achieving this point with operable windows may also be impractical due to the concern over the security of raw materials for the garment, and the climate may not lend itself to operable windows for much of the year. Under the thermal comfort design and verification, the building envelope and systems should be designed with the capability to meet the comfort criteria under expected environmental and use conditions and should be able to permanently monitor building performance: air temperature, radiant temperature, air speed, and relative humidity levels. According to the interviewees (I03 and I04), these points are feasible to achieve with the strong commitment of the parties engaged with the green building project. Both the interviewees (I03 and I04) opined that many projects attempted to achieve daylighting and views due to the benefits of daylighting and views became more desired over time. Most of the IEQ points need to commit construction owners and teams. However, not all parties are willing to maintain the level of management needed to ensure the performance necessary to meet these points successfully. These points may seem easy to achieve, but often turn out far more complicated, and thus less feasible, than anticipated. Therefore, most of the green industrial and office buildings in Sri Lanka have achieved less than 50% points for the IEQ feature over the allocated 15 points.

e. *Energy and Atmosphere*

As discussed previously, the energy and atmosphere feature consists of optimized energy performance, enhanced commissioning, enhanced refrigerant management, measurement and verification, and on-site renewable and green power criteria. Amongst, LEED has allocated more points for optimizing energy performance and site renewable energy. The certified buildings have scored less than 50% (17 out of 35 points) in terms of energy and atmosphere, while the feature has been assigned the highest number of points in the rating system. According to the Interviewee (I02), the points for the optimized energy performance were awarded considering the percentage of energy cost savings. Therefore, to achieve more points the investor should prove that the building is responsible for the threshold points which incurs a high initial cost to achieve that level. Similarly, the Interviewee (I01) stated that "*it is difficult to reach the higher percentages because these require innovative technology. Further, reaching these higher levels added significant costs and they especially need an early design commitment*". Considering the building commissioning, measurement, and verification, both interviewees (I03 and I04) agreed that these represent a significant

added cost. However, feasible to achieve with early commitment. Further, Interviewee (I03) opined that measurement and verification require a complex monitoring system that ultimately benefits the users. In terms of refrigerant management, both interviewees agreed that nowadays more energy-efficient air conditioning alternatives are available that use environmentally friendly refrigerants. Therefore, it is only a matter of selecting a system that is environmentally and economically beneficial in the long run. However, considering renewable energy and green power, these have a substantial construction cost impact and provide long-term cost savings. The Interviewee (I02) explained, "*Assume that to initiate an investment in the photovoltaic system, there should be financially backup for the investors. Currently, few organisations provide the Energy Service Contracts (ESCO) model for those kinds of investments. However, the location and climate conditions should also consider achieving uninterrupted solar energy supply*". Therefore, these green-certified industrial buildings were able to achieve a less than 55% of allocated points with an early commitment and integrated design process.

f. Material and Resources

The certified industrial and office green buildings in Sri Lanka have achieved a level of less than 50% in terms of material and resources. This feature is classified into two distinct categories: A) most projects pursuing the credits related to construction waste management, local content, and recycled content, and B) very few pursuing the other points like building reuse, renewable materials, material reuse, and certified wood. Therefore, the interviewees were asked to comment on the reasons for this achievement level.

Building reuse is the first point, Interviewee (I01) stated that "*it is difficult to reuse existing building structural and non-structural elements due to its impact on the cost of achieving energy and atmosphere points*". Similarly, the Interviewee (I02) added, that this point is uncommon in most projects due to the additional work and substantial material and resources that must sacrifice the energy and atmosphere of the building. However, achieving energy and atmosphere is more economical considering the long-term economic benefits. The interviewees (I03 and I04) opined that most projects are unable to incorporate rapidly renewable materials and reused materials into their design because these materials tend to be costly. Further, both interviewees

Table 5: Reasons for the Level of Achievement of Sustainability

Sustainable Features	Level of Achievement	Reasons
Sustainable Sites	≥ 80	Minimal design changes which require low cost and design impact
Water Efficiency		Feasible and familiar (no modern technology) alternatives
Innovation in Design	50 < % ≤ 80	Low-cost innovation strategies
Energy and Atmosphere	≤ 50	The high initial cost of implementation Early commitment and integrated design process
Material and Resources		Additional works and substantial cost Contractor's commitment and familiarity
IEQ		The commitment of the project owners and construction team

agreed that certified wood costs more than non-certified wood. Without a clear understanding of cost fluctuations, the investors were unable to establish the cost impact. Construction waste management is the highest achieved point in almost every green project. All the interviewees (I01-I04) explained that the cost to achieve this point is highly dependent on the contractor's commitment. If the contractor is familiar with the construction waste recycling programs and practices this can be achieved with a minimum cost. However, the cost is also dependent on the project location, usually in urban projects the cost is less. The interviewees (I01 and I02) agreed that the use of recycled content and regional materials usually incurs minimal costs. Therefore, the investors go for the projects in category A since the achievement of those features requires less cost compared to projects in category B and can maintain a sustainability level of less than 50%. Table 5 summarises the reasons identified through the content analysis under each sustainable feature.

5. Conclusion

This study aims to examine the extent of green certification in Sri Lankan buildings and their level of achievement of sustainable features. According to the research data analyses and findings, altogether 54 out of 97 buildings are certified under USGBC LEED certification in Sri Lanka. In other words, currently, nearly 56% of registered buildings have achieved green certification in Sri Lanka. Research results further depict that the water efficiency feature has achieved 100% and 90% of sustainability levels through low cost, feasible and familiar alternatives of water efficiency technologies and strategies in industrial and office buildings, respectively, whereas over 50% of sustainability level has achieved through making minimal design changes to the building which require low cost and design impact in terms of sustainable sites feature. However, in terms of energy and atmosphere, the certified buildings have achieved only approximately 50% of the allocated points as they required alternatives with higher initial cost, early commitment, and an integrated design process. Similarly, in terms of IEQ features, the industrial buildings have earned less than 50% of the sustainability level since most of the IEQ points seem easy to achieve, but often turn out to be far more complicated, and thus less feasible, than anticipated. The certified industrial and office buildings have achieved less than 50% sustainability in terms of material and resources because most of the points are uncommon in most projects due to the additional work and the substantial cost associated with the building. Accordingly, the research findings show that in the global context, approximately 50,000 buildings have achieved the LEED certification, whereas in Sri Lanka only 54 buildings have achieved green to date. Hence, the results of this study enable to increase the in green certification in Sri Lankan buildings by achieving more sustainable features.

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Investigating the Potential of Utilising Simulation Studies to Identify UHI Mitigatory Strategies in Proposed Cities

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Abstract*: Rapid development of urban areas catalyzed the movement of people from rural areas to urban areas. This led for the demand of more dwelling places. Urbanization and industrialization cause for the replacement of permeable land cover into impermeable materials. More solar radiation has been absorbed by impermeable materials as it has thermal bulk properties and cause for the increase of urban temperature. Change of urban microclimate caused the phenomenon identified as urban heat island effect which is identified from the temperature difference between urban and rural area. In Sri Lanka few researches have conducted on UHI effect for developed and existing cities. Identifying potential UHI mitigatory steps is vital when designing urbanities. Therefore, analyzing UHI effect and possible mitigatory strategies for proposed cities through simulation studies are highly beneficial in developing sustainable cities. The research focused on investigating the potential of utilizing simulation studies to identify UHI mitigatory steps for proposed cities in local context. Rhino 3D simulation software was utilized for the study. The paper presents the results of initial studies conducted. Research methods and workflow developed through the study can be utilized to evaluate the UHI effect, mean radiant temperature (MRT) and universal thermal climate index (UTCI) to identify the outdoor thermal comfort. This software and methodology can be used for future developments to identify the UHI effect as a result of the completion of project and mitigation methods that can be used to negate the UHI effect and enhance the human comfort.*

Keywords: *Urban Heat Island effect, Outdoor thermal Comfort, Rhino 3D*

1. Introduction

With the rapid urbanization trends and industrialization, people started to move from rural areas to urban areas. This caused for an increase of the urban population and demand for more dwelling spaces. Growing cities had to developed either vertically or horizontally. That will cause for warmer climatic condition by blocking urban ventilation and absorbing solar radiation by their impervious materials (Mirzaei, 2015). According to United Nations report, 68% of world population is predicted to be increased by 2050 in urban areas. Specifically in Asia and Africa this increase might be close to 90%. Increase of urban population demand for more dwelling places by adding negative impacts such as urban sprawl, high carbon foot print and urbanization (Vuckovic et al., 2019). Demand for dwelling places and unplanned developments replaced the green cover and pervious surfaces by impervious surfaces such as bricks, concrete, tiles, bitumen, asphalt, etc. of buildings, roads and parking lots. Compared to the ambient rural areas, these materials have a significant thermal bulk properties and surface radiative properties. Therefore, natural environment and ecosystem is negatively affected by urbanization and industrialization (Cinar, 2015; Ranagalage et al., 2017;Aflaki et al., 2017). Different human activities and anthropogenic emissions effect to the atmospheric composition and high air

temperature. All these activities affect to the urban microclimate. Changed microclimate of atmosphere cause the phenomenon identified as urban heat island effect. This phenomenon can be identified from high air temperature in urban areas compared to suburban areas. (Anniballe et al., 2014; AboElata, 2017; Qaid et al., 2016; Aleksandrowicz et al., 2017). The maximum temperature difference between rural and urban areas can be high as 5 ^{0}C - 15 ^{0}C (Wanphen and Nagano, 2009)

A. Research on uhi effect in global context

Numerous studies on UHI have been conducted in international context. Studies have focused on the effect of surface reflectance on UHI in many researches. A study reveals that the roofing system is the main envelop element which is capable to increase temperature more than 30^0 C, than ambient temperature (Doulos et al., 2004). As mentioned by Levinson et al., (2005) initial reflectance of 0.04 of a built up roof is increased to 0.8 after coating with a smooth, black asphalt layer. Reflectance of a single ply membrane can be changed to 0.2 from 0.04 by applying a gray coating whereas with white coating it is changed to 0.8. Initial reflectance of 0.1-0.2 of bitumen with mineral surfaces can be modified by coating white to the top, which changes the value of reflectance to 0.65-0.7. Oleson et al., (2010) have observed white roofs have a substantial effect on urban temperature. These applications decrease the maximum temperature by 0.6K, minimum temperature by 0.3K and annual heat island by 33%. A research done by Bozonnet et al., (2011) have mentioned cool roofs can reduce the surface temperature by 10^0 C. According to Pisello et al., (2015) indoor operative temperature decrease up to 2.6^0 C and temperature of the external roof surface could be decrease up to 19.8^0 C by applying only cool roof membrane. Overall temperature will be reduced by 3.1^0 C with combination of two cool solutions.

B. UHI effect in local context in existing cities

Several researches have been conducted on climate changes and UHI effect in existing cities in local context Maheng et al., (2019) have conducted a research to identify the effect of urban greenery for urban heat island effect in Colombo city by a simulation method. it has been observed that average temperature in Colombo can be decrease by 0.1^0 C by increasing greenery up to 30%. Perera,(2014) has observed the effect of materials which used in street canyon to the urban heat island effect in Colombo. According to the results, highest UHI intensity has been recorded by aluminium cladding in commercial area as 2.87^{0}C whereas aluminium cladding in sea front zone had the lowest UHI intensity of 1.87^{0}C.

Emmanuel et al., (2007) have stated that the increasing heigh to width ratio cause decrease in the air temperature within the canyon. However, as a negative impact could affect the wind flow through the street canyon as well. Further, it is identified that physiologically equivalent temperature will be decrease about 10^{0}C by increase H/W ratio from about 1 to 3. Herath et al., (2018) have conducted research on implication on urban green infrastructure to enhance microclimate in tropical urban context. It has concluded that applying trees in curbsides, 100% green roofing, 50% green roofing, 50% green wall and combination of trees in curbsides+ 50% green roofs+ 50% green walls can reduce the temperature by 1.87 °C, 1.76 °C, 1.79 °C, 1.86 °C and 1.90 °C respectively. Accordingly, this suggests that the surface fraction has a contribution for changes in urban heat island effect.

C. Need of identifying the UHI mitigatory steps in proposed cities

Urban planners and researchers have identified the egregiousness of this phenomenon and have initiated research on

UHI effect of future developments and urban changes. According to (Amorim et al., 2020), future developments in urban areas cause to increase the air temperature due to the change of land cover by buildings and impervious materials. Rathnayake et al., (2020) highlight that future trends of anthropogenic heat need to be studied before implementing future developments as it has a crucial impact on UHI. Previous scholars mostly focused on UHI effect, parameters and mitigation methods for historical and developed existing cities. Internationally reseach has been conducted for developing and proposed cities as well for existing and historical cities to identify the microclimatic changes with new developments and their negative impacts such as UHI effect. In local context there is a research gap in simulation studies for developing and proposed cities to identify future microclimatic changes.

D. Research studies on UHI effect in future cities

Yi and Peng, (2014) have researched on effect of microclimate change to indoor and outdoor comfortability in 2012 and 2050. Future predictions have been conducted through computational modelling. Interaction of outdoor microclimate with indoor thermal performance of a building has been identified through series of numerical simulations and prognostic visualization. According to results, outdoor microclimate was predicted to be increased by 1.7^0 C from 2012 and indoor thermal condition by 1.8^0 C. After applying passive cooling methods indoor thermal conditions were predicted to be decreased about 1.2^0 C and 1.4^0 C in 2012 and 2050 respectively. The research done by Amorim et al., (2020) evaluated the consequence of land use changes on summer temperature. Land use changes in 2030 and 2050 were simulated by computational modeling. Results depicts that the land cover changed by buildings and impervious surfaces cause to increase the air temperature by 0.29 °C and 0.46 °C in 2030 and 2050 respectively in Stockholm. Further, it is mentioned these data are supportive for urban planners to deal with urban adaptation to climate and good exchange of fresh air will help for drastic change in air temperature.

Fahmy et al., (2020) have discussed present and future microclimate change effectiveness to indoor comfortability with new suburban residential developments. Envi-met and design builder simulation methods were used to predict the microclimate change with and without of urban canopy green from present to end of 2080. Results signified that, applying materials such as green roof and green facades for construction of building envelope and design surrounding with greenery help to improve outdoor microclimate and energy consumption while maintaining indoor thermal comfortability. Naboni et al., (2019) have conducted a study on digital workflow to quantify regenerative in urban areas in the context of climate change. The research focus on climatic change in future with new developments. Digital workflow has been developed through rhino 3d software and grasshopper. Biophilia, outdoor human thermal comfort, energy use and production and daylight performance are the key factors considered based on data exchange and synergies across the different tools.

E. Experimenting simulation to identify UHI mitigatory steps in future cities in local context

The research was initiated to identify the potential of using simulation studies to identify the potential UHI effects in future cities of local context and to find mitigatory solutions. This research will focus on the methods and software that can be used to identify the effect of UHI and climatic changes as a result of future developments. Methodology of this research can be used for future studies to do quality and effective

developments. In Sri Lanka, proposed Port city development is the largest city development which is proposed as an extension of the central business district Colombo (CBD). As the port city is in the developing stage, still there is an opportunity to simulate the microclimatic change that could take place after the completion of the project and take relevant decisions and methods to mitigate the negative impact. Therefore, Colombo Port City was selected as the case study to continue a pilot study. The paper presents the findings of the pilot study conducted to establish a simulation work flow to identify the UHI effect for a proposed city in local context.

F. Simulation software applications

Numerical modeling methods are used in order to analyze UHI effect. There are several different softwares available to carry out the modelling. Some software solutions have merged different models to get a better performance while others use the traditional computational simulation methods. Softwares vary with its capability of detailed building performances, time taken for simulation and analysis methods. Envi met, ADMS temperature and humidity model, RayMan, CitySim Pro, Ladybug Tools and Autodesk CFD, Ecotec, CEA (City energy analysis), Urban Modelling Interface (UMI) are some of urban building energy modeling softwares which are used to calculate UHI effect (Ferrando and Causone, n.d.) ("Towards urban building energy modeling: a comparison of available tools," n.d.).

CitySim numerical modeling software aids in quantifying the energy demand at the outdoor radiative environment and in urban scale ("CitySim Software," n.d.). City energy analysis (CEA) software is developed to assess energy system rationalization and urban energy use. CEA can be used to assess diverse urban scenarios based on, carbon emissions, energy and financial criteria. Urban Modelling Interface (UMI) is a Rhino based interface. It calculates embodied energy, daylighting, operational energy use and walkability at the urban scale. ADMS-TH is an integral operational model. It facilitates to analyse the relative humidity within urban areas and air temperature change caused by land use change. Rhino 3D and ladybug tools are used to sky view analysis, solar radiation studies, outdoor thermal comfort analysis, urban heat island analysis and more ("Referring to Rhino/Grasshopper in scientific papers - Research Projects - McNeel Forum," n.d.). Envi-met is one of the widely used microclimatic simulation tool. Comparing with all numerical simulation tools, ladybug is linked with lot of supportive software and explored its output in a wide range. Therefore, considering the quality and accuracy of outputs and other offered benefits, ladybug numerical simulation tool in grasshopper has selected for this research ("Ladybug Tools | Dragonfly," n.d.). Rhinoceros 3D is a computer aided design application software. This used as the interface to develop the geometry of domain for the energy simulation. Ladybug tools are the numerical simulation tools which used for this research ("Ladybug+Honeybee for Grasshopper, Baker Lighting Lab," n.d.). These tools work in grasshopper interface which act as the main inter connector of the conceptual 3D model and simulation tools. Ladybug tools are mainly divided as ladybug, dragonfly, butterfly and honeybee. These individual tools collectively collaborate for the overall simulation. Only ladybug, dragonfly and honeybee tools have used for the simulation of this research.

Ladybug tool is allowed to import and analyze weather data in grasshopper. It helps to develop the urban and rural weather data as well as historical and future weather data for simulations. Ladybug is the tool which used to visualize the data of every simulation tool. There are different types of graphs available as per the requirement. These graphs are allowed to more detailed for better understanding.

H. Dragonfly tool is used to develop the city characteristics more accurately. It models large scale climatic phenomena such as climate change, urban heat island and local climate factors such as topography. Urban weather generator tool is a component of Dragonfly. It morphed the rural weather data to generate new urban weather file in "epw" format. It is the main component which need to identify the UHI effect. Honeybee tool used to create honeybee zones in 3D model for energy simulation. It connects validated simulation engines to grasshopper such as Radiance, EnergyPlus/OpenStudio for building energy and comfort, daylighting and lighting simulation. Workflow simulate the mean radiant temperature (MRT) and Universal thermal climate index (UTCI) to measure the outdoor thermal comfort perceived by pedestrian.

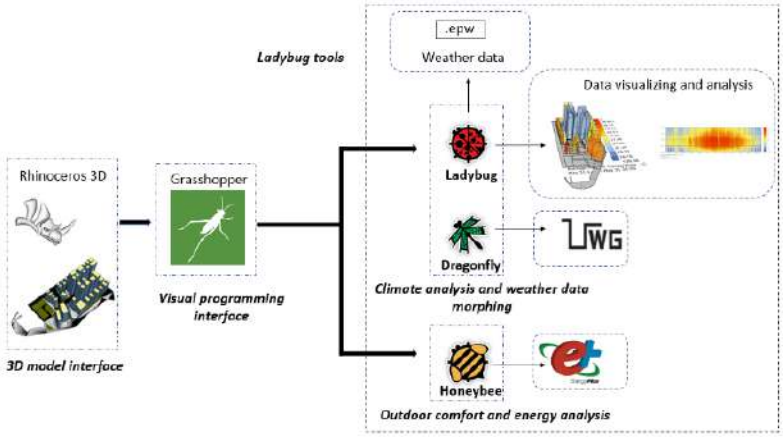

Figure 1 -Interconnection between Rhinoceros 3D, Grasshopper and Ladybug tools

This 3D modeling tool become one of the standard tools for designers and architects. Model can be developed in the Rhinoceros interface or can be imported from SketchUp or Revit softwares. Grasshopper is the interface of ladybug tools and other energy plus simulation tools. Case study domain can be developed in the Rhinoceros 3D interface. Auto cad drawing should be imported to Rhinoceros 3D to develop the building blocks according to the rules and regulations of the selected domain. Buildings and land use properties such as roads and pavements introduced as separate layers in Rhinoceros interface. This model is linked with ladybug tools for the simulations through the grasshopper interface. Grasshopper is a visual programming language that is a plug-in of Rhino 3D for more complex simulations in energy modeling. More specifically researches about climatic changes and UHI effect used Lady bug tool set for energy modeling. Each component has specific energy simulation. Final simulation is done by connecting this toolchain by assembling separate script. Building energy simulation is done by energy plus, RADIANCE, Daysim and openStudio engines. It is included in honeybee component. Outdoor microclimate conditions were presented as MRT and UTCI values which represent the outdoor thermal comfort. Results visualizing is done with the help of ladybug plug-in. As the overall simulation is a combination of individual tool chain, different scripts and workflows has to be developed. Case studies will be conducted in with several phases. For each phase separate script has to be developed.

2. Methodology

As the research is done based on a predictable and imagine situation, conducting a pilot study is needed to identify the application requirements and possible errors. Therefore, a pilot study was done for a small-scale building context to be familiar

with the new software and to confirm that all workflows are feasible to be implemented. After finalizing the workflow of each simulation phase, surface urban heat, canopy layer UHI and boundary layer UHI has been calculated. Getting familiarized with this software solution took a steep learning curve as the pilot study had to do be done with lot of experiments to develop the correct

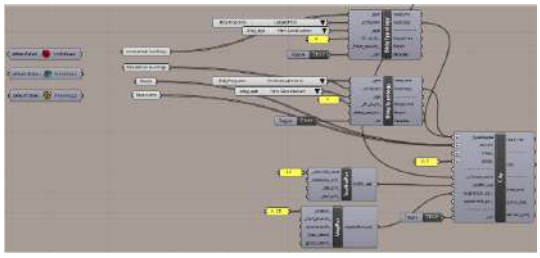

Figure 2 - Urban heat island simulation workflow

workflow. A considerable time was taken to study the software and identify all the simulation errors and create the correct workflow for each calculation. An area of the Port city Colombo was selected as the case study as it is the largest proposed city in Sri Lanka. By running each workflow for each scenario in the pilot study, temperature differences and effectiveness of material and greenery on surface UHI, boundary layer UHI and canopy layer UHI effect was identified.

A. Urban heat island simulation workflow

This script was developed to simulate the UHI effect of port city after the completion of project. Ladybug plug-in and dragonfly plug-in was utilized for the simulation. Output is taken as temperature differences and the results highlighted that there is a UHI effect in Port City.

B. Modeling the selected domain characteristics

Dragonfly city component is the feature that is used to develop the urban context. It is linked with several parameters which needed to model the actual context of the urban area. According to the UHI definition, it is a temperature difference between urban and suburban areas. Weather data of the urban area is morphed with reference to the rural weather. Building volumes are selected as Breps in grasshopper. Each building volume is moderated with its typology. Building typology component can group the buildings in the context according to building program, age, floor heights, fraction canyon. Each building typology is connected to the Dragonfly city component. Roads and pavement list of Breps, tree fraction, grass fraction, climate zone, traffic parameters, vegetation parameters and pavement parameters are the inputs which were needed to develop the urban city context. These inputs can be separately more detailed by using its components. Building typology factors and greenery has input according to the regulations of port city. Weather data was taken from EPW weather file and was developed according to the weather conditions of port city. Output of dragonfly

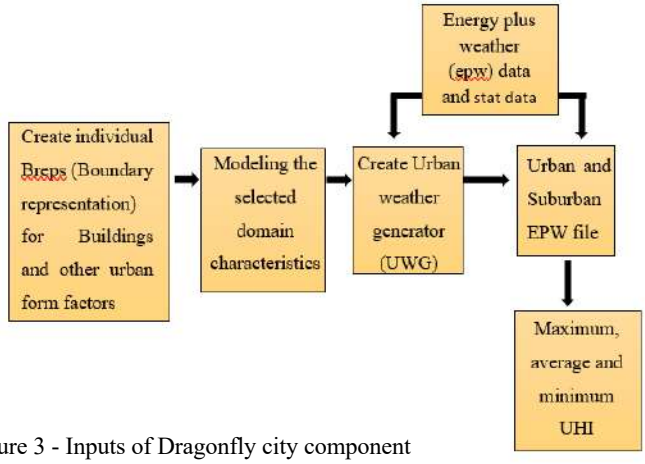

Figure 3 - Inputs of Dragonfly city component

city componentlinked to the urban weather generator model to simulate the UHI effect.

C. Create urban weather generator model

Palme et al., (2019) has developed Urban weather generator model by coupling an atmospheric model with a Building Energy Model (BEM). Urban microclimate is account by urban weather generator dragonfly plugin. UWG change the microclimate in urban canyon compared to the conditions of

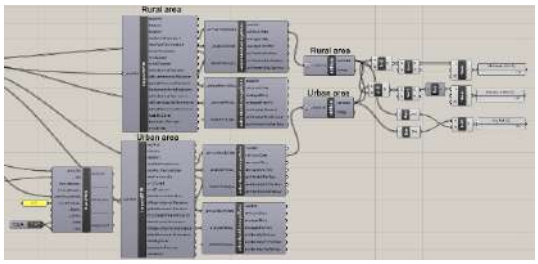

Figure 4 - Urban weather generator (UWG) model

weather stations in outside of the city. Future weather file generates by synthetic weather generator by processing UWG. UWG model urban heat island and calculate hourly values of urban air temperature and humidity. As the UHI definition, it is the temperature difference between urban and rural area. Therefore, temperature difference is calculated from the values of energy plus weather data of urban and rural area. By input all the geometric data, UWG run to simulate UHI value and simple custom Grasshopper code filters give average, minimum and maximum UHI values.

D. Result visualization

Ladybug plugin work as a data visualizing tool. Dry bulb temperature of rural and urban, outdoor thermal comfortability, and other relevant data can be presented as graphs which is easy to compare the differences to get a better understanding. Average data can be presented as hourly, daily and monthly in graphs. Building surface variations can be displayed by changing the colors in the model.

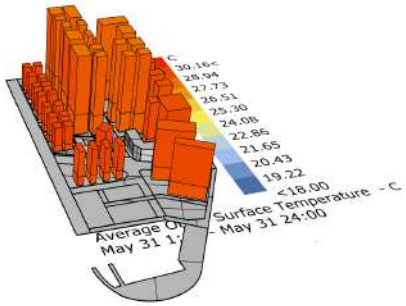

Figure 5 – Results visualization

E. Material and greenery variation workflow

Honeybee (HB) is the grasshopper plug-in which used to change surface materials and greenery in buildings. Honeybee create HB Zones in building context. Then it is divided into individual surface as roof, walls and floors. Materials can be easily applied to each surface.

HB provides opportunity to apply different materials in different surfaces in the same building when individual surface are select by sliders. Figure 6 shows the set of surfaces selected to import surface materials for this research. Likewise for other materials applications, relevant building surface should be selected.

In honeybee, some materials are available in HB Library. And also, materials can be created according to the requirement. Actual property values need to be added when developing the materials. Individual surface material and ratio can be changed in this plug-in. Material creation has another set out workflow. Individually created materials has to be added to HB library before using.

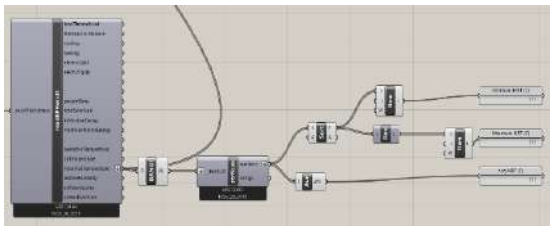

Figure 6 - Surface selection from HB zone workflow

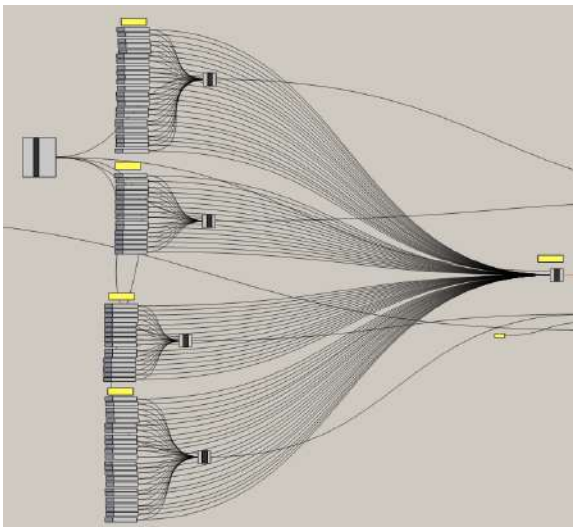

Figure 7 - Universal thermal climate index simulation workflow

F. Outdoor microclimate analysis workflow

Outdoor thermal comfort is simulated by another component of Honeybee plug-in. Mean radiant temperature (MRT) and universal thermal climate index (UTCI) are the metrics used to define the outdoor thermal comfort. View factor of every surface is calculated by the indoor view factor component. It gives the view factor info

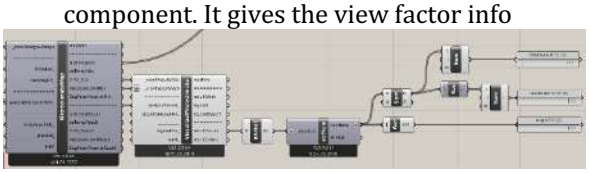

Figure 8 -Mean Radiant Temperature analysis workflow

which needed to simulate the outdoor comfort recipe component. View factor mesh and outdoor surface temperature are the other two inputs which needed for outdoor comfort recipe component. Finally, microclimate map defined universal thermal climate index. "Read EP result" component gives MRT values for simulate outdoor thermal comfort of pedestrians.

3. Discussion

The research is conducted on a proposed city. Therefore, only the zoning and rules and regulations has been completed up to now. The constructions are in the infrastructure stage at the moment of this research done. Therefore, building designs are not finalized. As the Port city authority is restricted giving data even for an academic purpose due to high security and commercial reasons, data has been collected to an extent. Because of that, by using zoning map and rules and regulations, 3D model has to be developed in to its maximum capacity with the help of Rhino 3D for the pilot study. As the simulations of this study based on the software, it should be more accurate and suitable. But there can be limitations in performance in student versions. Finally, the workflow and the scripts which were developed in this research can be used for proposed and future developments in the local context. And also, the results can develop more detailly by modifying the scripts. This method can be used mitigate the climate changes and UHI effect which will be emerged due to the future developments and proposed cities. According to above process, the method which can be used and the effect after the completions of the projects can be identified. Therefore, using this method is an important factor to protect the atmosphere and enhance the human comfort in future.

4. Conclusion

Urban heat island effect and climatic changes in urban context is a suffering problem in present. Therefore, researches have done several studies to mitigate the current situation and enhance the human comfort. In local context, researches have done only for existing cities. In other countries, they have conducted several researches regarding proposed cities. Due to the rapid

developments in urban context, climatic conditions can be worst in future. Therefore, there is a need of doing a study about the effect of climatic condition and UHI effect before implementing a project in local context. This research was done regarding the software and the methods that can be used for those studies. Rhino and grasshopper has been identified as the most suitable software and the methodology is developed to the mitigate the UHI effect in this research. This research will help in advance to protect the atmosphere and mitigate the UHI effect from future developments and proposed cities by identifying the most suitable materials and mitigation methods.

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Acknowledgement

I would like to express my great appreciation to Mrs. HT Rupasinghe for their valuable and constructive suggestions during the planning and development of this research work. I would also like to thank the staff of the Department of Built environment and spatial science at KDU, for their valuable and precious time, which is generously and highly admired.

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Investigating the Thermal Comfort and Well-being of Differently Abled War Veteran's Housing in Sri Lanka

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Abstract*: Wellbeing inindoor built environment has become a crucial research topic in relation to thermal comfort which help to improve sustainable builtenvironments. Thus, thermal comfort requirements for humans is a main consideration in building designing.It's important to consider comfort and wellbeing of people with physical disabilities. Thus, this research was conducted to investigate the indoor environment quality of spaces in relation to the thermal comfort in physically disabled war veterans' housingin Sri Lankan context.Onfield investigation was carried out to obtain physical measurements of microclimatic parameters of interiors including indoor temperature, relative humidity and air velocity. Secondary data were collected through semi structured interviews.*

Results explicitly prove through onfield investigations that the mean value of the operative temperature is 32.2°C, which is above the ASHARE 55-2013 standard for comfortable thermal conditions.Mean wind velocity is 0.25m/s, is low, as there is a high operative temperature adequate interior ventilation needs to be provided. The Humphries comfort equation states the required comfort temperature is 28.92°C, the obtained mean operative temperature is more than this comfort temperature, proving the interiors are overheated. Most common adaptive behaviour of the veterans are switching fans on and moving towards open spaces. Results also indicate that there is a psychological link with thermal adaptive behaviour as these veterans opt to remain in free outdoor spaces rather than confined spaces as their battlefields. Thus, this research paper highlights on the thermal conditions needed for interior spaces for disabled war veterans and in the long-run contributing to regulations to add developments to the National Policy on Disability in Sri Lanka.

Keywords: *Thermal comfort, physically disable people, indoor built environment*

1. Introduction

Thirty years of civil war in Sri Lanka resulted in massive human and social costs as many soldiers from tri-forces suffered from traumatic experiences which caused immense physical, emotional, and psychological distress. Thus, rehabilitation of differently abled war veterans is a prime national obligation.

The vision of facilitating a comprehensive rehabilitation process was fulfilled by originating the Ranaviru Sevana Rehabilitation Center in the year 1990. This need was further expanded by establishing seven long term caregiving homes for war veterans in varying locations of the country.

These shelters for war heroes are for residential patients with spinal cord/head injuries and amputees with one or more limb losses mainly under knee and the rehabilitation process prioritizes life-long health care with physical, mental, social and spiritual well-being. Although the built

environment supports to accommodate essential functions of these centers with a focus on physical well-being the major challenge of these centers is on mental health treatment as many of the residents suffer from Post-Traumatic Stress Disorder (PTSD). Thus, informs the importance of investigating the spatial and microclimatic ambience of these centers in facilitating the psychosocial rehabilitation process which contributes to life-long health and well-being of the differently abled war veterans of Sri Lanka. Thus, the primary objective of the research is to experimentally investigate indoor environmental quality of occupied spaces in relation to thermal comfort and secondary objective is to understand the user perception on spatial ambience of the built environment.

2. Background and Literature Review

The consequences of war-related trauma cause enormous suffering and problems adjusting to post-war life in many parts of the world (Odenwaldet al.2007). War has a catastrophic effect on the health and well-being of nations (Murthy & Lakshminarayana, 2006). The World Health Organization (WHO) defines mental health as a state of well-being in which the individual realizes his or her own abilities can cope with the normal stresses of life, and can work productively to make a contribution to his/her community. War trauma negatively affects the mental health parameters. The civil war with the LTTE in Sri Lanka was brought to a halt in 2009 by the tri-forces of Sri Lanka. However, this victory came with a massive human and social cost. Following the thirty year armed conflict in Sri Lanka many combatants underwent traumatic experiences that caused immense physical, emotional, and psychological distress. These experiences were events outside the range of usual human experience.

The number of persons with physical disability among defence personnel is estimated as 20,000(Asia Development Bank, 2005). These were the numbers by the year 2005, the war ended in 2009, thus the projected number of disable veterans is higher. Rehabilitation is an ecological approach that aims at the long term recovery and maximum self-sufficiency. The World Health Organization in 1996 developed a consensus statement on psychosocial rehabilitation. The WHO defined psychosocial rehabilitation as a process that facilitates individuals who are impaired, disabled or handicapped by a mental disorder to reach an optimal level of independent functioning in the community. In order to achieve optimum level of independent functioning, the long term caregiving homes for these disabled war veterans need to promote optimum living interior conditions. Built environment has an effect on physical and psychological wellbeing of occupants (Hashemi S, 2019) Thus, it is of paramount importance to prioritize the built environment and the environmental health factors on both the physical and mental health of these disabled war veterans.

Many researchers have found that human well-being depend on social interaction, genetics as well as physical environment (Hashemi S, 2019). According to the model of built environment and well-being which introduced by Clements-Croome and Wang (2016), thermal comfort is one of main influenctial factor coming under indoor built environment.

The needs of standards on thermal comfort for people with disability (also the aged) had been identified bytheInternational Standards Organisation (ISO) through their system of international voting. Parsons. K, (2005) has emphasized that, requirements of thermal comfort are similar for the people with disability and without disability. “There were no significant differences found in the Thermal Comfort requirements of people with physical disabilities and people without physical disabilities” (Webb L.H, 2000).

Thermal comfort has been defined as "the condition of mind that expresses satisfaction with the thermal environment" (ISO 7730, 1994). It is satisfactory perception of thermal environment which assessed subjectively.Variables of thermal comfort can be categorized into environmental and physical variables. The environmental variables vary from: air temperature, air relative humidity, air velocity and mean radiant and two human variables: clothing insulation and human activity.

There is a limitation in research with regard to the preffered thermal environments of the disabled in Sri Lanka. No comfort range standards are established for this group of individuals. Thus, this paper explore the thermal environment requiremnts for the differently abled people which special reference to the war veterans as there is an added psychological component which contribute aspects regarding thermal environments. This paper can serve as a stepping stone for contributing standards in the policy developoments to the National Policy on Disability in Sri Lanka.

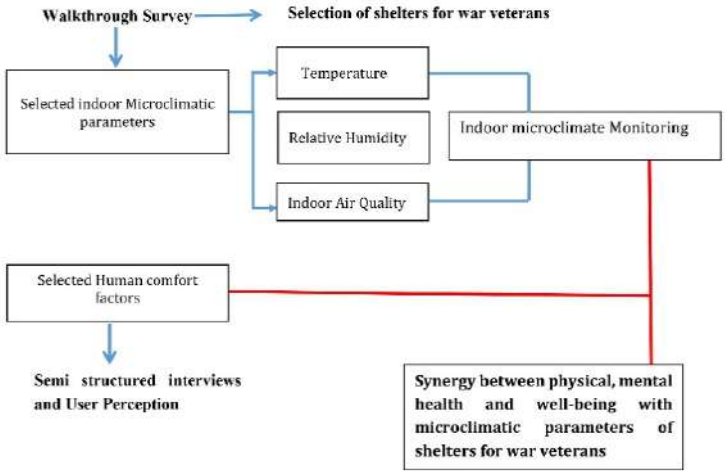

Figure 01:Graphical Representation of the Research Design*Source: By Author*

3. Methodology

Research design is composed major steps as follows;

a) Literature survey
b) Walkthrough survey: Filtering process of case study shelter for war heroes- Abimansala Anuradhapura
c) Onsite experimental investigation
d) Semi structured interviews

The selected case study is Abimasala in Anuradhapura. The population sample size is 53. The research was conducted in two parts- an on field investigation was carried out to obtain physical measurements of the microclimatic parameters of the interiors, Table 01 illustrates the equipment used to obtain these measurements.All the measurements are taken in the month of August 2019. Semi structured interviews were carried out to explore the perception of the veterans in these veteran care homes.

Table 01:Equipment Used to Obtained the Measurements Source: By Author

	Parameter measured	Equipment used	Place of measurement
01	Indoor temperature	HOBO Temp/ Temperature data logger	In two locations inside the veteran home (bed rooms)
02	Relative Humidity	HOBO humidity/ Humidity data loger	In one place immediately inside the building.
03	Wind Velocity	Anemometer	In the same place where the HOBOs were placed indoor.

The seated individuals were subjected to the measurements under the standards of ANSI / ASHRAE 55-2013 and ISO-7730 while the indoor thermal microclimatic parameters were obtained within 1m from an individual and of a height of 0.6m from the floor. The time period for the measurements were every 10 seconds(ISO, 2001). The operative temperature and mean radiant temperature were calculated using standardised formulas.

For the second part of the research, semi structured interviews were carried out figure out the adaptive measures these veterans undertook for maintaining thermally stable environments.

4. Results and Discussion

A. *Metabolic rate and clothing insulation*

During the process of the field investigations the commonly worn clothing type is sarong with a sleeveless or a t-shirt with a short sleeve which are typical clothing types in Sri Lanka. Their foot-ware is rubber slippers, whilst most of the veterans were barefoot. The clo values used for identifying the levels of clothing insulation (*Iclo*) were based on the evaluation values set by ISO 9920-2004, ASHARE standards 55-2004 and 2013. For obtaining the clo values, the war veterans were subjected to a seating position. The obtained clo values were as follows with regard to the clothing levels.

Table 02:Clo Values related to the clothing levels Source: By Author

Maximum	Minimum	Average	Most common Clothing items
0.38	0.15	0.33	Sarong and shirt

According to the ASHARE 55 2013 specify standards, there are no specific standards for disabled people. The provided mean clothing summer standard is an average of 0.5clo, while the veterans in Sri Lanka reflect an average value of 0.33clo which is lower than the ASHARE 55 2013 standards. Along with the clo values, the metabolic rate is also a determinant of thermal comfort as a personal factor. The metabolic rate is defined as the energy which the body produces due to various activities. It is important to note that the metabolic rate reduces with disability factors **(**Gomas A.S, Vigario P et.al, 2014). This is aided with the fact that the physical measurements of the veterams were obtained whilst they were seated. Thus, due to the aspect of the majority of veterans not being able to move, the metabolism rate was 1.0 which indicates seated, writing or reading. Thus, we can consider 1.0 as the metabolic rate for the veterans. The obtained metabolic rate and the clothing insulation value (Iclo) can be used to identify the Predicted mean vote(PMV), this aspect is not investigated in this paper.

B. *Thermal comfort parameters- indoor microclimate*

In spaces where there is a significant mass within the interiors the air temperatures can vary with the mean radiant temperatures. This aspect can be very useful to assess the thermal comfort of the occupants within the interior spaces. Thus, the operative temperature (Top) is calculated as it is a vital measure of human comfort which is obtained from the values of air temperature (Ta), mean radiant temperature (MRT) and the wind velocity. The formula which is used to calculate the operative temperature is as follows.

$$Top = \frac{Ta\sqrt{10v} + MRT}{1 + \sqrt{10v}}$$

The variation of the interior operative temperature and wind velocities in all the interior spaces of the veteran care homes were investigated. The mean value of the operative temperature is 32.2°C and the temperatures range from 29°C to 36°C, which a majority of temperature within the range 30°C to 33°C. These are aided by low velocity, as a majority of the frequency of the range of the wind velocity is between 0.06 to 0.3m/s. The mean wind velocity is 0.25m/s. As the wind velocities are very low, the operative temperature tends to increase and this proves that the level of ventilation received into the interiors is not adequate and
the design measures need to be undertaken to improve this aspect.

Mentioned previously are the existing temperatures of the interiors of the veteran care homes. However, these need to be compared against the standard thermal comfortable temperature ranges. The ASHARE 55-2013 standard for comfortable thermal conditions, the temperature within the range of 19- 28°C at 80% humidity levels. There are established thermal comfort ranges in some tropical countries such as in Thailand (Busch et al, 1992) the comfort temperature range is between 25.6°C-31.5°C.

Studies have proved that there is a correlation between this comfort temperature and the outdoor temperature (Humphreys, 1992 and Nicol, 2004). According to Humphreys (1992) there is a relationship between the comfort temperature and mean outdoor temperature for naturally ventilated building. The equation is-
Tc = 0.534Ta + 12.9.
The mean outdoor temperatures for Anuradhapura is 30.1°C. Thus according to the abover equation, the comfort temperature for these places include 28.92°C. The above mentioned comfort equation proves that in the higher outdoor conditions will have higher levels of comfort temperatures. Although the required comfort temperature is 28.92°C for these places, the obtained mean operative temperature through measurements indoors is 32.2°C. This proves that the interior spaces are overheated and there is a need to lower the temperature of the indoor spaces with the proper provision of natural ventilation.

For the next part of the research, actions of the war veterans were explored to understand the measures they undertake for maintaining their comfort levels in the interiors. These adaptive behaviours were investigated through semi-structured interviews. There is a theory defined as the adaptive comfort theory which explains the adaptive behaviors people undertake in order to adjust to existing micro-climatic conditions (Humphries and Nicol, 1998).

The results obtained with regard to these adaptive measures are two-fold as most veterans preferred the usage of a mechanical ventilated system such as switching on fans, whilst the other common option included the opening of windows and moving slowly into open spaces. The movement of these veterans are limited due to their disability,

thus they prefer open spaces within close proximity. Another reason attributed with

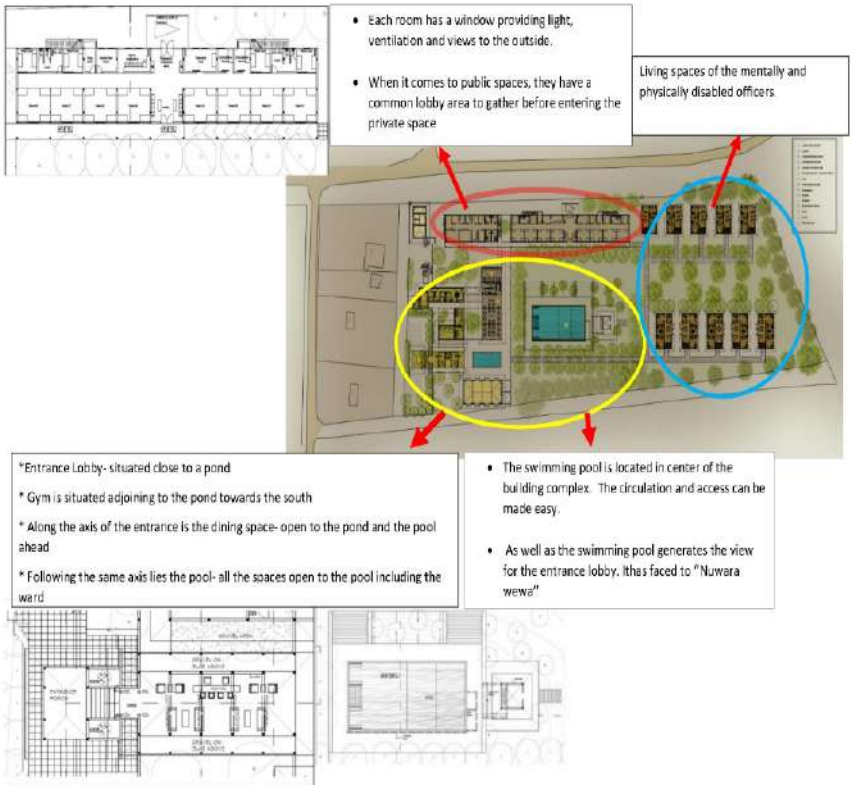

Figure 02: Connection ofIndoor and Outdoor Spaces in Abimansala, Anuradhapura Source: By Author

the preference of these open spaces is the psychological situation of these veterans. The veterans explain that they don't prefer to stay for prolonged hours in close enclosed spaces as they feel traumatised by feelings of enclosure with related to their traumatic experiences of being held captive during the war times. Although their movement is limited, they prefer to walk, and move in wheelchairs in outdoor and semi-outdoor green spaces has mentally they feel free opposed to the confined battlefield experiences. Results indicate a link of adaptive to thermal conditions with psychological conditions with these veterans. These aspects can be justified as (Thorosson et al, 2004 and Spangnolo et al, 2003) state that thermal preference is also dependent on psychological factors such as perception and culture. Futhermore, (Rajapakse, 2019) proved that elderly population in Sri Lanka opted to open windows for better thermal comfort conditions as opening of windows is a cultural habit of Sri Lankans. The Abimansala in Anuradhapura does have several outdoor and indoor connecting spaces, as illustrated in the Figure 02, however, several more interventions need to be implemented in order to achieve prescribed thermal comfort standards.

There is a limitation in the design of the inclusion of open spaces and semi-outdoor spaces in architecture for the disabled (differently abled) in Sri Lanka. Thus, more needs to be implemented in this area of research for the differently abled population in Sri Lanka. As the physical aspects and psychological components indicate a close relation, more effort needs to put to identify developments for the differently abled community of Sri Lanka. This will aid in the policy development process for adding comfort ranges for the disabled with regard

to the National Policy Development in Sri Lanka.

5. Conclusion

This research explored the thermal comfort aspects of war veterans in Sri Lanka. Several conclusions can be made from this research paper, these include,

- The mean value of the operative temperature is 32.2°C, which is above the ASHARE 55-2013 standard for comfortable thermal conditions, the temperature within the range of 19- 28°C.

- The mean wind velocity is 0.25m/s, which is low and as the operative temperature is high, the level of ventilation received into the interiors is not adequate and the design measures need to be undertaken to improve this aspect.

- According to (Humphries, 1992) comfort equation the required comfort temperature is 28.92°C for these places, the obtained mean operative temperature through measurements indoors is 32.2°C.

- This proves that the interior spaces are overheated and there is a need to lower the temperature of the indoor spaces with the proper provision of natural ventilation.

- According to the results of the adaptive behaviors of veterans, a majority preffered for the usage of fans and means of having access to open spaces. This reason attributed with the preference of these open spaces is the psychological situation of these veterans.

- There is a link of adaptive behaviours to thermal conditions with psychological conditions with these veterans.

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