KDUIRC
INTERNATIONAL RESEARCH CONFERENCE

14TH INTERNATIONAL RESEARCH CONFERENCE

" Security, Stability and National Development in the New Normal "

09TH - 10TH SEPTEMBER 2021

BUILT ENVIRONMENT AND SPATIAL SCIENCES

PROCEEDINGS

GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

14TH INTERNATIONAL RESEARCH CONFERENCE

SECURITY, STABILITY AND NATIONAL DEVELOPMENT IN THE NEW NORMAL

Built Environment and Spatial Sciences

PROCEEDINGS

General Sir John Kotelawala Defence University

Ratmalana, Sri Lanka

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Vice Chancellor, General Sir John Kotelawala Defence University

Keynote Speaker, Mr. Lalith Weeratunga Principal Advisor to H.E. President Gotabaya Rajapaksa, Secretary to the Ministry of Defence, General (Retd.) Kamal Gunaratne, DVC Administration and Defense, Brigadier Wipula Chandrasiri, DVC Academic, Prof Sanath Dhammika, Deans of the respective faculties, Centre Directors, Academics, Senior Military Officers, Administrative Staff, Students and all distinguished guests who are connected with us in the cyber space.
Good Morning to you all!

It is indeed with a great sense of responsibility that I deliver the welcome address at this 14th consecutive international research conference of General Sir John Kotelawala Defence University held on the timely theme, 'Security, Stability and National Development in the New Normal", at one of the most crucial times of our history.

To begin with, let me very warmly welcome our chief guest and keynote speaker, Mr. Lalith Weeratunga, the principal advisor to HE the President Gotabhaya Rajapakse. Of course, Mr. Lalith Weeratunga is not at all a stranger to KDU. He is one of the great personalities who clearly understands the role played by KDU for the betterment of the nation and who has long been assisting us in numerous ways to develop this institution to what it is today. As I remember Mr. Lalith Weeratunga was the keynote speaker of our 6th research conference in 2013. Sir, your keynote on our theme, "Sri Lanka as a Hub in Asia: the Way Foreword" still reverberate in our minds even after 8 long years.

And it is a remarkable coincidence that I welcome you once again to deliver the keynote address on our current theme, 'Security, Stability and National Development in the New Normal", which highlights the importance of stability created by the development and security nexus in the context of emerging new threats to national, human, and global security. Sir, we are looking forward to listening to your words of wisdom today as well.

Mr Weeratunga, it is also remarkable that eight years ago, you were accompanied by the Secretary Defence during that time, who has been destined to be President of our country today, H.E. Gotabaya Rajapaksa, and today you are accompanied by the present Secretary Defence and the Chairman of our Board of Management, General (Retd.) Kamal Gunarathne, and I am indeed honoured to welcome General Kamal to this conference as the Guest of Honour because he has been a tower of strength for KDU at this crucial time of its history.

Let me also welcome all distinguished invitees including the Tri-Service Commanders and other BOM members including the Chairman of the UGC, distinguished members of the diplomatic corps, Vice Chancellors and academics from other universities, senior tri-service and police officers, and national and international participants joining this event on line.

Ladies and gentlemen, this year's conference is significant to us at KDU on several accounts. First, 2021 is the year in which we mark the 40th year of KDU's existence in the higher education landscape of Sri Lanka, and we are proud of the role we have been playing therein, whilst continuously growing in its stature as a national university doing its call of

duty towards the nation with fullest commitment and dedication.

Secondly, this year's conference is the one that we hold under the most trying circumstances in our history. Last year too, we conducted our research conference in a hybrid mode due to the first wave of the COVID 19 pandemic that took us all by surprise.

But we hoped that we would be able to conduct the 2021 conference freely and in the usual glamour. But this year, it turned out to be even a worse scenario with the third wave of the pandemic hitting us harder. So we consider that this is a more challenging test of our resilience as the nation's defence university.

Ladies and gentlemen, we always believe in the dictum that a quitter never wins and a winner never quits. So we were determined to challenge the challenges, how hard they may be. And we ensure the continuity of the conference adjusting and amending the circumstances, while taking the highest precautions against the pandemic scenario. We were able to slowly but steadily accept the prevailing danger, assess the situation realistically, and to see the best options for the best interest of our University. Therefore, we finally decided that this year's conference will a hybrid one with a major virtual orientation.

Ladies and gentlemen, the reason why we conduct this conference somehow or the other is because of our belief that we need to set an example for the nation to stand on its feet at times of crises. We as a nation cannot afford to continue to play the waiting game for ever. As our theme highlights, we need to find ways to ensure security and national development in the new normal adjusting ourselves to the new normal conditions sooner than later.

And thirdly, we believe that this is the time in which a nation's intellectual community must come forward to engage in serious and meaningful research to help overcome innumerable issues and problems that crop up in diverse fields such as defence and security, economics, science, technology and engineering, medicine and health services, management, social sciences and humanities, law and so on and so forth. It is the responsibility of a university to create the necessary environment and enabling grounds for important research outcomes, which the nation yearns for.

Ladies and gentlemen, we are glad that the intellectual community of the country has very positively responded to our initiative. Despite some adverse comments and criticisms of KDU and its role in higher education in Sri Lanka from certain quarters in recent times, the large majority of fair thinking academics, professionals and ordinary people are with us fully, and that is evident from the large number of research papers submitted by researchers from all over the country representing various higher educational institutions.

Despite the difficulties in adjusting to the online mode, the organizers of the KDU international research conference have done their best to maintain the quality of the conference in the highest level. They intend to set the tone to initiate more collaborative research to face new global challenges. As I always point out these types of research conferences are ideal platforms to make connections nationally and internationally for mutual benefit.

I hope that authors of KDU and various other local and international universities will take the opportunity to interact and develop friendly relationships, establish networks, and explore opportunities to embark on productive research collaborations.

While assuring our commitment to providing best opportunities for research collaborations, I wish all the very best for the presenters and hope you will enjoy every moment of this academic fusion. Thank you.

Keynote Address

Mr Lalith Weeratunga

Principal Advisor to His Excellency the President of Sri Lanka

Secretary, Ministry of Defence, Chief of Defence Staff and Commander of the Army, Commander of the Air Force, Vice Chancellor of the KDU, Distinguished academics, Honoured guests, Friends, *Ayubowan!*

Once again, I am delighted to be with you this morning at this research conference. It gives me much pleasure to be at the KDU because it is one of the best universities we have in Sri Lanka. Since of late, there have been much attack on and criticism of the KDU. That's because the KDU is doing well and has brooked no nonsense. With a village background, my mind goes back to a famous Sinhala saying, which means "only those mango trees that have sweet fruits are attacked."

The entire world is undergoing a massive reorganization with the COVID-19 pandemic, and the traditional themes and arguments in security seems rather irrelevant in the present context. "Security, Stability, National Development in the New Normal" is a timely theme, giving us much food for thought in terms of the advancement of a country like Sri Lanka. If you take the first component, security, the bottom line of security is survival. *Survival,* is based on a number of factors. Barry Buzan, the veteran in international security rejected the practice of restricting security to just one sector and defined it as "a particular type of politics applicable to a wide range of issues."

As eminent representatives of the security sector, you are aware that the concept of security can somewhat vary from one country to another. When Mexico's major national security threat has remained to be organized crime for quite some time, Afghanistan's has been religious extremism. For a country like Somalia, it is the inbuilt corruption into their governance. For some countries, it might change abruptly. A few days ago, we all saw corruption and mismanagement which was the major security threat of the African nation Guinea, getting substituted by another – an armed unrest. In spite of these differences, almost all countries in the world have developed a commonality during the past year, where the health insecurity assumed a major role over and above all others.

The COVID-19 pandemic has caused the entire world to assume a 'new normal' to fight this common insecurity that is caused by a tiny, microscopic virus. Even during the new normal, however, certain fundamental features of the modern-day security have not changed. Security in the 21st Century was, to a great extent, focused on internal factors of a country, rather than external ones. The organization of the threat factor has changed from state militaries to terrorist organizations to even pirates. The underlying motivation for creating insecurities has shifted from being political to one that is economic.

Targets have shifted from soldiers to civilians. The distinction between 'high profiles' of national security and 'low profiles' of economic and social interactions have softened. This has given rise to new sources of global insecurity in the 21st Century which are essentially 'soft' in nature.

The 21st Century has continued to witness these new sources throughout its first two decades. Donald Rumsfeld, the onetime Defence Secretary of the United States said at a key decision-making point in the history of his country, "there are known knowns; the things we know we know, we also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know." Although stated in relation to a completely different scenario, when recalling this statement, I see that it resonates with the pandemic that we are facing now. In 'security

terms', COVID-19 is a 'wild card', an 'unknown unknown'. It is a security threat without a passport. It caused the 'health security' to assume the prime position in the security landscape of the modern day, surpassing the food security, water security and all other soft securities.

When we view the modern-day threats, we see that none of these is of a purely military nature, as those perhaps were, during the cold-war period. As a result, they also cannot be tackled by purely military means. There is another factor that contributes to the restriction of military means as a response to insecurities. In today's security landscape, States do not have the monopoly that they used to enjoy. Human beings have assumed that role. When the individual is considered as the central point in security rather than the 'State' as before, it gives a new insight into all our security related concerns. This helps us to understand the present-day global vulnerabilities with a new eye.

When the centre of focus in security becomes the individual, it changes the state-centric understanding of national, regional as well as global security. When a pandemic, which cannot be controlled by military means is plaguing the world, the human-centric understanding of security becomes vital to address it in order to ensure development of any country. This is why the 'soft component' of security, or the 'human security' gains more prominence over the 'hard component' of security during this new normal, created by the worst health pandemic in the recent history of the world.

The pandemic has given rise to a number of human security threats. To mention a few, the threat to economic security through unemployment, to health security through the deadly infectious virus and to environmental security through the mass accumulation of the waste generated in the health sector. It has also given a signal on food security as well, which is precisely when the Government declared essential services and appointed an authority to manage the situation in Sri Lanka. So you see, security in the new normal is connected with the stability of a country, but in a different way from how it did with conventional security under the normal conditions.

National development, as we all know, is an all-encompassing term. It includes both the individual and the nation. Therefore, national development can be considered as the process of development and reconstruction of all dimensions of the nation, along with the development of the individual. This concept is essentially linked with both the growth and the change where *change* can be socio-cultural or economic, tangible or intangible. National development involves activities through a planned national economy, application of modern technology in agriculture to enhance production, application of science and technology in the production sector, improving the human resource and providing education for all among many others.

During a disaster such as the COVID pandemic, it also includes providing facilities and assistance to the poorest segments of the society. In theory, addressing the security needs, especially those of soft security and implementing broad array of the previously mentioned key activities in national development ensures the stability of the country during the new normal. This theory is in practice in Sri Lanka today, in different sectors to different degrees.

Let us consider the vaccination drive for example. Two months ago, Sri Lanka was struggling with the inadequate human resource in the civilian component of the health sector to conduct the vaccination programme at its full length. Health sector employees were getting exhausted with the enhancing demand for services. At this point, the Government employed its military health professionals to assist their civilian component. That accelerated our vaccination drive to such an extent that Sri Lanka became the first country in the world to have the fastest vaccination drive to its population.

H.E. the President had first-hand supervision of this process, at times acting as a 'vaccination planner', which contributed to the success of the

whole programme. This measure addresses our health security, and at the same time contributes to our national development by making the workforce resistant to the pandemic. Together, the two outcomes contribute to enhancing the stability of the country during this new normal.

Now let us consider a few of the numerous initiatives that the Government has introduced to ensure food security. The Government recently decided to take a transition from inorganic agriculture to organic agriculture, in keeping with pledge given to our people by the President, H.E Gotabaya Rajapaksa, in his policy document, 'Vistas of Prosperity and Splendour." The primary aim was to safeguard the public, and especially the future generations from non-communicable diseases including renal diseases, again ensuring the health security. This also gave an added advantage where the imports of chemical fertilizers became minimal and that saved a considerable amount of money to our Treasury. This also resulted in enhancing organic and bio fertilizer production within the country, opening up new employment opportunities.

Linked with these two activities, the Government also launched 'Wari Saubhagya', a programme to rehabilitate 1000 small tanks across the country. This was to provide water for both irrigation and drinking purposes. These projects ensured irrigation water to a greater area of paddy and other field crop cultivations and also created additional employment opportunities within the country. Overall, those made a noteworthy contribution to the national development as well as to the soft security of the country during the new normal.

National development not only involves the infrastructure development, but also the human development. A developed human resource is a shield against certain soft threats. The programme 'connect Sri Lanka' was launched during the new normal, initially providing four remote areas with 4G connectivity. We are planning to expand it into all 9 provinces.

The pandemic period where schools had to be closed was also used to plan education reforms aiming at producing future generations that are better equipped with battling their way through the ever-changing global order. These enhance opportunities for the public, especially the children to gain access to knowledge that is amply available to children and citizens of many developed countries, and also to equip themselves better to assist with development initiatives of the Government.

Fruits of this labour will be reaped only in the future, where our country will continue to have a learned, open minded younger generations, and through them, smarter work forces. The activities that the Government has started today contribute to national development in the future on the one hand, security on the other, and to stability of the country, overall.

The last example that I wish to draw has a direct connection with all institutions in the public as well as the private sector, electricity. The Government spent over US$ 2.3 Bln for oil imports in 2020. We all know that a considerable amount of this is spent for generating electricity. This is an unbearable amount for a developing country like Sri Lanka, to be spent notwithstanding the prevailing health pandemic. It is also a waste of funds considering the vast and untapped potential that Sri Lanka has for renewable energy.

The Government gave due consideration to both these when establishing 'Thambapawani' the first wind power station owned by the Government of Sri Lanka. Another similar plant has been launched in Pooneryn. Use of solar power has been introduced to households. A waste-to-power plant was also declared open at Kerawalapitiya. It is not an easy task for a developing country like Sri Lanka to manage this shift while battling with a pandemic, but amidst all, the Government plans to increase the renewable energy component to 70% of the total consumption of the country by 2030. It Is an ambitious target, but it helps the country to reach a higher status in self-sufficiency and also prepares the country to face worse calamities than the present one that might arise in the future. The 'failure to prepare' as the old saying

goes, is 'preparation for failure'. We intend to avoid it.

Moving back to the concept of security with these examples, with special emphasis on human security, it is evident that the national development and security are inter-linked. These cannot be achieved separately. This is probably what caused the formerly known definition of security, 'freedom from fear', to be redefined as 'freedom from want', indicating the link between security and development. Human security, as we all know, is an integral part of State security, which in turn, has an equally strong connection with national development. This is why if you have a closer look at Sustainable Development Goals, you will see that all 17 goals are connected to human security.

In this context, I believe there is something vital that we all need to understand about security, development and the stability that those bring about. The new normal caused by the COVID-19 pandemic is calling us to re-think our actions, plans and concepts on security and development both.

Is it not high time for us to re-think our national security and national development?

Is this not the best time for us to redefine our development-security nexus?

Let me conclude by bringing back to your memory, extracts from a famous speech delivered by Robert F. Kennedy during his run for the Democratic nomination for the Presidency of the United States. Over 50 years later, his remarks about the measurements of development resonate with something that we need to re-discover with experience we had during this new normal. He said, and I quote,

"… the gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country, it measures everything in short, except that which makes life worthwhile."

Distinguished scholars, ladies and gentlemen, let us try to fathom the lesson that this global pandemic and the new normal is trying to teach us. Let us acknowledge the all-encompassing nature of national development and pay attention to the vital fact that has evaded our comprehension thus far – the fact that the individual, the human has assumed the central focus in security as well as in national development. Let us use that understanding to re-define our development-security nexus and bring a lasting stability to our country during the new normal.

Stay safe and take care of yourselves.

Thank you.

Address by Secretary, Ministry of Defence, Sri Lanka

General Kamal Gunaratne (Retd) WWV RWP RSP USP ndc psc MPhil

Secretary, Ministry of Defence, Sri Lanka

Chief Guest and Keynote Speaker of the 14th International Research Conference of KDU, Principal Advisor to the President Mr. Lalith Weerathunga, Ambassadors and High Commissioners, Foreign Secretary Professor Jayanath Kolombage, Chancellor of KDU General Jerry De Silva (Retd), Chief of Defence Staff and Commander of Army General Shavendra Silva, Commander of the Navy Vice Admiral Nishantha Ulugetenne, Chairman of University Grants Commison Professor Sampath Amarathunga, Vice Chancellors of other Universities, Vice Chancellor of KDU, Chief of Staff of Air Force, Director General at Institute of National Security Studies Professor Rohan Gunarathna, Deputy Vice chancellors, All Deans and Directors, former Chancellors and Commanders at KDU, Eminent Scholars, Senior Officers of the Armed forces and Police, distinguished guests joining us virtually from Sri Lanka and Overseas, Ladies and Gentlemen;

I consider it as a great pleasure and a privilege to be present here today at the inauguration ceremony of General Sir John Kotelawala Defense University's International Research Conference which is taking place for the 14th consecutive year and I would like to thank the Vice Chancellor and the conference organizers for the invitation extended for me to be present here to participate in this event. The International Research Conference of KDU is providing the opportunity for academics, professional researchers and practitioners to share their research findings and expertise addressing the mutual challenges in their fields. Therefore, this event has gained tremendous recognition among all interested parties around the world. Further, the provision of a wider interaction and networking with national and international scholars in respective fields would be absolutely beneficial for all the participants to broaden their horizons of knowledge through intellectual discussions. However, due to the global pandemic situation in effect, most participants may join the event through a virtual platform for this conference as same as the last year. Yet, I'm sure we will be able to achieve the desired objectives in a state amidst this pandemic situation.

Furthermore, I'm extremely pleased that the theme selected by the KDU for the conference this year security, stability, and the national development in the new normal is a timely theme capable of augmenting the significance and focus of the subject of strategic national importance. Further, I firmly believe that the endeavor towards warranting the national development and ensuring national security becomes further from achievement by undermining the routine activities due to the ill effects of the pandemic but becomes attainable by ensuring the adaptability to the new normal as widely accepted by all the countries in the world, today which is implied by the theme that you have selected. In fact, as comprehensively illustrated by the keynote speaker Mr. Lalith Weerathunga it is quite imperative that all of us understand and pursue the ways and means of adopting the circumstances embedded with the new normal. in order to coexist with the Covid 19 pandemic which has not shown any expiry date as of yet.

Ladies and Gentlemen in a context of globalization and further economic integration, in recent decades the relationship between national development and national security of a country has become increasingly

interlinked for Sri Lanka. These connections represent both opportunities and potential threats to the country's national security. The open and interconnected Sri Lankan economy creates vulnerabilities from potential international and external threats. Against this backdrop, national development has emerged as an important strategic priority for the Sri Lankan government with the connection between development and national security which will be orchestrated upon the vistas of prosperity and splendor, the national policy framework of our government headed by his excellency the president Gotabhaya Rajapaksha.

Ladies and gentlemen, the development generally depend on the stability of a country which should be achieved by ensuring national security. Sri Lanka being a country endangered by ruthless terrorism for almost three decades has experienced a lot of hardships during the past and was in the stage of eyeing its development in the last decade. Even though we were able to relieve the country from the menace of terrorism we have found another security threat in the form of a pandemic which has posed a greater threat to the entire world. The threat that we face today is progressing in its second continuous year without any indication of a possible termination we are yet to find a permanent solution for the same. However, we must always work towards reaching our development goals without letting our country at peril. In such a context our endeavor here as Sri Lankans should be to seek possibilities to find ways and means to steer the country towards development goals amidst said difficulties. Sri Lankan government is at the threshold of trying all possible methods to meet its economic growth and objectives yet with lots of empidements while ensuring human security. When the domestic affairs of a country are affected it is extremely difficult for a country to reach its desired end state. Sri Lanka is no exception in this, regard being a developing country Sri Lanka cannot accept any economic standstills for a protacted time frame. However, any plans to expedite the economic gains should never be at the expense of human lives. Therefore, his excellency the president himself has expressed his keenness on this aspect to see and inspire all possibilities available to ensure the maintenance of momentum in the economic sphere.

On the contrary, we should also note the other contemporary security concerns such as violent extremism, terrorism, piracy, drug, and human trafficking, smuggling, cybercrimes, and other organized crimes and natural disasters pose a grave threat to the stability of a country. Sri Lanka's geostrategic location is susceptible to such threats as it is located in the main sea routes in the Indian ocean. The same geopolitical significance has given a greater recoginition to the country, thus it has gained greater demand from the rest of the world. In such an instance, the possibility of Sri Lanka becoming susceptible to threats posed from violent extremism and organized crimes is very high and present the government has initiated several steps to curtail such illegal activities and such measures taken such as the demarcation of maximum security prisons concept and highly effective maritime domination programs launched by the Sri Lankan Navy which have become very effective in restricting such threats. However, the effects of such activities pose a moderate level threat to the stability of our country.

Ladies and gentlemen, a government alone cannot afford to force all these threats that are in concert ruining the stability of a country. Therefore, as responsible citizens, it is our bounded duty to provide novel ideas, suggestions, and proposals to consider in regaining our country's stability and development. I hope the academic events of this nature will undoubtedly serve this national requirement. Such efforts are

arranged to address emerging challenges. Promoting more research and development becomes a task of topmost priority for all of us.

Fortunately, as the Secretary of Defense, I feel tremendously proud and content to say that the Kotelawala Defence University is at the forefront of researching the development of security-related problems in the new normal. The approach adopted by the Kotelawala Defense University to understand the contempaty complex situations concerning the bigger picture rather than dwelling on the narrow passages will become far more effective in resolving the emerging complexity of future challenges. Therefore, I'm well certain that the faculties of General Sir John Kotelawela Defence University with their interest, commitment, dedication, and knowledge in diverse academic disciplines and outside rich researches inputs would contribute immensely to this year's conference theme. The knowledge that you are going to unearth and share during this conference would be of immense benefit not only to the academic community but to the entire humankind to make their lives better.

In conclusion ladies and gentlemen, I should express my most sincere appreciation to the Vice Chancellor and the organizers of the General Sir John Kotelawala Defense University's 14th International Research Conference 2021 for organizing this timely important event amidst the covid 19 pandemic concerns and I wish this event be successful in all way imaginable. Ladies and Gentlemen thank you very much for your patience, thank you.

Vote of Thanks

Dr Harinda Vidanage

Conference Chair, 14th International Research Conference, General Sir John Kotelawala Defence University

Mr Lalith Weeratunga, Principal Advisor to HE the President of Sri Lanka, Secretary to the Ministry of Defence, General Kamal Gunaratne, Vice Chancellor – Maj Gen Milind Peiris, Deputy Vice Chancellor (Defence & Administration), Deputy Vice Chancellor (Academics), Rector – Southern Campus, Senior Professors, Deans and Directors, Senior officers representing Tri Forces and Police, Distinguished guests, colleagues, Ladies & Gentlemen, Good morning!

In its 40th Anniversary since its inception the flagship academic conference of the KDU, the international research conference progresses to 14 years of continuity. I stand here to reflect and provide my gratitude to a team of individuals who despite every challenge in the form of material and the forces of nature has confronted us with, have managed to successfully bring us to where we are today.

Since 2019, the country has witnessed unprecedented upheavals from violent extremism to microbial threats that have forced a drastic rethinking of every aspect of social life. These challenges have made all of us believe in a reality that long established norms, traditions, beliefs do have their limits and if we are to survive and thrive in the new normal, we must adapt, adopt and innovate. The core fundamentals driving this year's IRC is based on this conviction and that the KDU as a leading force of defiance and a beacon of hope amidst such calamities.

On behalf of KDU, I would first and foremost like to extend a heartfelt appreciation to our Chief Guest and Keynote Speaker, Mr Lalith Weeratunga the Principal advisor to H E President Gotabaya Rajapaksa. Your presence today is a blessing to us as an institution and to the IRC as a process and your observations made at the keynote enriched us with knowledge and perspective. Your wise words of wisdom will have a bearing on the deliberations of all academic communities within and well beyond this conference. I also would like to thank Secretary to the Ministry of Defence, General Kamal Gunaratne for his presence, his insights and his towering leadership that has seen KDU through fair weather and through some rough storms.

I would like to highlight and appreciate the visionary leadership of the Vice Chancellor, Maj Gen Milinda Peiris and his belief in maintaining continuity of this apex academic event of the KDU. I must then appreciate the critical roles played by Deputy Vice Chancellor (Defence & Administration) Brigadier Wipula Chandrasiri in ensuring that the IRC will take place and in providing the administrative leadership towards the materializing of the conference. The support and blessing of the Deputy Vice Chancellor (Academic) Professor KAS Dhammika is highly appreciated, along with the support of all Deans of faculties who came together to make this event a success.

Even at a time when every institution is careful about its purse, our sponsors have stood by us, let me profoundly thank and appreciate the generosity of our Gold Sponsors, the Bank of Ceylon and the People's Bank and with Huawei Sri Lanka and National lotteries board being our silver partners. There are many more who have chipped in and do not want their names mentioned and a big thank you for all.

I must mention that this year it is the first time the faculty of Defense and Strategic Studies have been tasked with the overall IRC and holds the chair. I must with gratitude mention the hard work of my colleagues in

both departments of Defense and Strategic Studies under the leadership of Col Enoj Herath the Dean of the faculty. The FDSS represents the tip of the Spear of the KDU and bears testimony to the perfect convergence of civic-military relations.

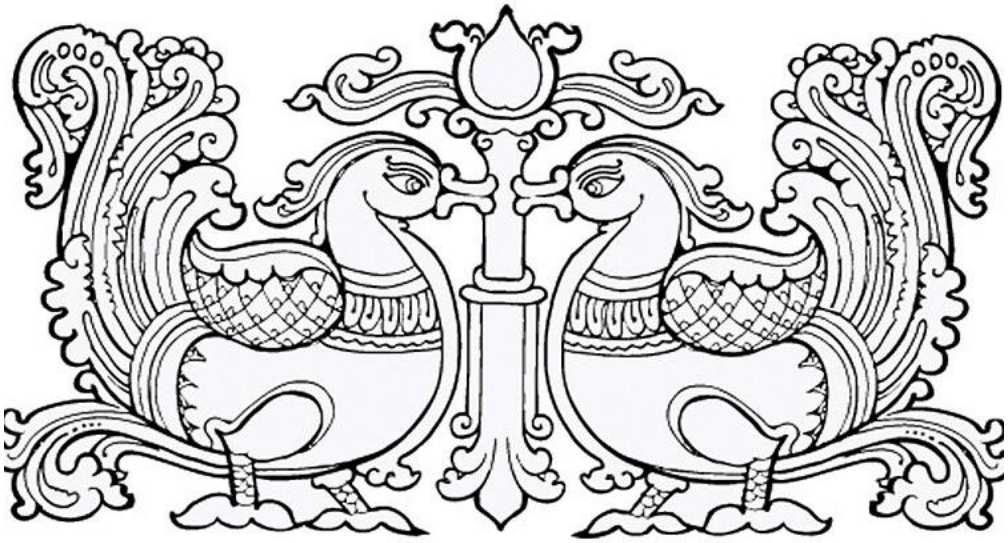
Towards the buildup to the conference the shutdowns became lockdowns and lockdowns became enforced quarantined curfews, yet the main committee of the IRC 2021 managed to work tirelessly around the clock. We knew it was all for a greater cause and I must appreciate the gargantuan task that was handled by the secretary of the IRC committee Ms Lihini De Silva who virtually was my prime buffer and the tremendous work done by the three co secretaries, Maj Ranushka Ferdinandesz, Ms Isuri Uwanthika and Captain Abeetha Athukorala. We were all supported by the dynamic team of faculty coordinators who labored hard and were endowed with patience.

It is with sincere gratitude I appreciate the services of Mr Kithsiri Amaratunga the president of the Editorial committee and Dr Faiz Marikar the deputy editor. I also want to mention the prudent actions taken by Commander Bogahawatte, the president of the publication committee. I would like to thank all committee presidents, committee members, faculty committees, the office of Bursar, Registrar, Adjutant and C/O Admin and the staff at the Vice Chancellor's office.

New normal pushed us to the limits, yet we managed to overcome as we functioned as a collective team. Yet, finally the work would be incomplete if not for the researchers who had put faith in us and submitted papers and reviewers who filtered them. This year's IRC is the most decentralized event out of all IRCs, facilitating intellectual deliberations of this scale is no easy task. To keep this grid alive and robust the contributions made by Director IT and his team needs a special word.

We have truly embraced the new normal. We have not run away from it, instead we have transcended it. Thank you all for accepting and believing in us. We shall prevail and we shall overcome.
Thank you very much!

Built Environment and Spatial Sciences



Technical Sessions

Accuracy Analysis for Total Station Based on the Reflectorless Distance Measurement Using ANOVA

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Abstract - Reflectorless distance measurement (REDM) was used to form various platforms in specific total stations for engineering projects, land surveys etc. It provided rapid measurement by saving time and field hands for surveyors; hence, the reliability of the measured distance from an object has great importance. Also, it increased personal safety without approaching unsafe surfaces. This study aimed to investigate the accuracy difference between the reflector and reflectorless distance of the total station with ten different materials and two different environmental conditions. The study was conducted outdoor using Sokkia SET530R and Trimble M3 total stations. Ten different materials were tested typically in construction fields. Two different conditions were investigated, including dry and wet targets. Two dissimilar incident angles were also inspected, 000 and 300 respectively. The experiment was evaluated by taking the reflector reading as true value to check the accuracy of reflectorless measurement. It concluded that Sokkia SET530R total station gained deviations between 12-23 mm for all conditions and incident angles. The Analysis of Variance (ANOVA) tables proved that eight materials were reflected with good accuracy except for granite and plywood materials for the Sokkia total station ($P<0.05$). In addition to that, the results of all materials showed a deviation between 5-8 mm for Trimble M3 total station at an incident angle of 000 for both dry and wet conditions.

Keywords: *ANOVA, reflectorless, total station*

I. INTRODUCTION

Technology has become more influential in many ways of surveying as in many professions. Computer technology and Auto CAD packages allow us to design, store and manage geospatial data, while at the same time technology engages in faster data collection with increasing of speed and accuracy. One of such pieces of technology is the reflectorless measurements, also it is known as prism less total station. In this measuring mode, the laser beam directly reflected from the measured surface.

A total station is an electronic surveying instrument. It combines Electronic Distance Measuring Equipment with an electronic theodolite and a computer. The electronic theodolite measures the angle in two ways, such as horizontal plane and vertical plane. The Electronic Distance Measurement (EDM) takes measurements by using the LASER (Light Amplification by Stimulated Emission of Radiation) technology (Key & Lemmens, 2005).
The effect of the incident angle of reflecting surface, its colours and types on the accuracy of reflectorless have been examined recently for the total station (Zámečníková & Pegritz, 2014). The instance of the reflectorless distance measurement is diffused reflection as the pulse reflected in all directions and the reflected light rays are scattered (Evangelia Lambrou, 2018). Additionally, some multipath error may be occurred and it would be an increased error. Therefore, it would effect on the final calculated distance. Accordingly, the impression of the material is also a main parameter. Based on the material of the surface, reflection is also varied. A smooth surface has a perfect reflection, whereas rough surface has diffused reflection as shown in figure 1.

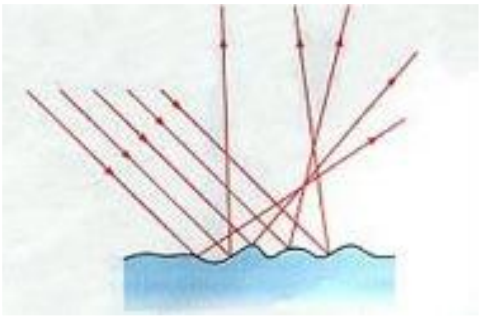

Figure 1. The diffuse reflection
Source: Evangelia Lambrou, 2018

Also, the meteorological conditions are the parameters that influence the EDM with or without prisms. For these reasons, temperature of the target surface was changed (Rüeger, 1996). So, it is important to emitted EDM signal and then it reflected back to the EDM receiver from the right point of the sighted surface.

Reflectorless technology is used in different circumstances to survey infrastructures that are inaccessible, and to improve the efficiency. Also, it increases personal safety without approaching to unsafe surfaces. Some advantages of the reflectorless distance measurement are the reduction of the time and the number of helpers. The control of the team reduces to one person, to exact targeting of points and to setting the prism is not required. Most of the projects require observing points which are not required to install a reflector on them, or are situated in a dangerous area for people to operate. In such cases, preferences are given to reflectorless total stations.

At present, reflectorless total stations are being used in several civil engineering projects for taking distance measurements. When the distance from the instrument's object is increasing, the width of the signal beam also is increasing. Due to the uncertainty of the incident angle of the material surface, REDM (Reflectorless Electronic Distance Measurements) cannot be obtained a perfect reflection from the incident ray. It has affected to the accuracy and reliability of the measurement. Also, it can affect the accuracy of the final reading. The effects of meteorological conditions are also taken into consideration. Therefore, the difference in final accuracy was which compared with the reflectorless distance, and the reflector distance was the main problem in this research.

The main objective was to analyse the accuracy of reflectorless total stations for SOKKIA SET530R and Trimble M3 with the distances and sub-objectives were to investigate the effect of the distance measurements for different materials, different environmental conditions and changing the incident angles of targets with the distances.

II. METHODOLOGY

Sokkia SET530R and Trimble M3 total stations which are currently available of the department of geodesy were used to observe the accuracy of reflectorless distance measurements. Accuracy of the instrument was 3 mm ± 2 mm /1 km in reflectorless mode for both instrument (Trimble, 2013) (SOKKIA CO., 2006). Ten materials were used with smooth and rough surfaces of different materials such as Jack wood, Rock, Granite, Brick, Tile (smooth), Tile (rough), Plywood, Steel, Aluminium and Concrete with dimensions of 0.15 m x 0.15 m. The measurements were taken in outdoor conditions with same weather condition. The test materials were fixed on a specialized steel bracket which was used to attach the materials on tribrach of a tripod. E. Lambrou used the design which I used, similar to construction of the bracket in their testing (E Lambrou & Pantazis, 2010) as shown in figure 2.

Figure 2. Special Bracket

The total stations and the target were set up at a distance of 10 m apart. The distances were measured firstly by the prism target and repeatedly on all the materials. Namely two incident angles of 0° and 30° were tested, and incident angle of 0° was considered as the

perpendicular position of the material to the sighting line of the instrument.

Dry and wet conditions were tested for each material and sprayed water for wet condition to take the distance instantly. Each measurement was taken five times and mean was calculated. This procedure was done by all 10 m distance intervals up to 100 m for both total station and for each material.

A. ANOVA analyses

Analysis of Variance (ANOVA) is a statistical test, which was used to analyse the difference between the means of one or more than two groups. The two-way ANOVA was used to estimate how the mean of a quantitative variable is changed according to the levels of two categorical variables (Hasegawa & Yoshimura, 2007). Usually, two-way ANOVA is used, when you need to know how two independent variables in combination effect on a dependent variable. In this research two-way ANOVA was used to clarify the factors affecting the REDM in total stations. The dependent variable consisted of the prism distance while the independent variables were the dry and wet conditions, incident angles and materials.
The more researcher fulfilled an ANOVA analysis using disparities to perform statistical tests for differences in reflectorless distance measurements. The analysis of disparities completed using the R 3.6.1 programming. R is a free software environment for statistical computing and graphics. It compiled and ran on a wide variety of platforms. These tests confirmed that the performance of the dry and wet conditions, incident angles and materials which are significantly associated with the total stations.

III. RESULTS AND DISCUSSION

The results outlined for materials, conditions (Dry and Wet) and incident angles. Each material was charted and analysed individually to determine accuracy. Also, a comparison was made between the prism target and different material targets. Those comparisons were used to determine, if materials and conditions effect on the REDM. The prism observations were taken as true distance for all analyses, the prism distance between the control points and it presented in solid thick black line. Reflectorless distance and prism distance difference for different materials/ targets is represented in the Y- axis.

The results from jack wood and tile (smooth) materials are shown in figure 3 and figure 5 respectively. For Sokkia deviation between all measurements at different incident angles and under different conditions had 10 m interval up to 100 m. This set of data had a range of 15 mm for Sokkia SET530R and 34mm for Trimble M3. This range would be less than 8 mm if the fallouts of the dry and wet condition at 00^0 IA (Incident Angle) for Sokkia SET530R and 6 mm for Trimble M3. These two outcomes had less varying between 00^0 IA and 30^0 IA out of ten materials.

The brick material outcomes are presented in figure 7 for Sokkia SET530R and figure 8 for Trimble M3. It had arranged of 21 mm for both Sokkia SET30R and Trimble M3. This range would be less than 8 mm if the results of the dry and wet condition at 00^0 IA for Trimble M3. The general trend of the data in Sokkia SET530R relatively downward over the whole 100 m distance. With the variable differences in Sokkia SET530R and Trimble M3 at 30^0 IA were spread of graphs further down and overhead relevant to the true distance.

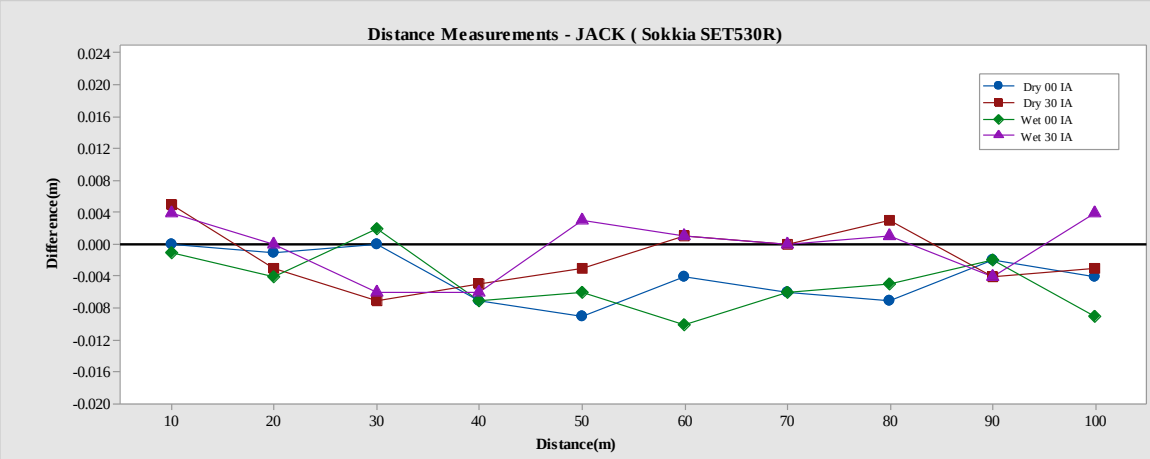

Figure 3. Distance Difference in the reflector and reflectorless distance measurement using SOKKIA SET530R for Jack wood material

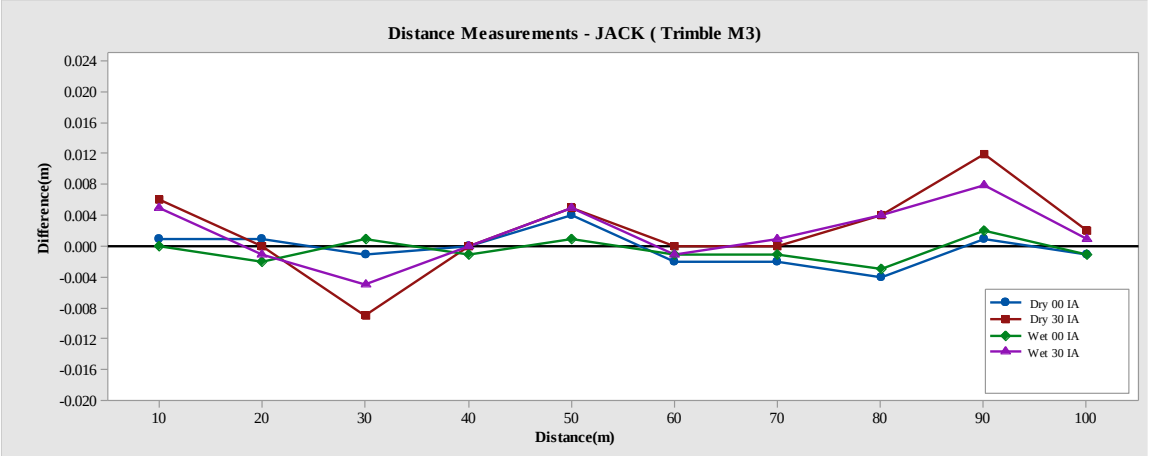

Figure 4. Distance Difference in the reflector and reflectorless distance measurement using Trimble M3 for Jack wood material

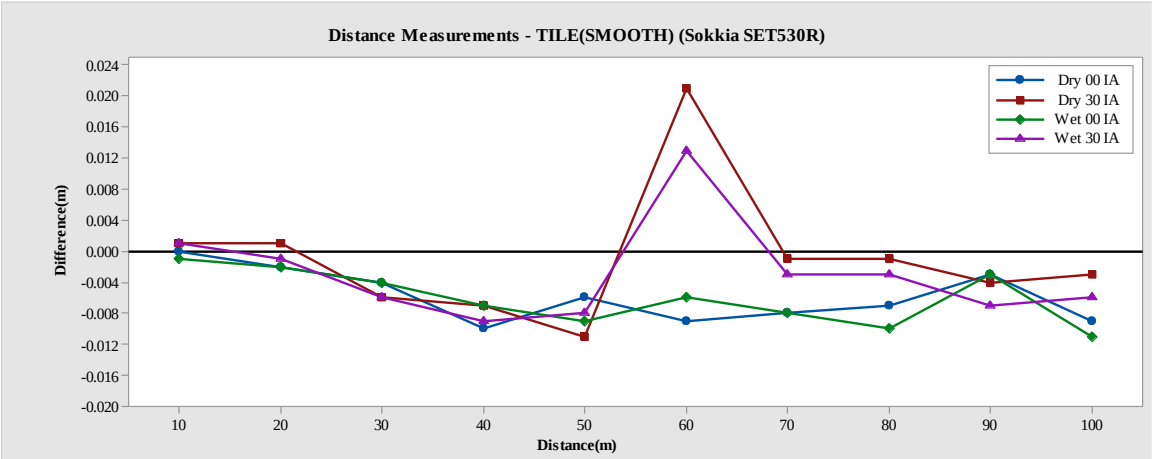

Figure 5. Distance Difference in the reflector and reflectorless distance measurement using SOKKIA SET530R for Tile (Smooth) material

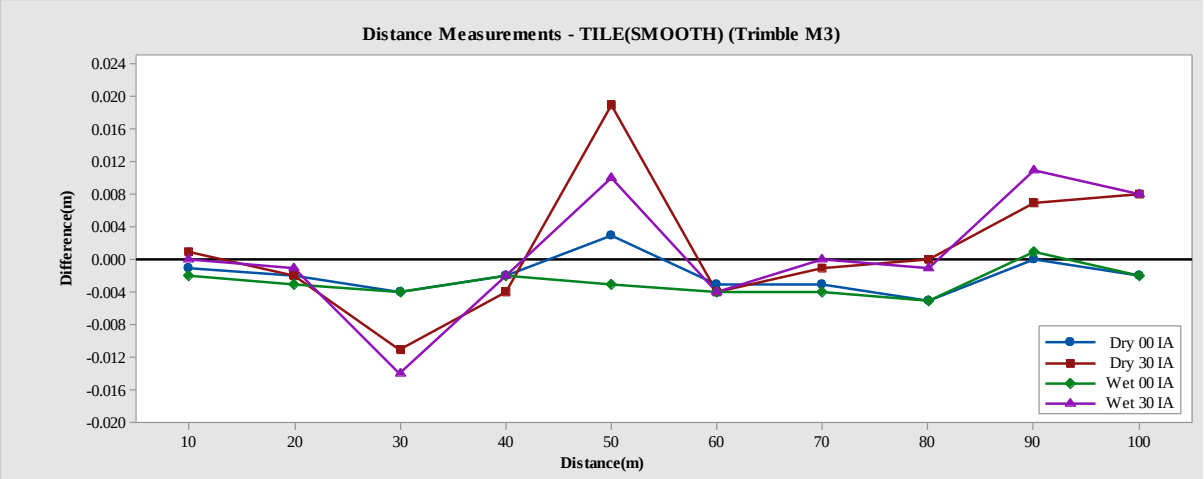

Figure 6. Distance Difference in the reflector and reflectorless distance measurement using Trimble M3 for Tile (Smooth) material

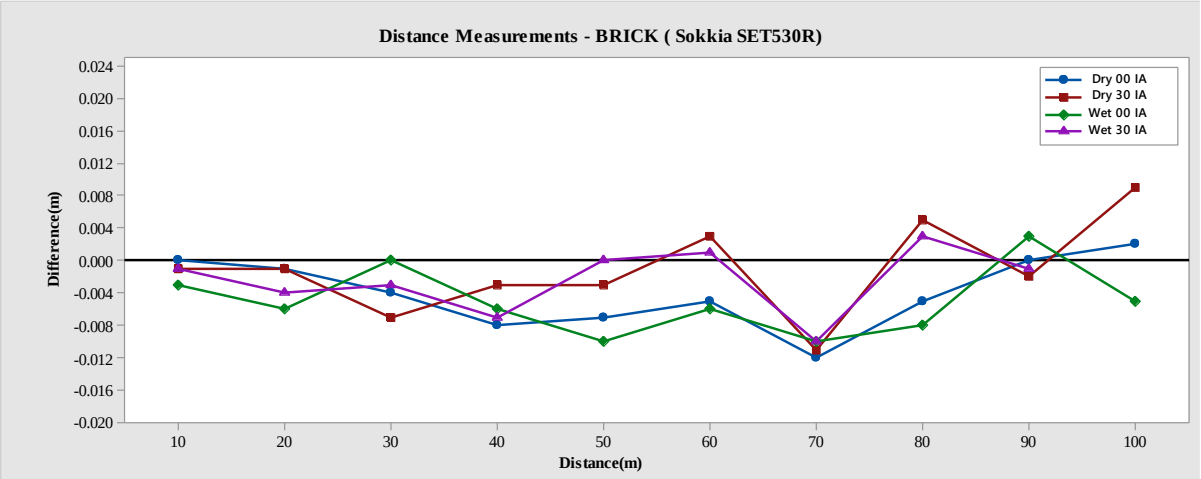

Figure 7. Distance Difference in the reflector and reflectorless distance measurement using SOKKIA SET530R for Brick material

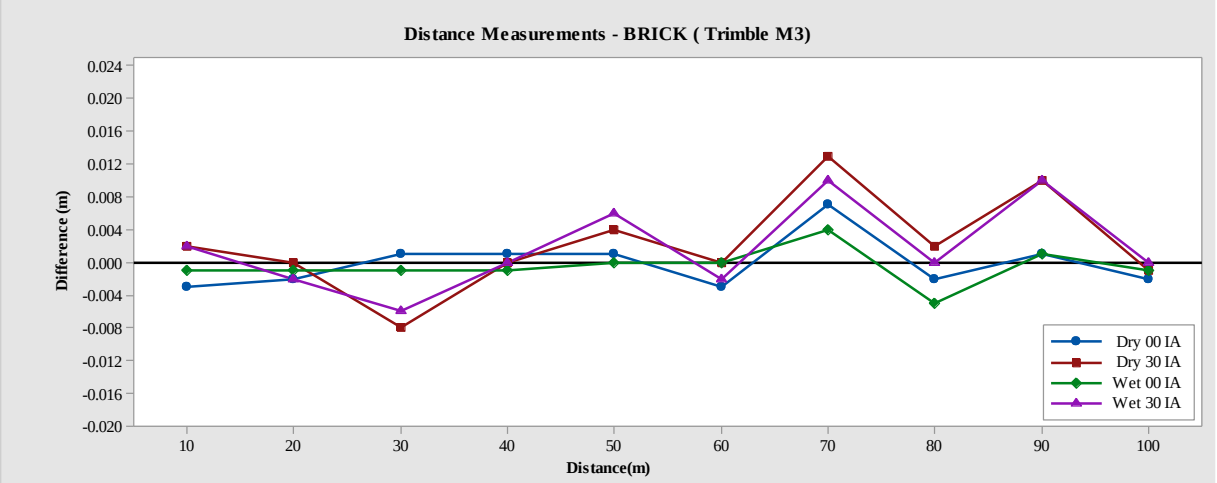

Figure 8. Distance Difference in the reflector and reflectorless distance measurement using Trimble M for Brick material

Results of ANOVA

Before ANOVA is being applied, it has to be checked whether there is a correlation between the variables. If P value < 0.05, that means there is a relationship between independent variable and dependent variable. Table 1 shows that all P values were less than 0.05 for all the materials and instruments. Then ANOVA could be applied for these variables.

Table 1. Results of correlation for Sokkia SET530 and Trimble M3 total staions.

Variable	Instrument	
	Sokkia 530	Trimble M3
	P- value	P- value
Jack wood	0.000	0.000
Rock	0.001	0.000
Granite	0.038	0.000
Brick	0.000	0.000
Tile (smooth)	0.000	0.000
Tile (rough)	0.000	0.000
Plywood	0.000	0.000
Steel	0.041	0.000
Al	0.000	0.000
Concrete	0.000	0.000

In this research, two-way ANOVA was used to clarify the factors affecting the REDM in total stations. In this analysis, tables 2 and table 3 summarize the analyses of dry and wet conditions with incident angles and tables 4 and table 5 of materials, respectively.

According to table 2 incident angle were not any significant differences (P>0.05) among the dry 30^0 incident angle (DRY30IA), wet 00^0 incident angle (WET00IA) and wet 30^0 angle (WET30IA) comparatively the dry 00^0 incident angle (DRY00IA) for Sokkia SET530R total station. The interaction effect of the three factors were also not significant. According to the table 3, incident angle has significant differences (P>0.05) among the dry 30^0 incident angle, wet 00^0 incident angle and wet 30^0 angle comparatively for the dry 00^0 incident angle. These results were indicated differences between the incident angles which are not associated with differences among the Trimble M3. Furthermore, table 4 displays that materials, were not significant differences (P>0.05) among the granite and plywood, while other all materials have significant differences (P<0.05). These results were indicated significant differences between the materials which are not associated with differences among the Sokkia SET530R without granite and plywood.

And also, table 5 expressions that, there were significant differences (P<0.05) among the jack wood, rock, granite and brick while all other materials have not a significant difference(P>0.05).

Table 2. Results of ANOVA for dry and wet conditions with incident angle for SOKKIA SET 530R total station

Source	Df	Sum Sq	Mean Sq	F value	P value
DRY30IA	1	2.567e-06	2.567e-06	2.756	0.148
WET00IA	1	1.198e-06	1.198e-06	1.286	0.300
WET30IA	1	2.486e-06	2.486e-06	2.668	0.153
Residuals	6	5.590e-06	9.316e-07		

Table 3. Results of ANOVA for dry and wet conditions with incident angle for Trimble M3 total station

Source	Df	Sum Sq	Mean Sq	F value	P value
DRY30IA	1	6.241e-07	6.241e-07	5.541	0.0568
WET00IA	1	8.885e-07	8.885e-07	7.888	0.0308 *
WET30IA	1	5.250e-08	5.250e-08	0.466	0.5203

Residuals	6	6.759e-07	1.126e-07

Table 4. Results of ANOVA for all materials of Sokkia SET530R total station

Source	Df	Sum Sq	Mean Sq	F value	P value
Jack wood	1	26691	26691	4.432e+09	0.0000 ***
Rock	1	0	0	4.569e+01	0.0000 ***
Granite	1	0	0	3.711e+00	0.0655
Brick	1	0	0	1.543e+01	0.0006 ***
Tile(smooth)	1	0	0	1.995e+01	0.0001 ***
Tile(rough)	1	0	0	1.276e+01	0.0015 **
Plywood	1	0	0	4.908e+00	0.6662
Steel	1	0	0	1.995e+01	0.0361 *
Al	1	0	0	9.817e+00	0.0044 **
Concrete	1	0	0	4.996e+00	0.0346 *
Residuals	25	0	0		

Table 5. Results of ANOVA for all materials of Trimble M3 total station

Source	Df	Sum Sq	Mean Sq	F value	P value
Jack wood	1	29707	29707	4.225e+09	0.0000 ***
Rock	1	0	0	1.511e+01	0.0006 ***
Granite	1	0	0	8.706e+00	0.0065 **
Brick	1	0	0	6.297e+00	0.0184 *
Tile(smooth)	1	0	0	1.070e-01	0.7467
Tile(rough)	1	0	0	4.000e-03	0.9532
Plywood	1	0	0	2.720e-01	0.6064
Steel	1	0	0	3.061e+00	0.0915
Al	1	0	0	7.000e-02	0.7934
Concrete	1	0	0	3.796e+00	0.0619
Residuals	27	0	0		

(* Significant at the 0.05 level, ** Significant at the 0.01 level, *** Significant at the 0.001 level, Df- Deg. of freedom, Sq-Squares)

IV. CONCLUSION

This research was able to find the accuracy of reflectorless total stations with distance in outdoor circumstances; two reflectorless total stations were tested for a distance of 10 m intermission up to 100 m with 10 materials in two different incident angles and dry and wet conditions. This experiment was evaluated by taking the reflector (prism) reading as true values. The first important finding was the

limitation for the incident angle. Based on the research, it did not reflect at the incident angles of 60^0. It could be safe to say that "angles of 30^0 provide results that were reliable to any surveying task over a short distance in reflectorless mode".

By considering both graphically and ANOVA outcomes, Sokkia SET530R total station gained the fluctuation between 12 mm and 23 mm only, these differences of range were presented graphically for all materials, dry and wet conditions and incident angles. In addition to statistics, the ANOVA tables were proved that 8 materials which were reflected with good accuracy ($P<0.05$), and only two P values ($P>0.05$) were observed to granite ($P=0.0655$) and plywood ($P=0.6662$) materials for the Sokkia SET530R total station.

The effects of the dry and wet conditions on distance measurements were found statistically equal only incident angle of 00^0 for Trimble M3 total station ($P<0.05$). Besides that, the results were displayed graphically the error of variance between 5 mm and 8 mm only for all materials in Trimble M3 total station. The outcomes also were showed statistically and graphically and observations were not equal between dry and wet conditions as well as incident angle of 00^0 and 30^0 for both total stations ($P>0.05$). The deviations of the repeated measurements were indicated that "Trimble M3 total station was precise enough and had high accuracy in the reflectorless mode at incident angle of 00^0."

In this area of research, there was the possibility for further researches. A key recommendation was made which it can be conducted properly, and it will provide more knowledge to the surveyor on how REDM interacts with targets along with different materials tested. This was not limited to different materials but a combination of different colours in same material tests are also useful to understand, if there was any difference in colours of same material.

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I have Studied BSc Surveying Sciences (Surveying and Geodesy). I have an interest in modern land surveying methods and topographic surveys for engineering projects. I hope to develop a model for drone surveys in future.

I am a senior lecturer in Urban Planning & Land Surveying at the Department of Surveying and Geodesy, Faculty of Geomatics. Further, I have sound experiences and skilful capabilities to conduct research studies, which I have already proven by achieving several international publications. In addition to that I have been a Chartered Town Planner in Sri Lanka since March 2015.

ID 445

Detecting Urban Expansion Trends in Weligama Urban Council using Remote Sensing and GIS

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Abstract- The extensive history goes back to urban development, and human convinced build-up area and urban spreading through the specific region is one of the most important areas of human-induced urban expansion. Due to the unplanned urban expansion, Urban sprawl is a prominent issue in the cities nowadays. In today's world, these have become important topics in many scientific fields. This study probes the expansion of the 13 GN divisions in the Weligama urban council area. The main objective of this research is to find the urban land expansion index (SI). Remote sensing and GIS (Geographical Information Science) provide some methods for finding the expansion index using satellite imagery. Satellite images were used in 2005, 2010, 2015, and 2020 as primary sources taken by USGS earth explore. By using the NDBI (Normalized Difference Built-up Index) extract the built-up area and then the urban expansion index/sprawling index (SI) were calculated to identify the expansion of the study area. Finally, the maps of expansion of the built-up areas were prepared in Weligama urban council area to identify the urban expansion index. Considering such context for the town planning, it is better to use the expansion and sprawl analysis method to determine the extension patterns to create sustainable development. As per the results, the region has slightly expanded between 2005 and 2010, but between 2010 to 2015 and 2020 it takes a moderate speed for expanding the Weligama urban council area. Consequently, the final output shows that the urban expansion has happened along the beachside to the city center area.

Keywords: *remote sensing, GIS, NDBI (Normalized Difference Built-up Index), SI (Sprawling Index/ Urban Expansion Index), urban sprawl*

I. INTRODUCTION

The sustainable development of the country affects various areas of society. With during the development, the land cover undergoes various changes. Earth is the main nature resources that underlie many development activities. Spatial characteristics of the earth types of land use using and their transformations are tending for the urban planning in sustainable development. Urbanization is a major cause of land and land use changes transfers. Urban spatial expansion directly reflects the development of urbanization (WuDunn, Marc, Zakhor, Avideh, Touzani, et al). We can understand the nature as well advice on spatial decision making for sustainable urban development through urbanization and analysis urban expansion process. In today, a series of problems overwhelming the sustainable utilization of the urbanization considered with the land use, its structure, and the environmental protection. Urbanization monitoring provides essential information for long-term planning. Unfortunately, traditional surveying and mapping techniques are expensive and time-consuming estimate the urban center, especially in developing countries. As a result, interest in research is increasing directed for mapping and monitoring urban sprawl using GIS and remote sensing techniques (Krishnaveni, K. S. Anilkumar,2020)

Remote sensing is extensive technique that physically untouched and detecting objects, records the details by using the characteristics of electromagnetic waves of the objective from far distances and reveals characteristic and changing things through image analysis. This technique is cost effective and technologically

sound in the case of urban sprawl, it is increasingly used in analysis. GIS provides a flexible environment for displaying, storing and analyzing digital data required to detect changes. The combination of satellite remote sensing and GIS technology is becoming more advanced applicable to land use and land cover surveys especially in urban growth area. Weligama Urban Council area was selected as study area of this research because of it is increasing urban area year by year. It is essential to detecting the urban expansion for the urban planners and indicates the changing direction of the urban expansion in the Weligama, decision basis for sustainable urban development in this region.

The main objective of this study research is identifying the direction of increasing the urban expansion of Weligama urban council area. As for the relevant details, Finding the increasing of built-up area and finding urban expansion and sprawling of this case study.

In this study try to define urban expansion by using the changes of built-up area. Therefore, need to extract the built-up area through the NDBI according to the WuDunn, Marc Zakhor, Avideh Touzani,2019. Building area and bare land reflect MIR (Mid Infrared) more than NIR (Near Infra-Red). Water bodies do not reflect the infrared spectrum. For green surfaces, the reflectance of NIR is higher than that of MIR Spectrum. Image classification technology is a long and complex process. So that identifying the built-up area was focused on NDBI. This requires applying synthetic scope and many operations to the final result.

The urban land expansion index (SI), SI is divided into five stages. When SI<0.001%, it represents an area with no changer; when 0.001 %< SI<0.1%, it demonstrates that this area expanded slightly; while 0.1 %< SI<1% represent that area expanded at middle speed; when 1 %< SI<5%, it stands that the area had a fairly rapid expansion; and then SI>5% mean this area got through a sharp expansion (Yang, Jian Pu, Yingxia,2008).

The Weligama Urban Council area has been identified as the planning boundary. Weligama city it is located in the southern coastal strip near Weligama Bay in Matara Southern area. The Weligama Urban Council is the only urban council for the Matara district the urban areas announced in the Official Gazette in accordance with the Urban Development Authority Law. Weligama Urban council area consists of 13 divisions of GN (Grama Niladhari) covering an area of 543.7 hectares (UDA,2019). Weligama is one of the major tourism attraction destination Matara and main commercial center of Matara district and administrative center of Galle district. Selected study area is extended up to 13 GN divisions around the Weligama urban council area. According to the Census and Statistic data in 2021, total population of the Weligama Urban Council area is 22,030. Basically, Weligama was developed based on the location which is strategically in Weligama Bay and the tourism industry and the fishing industry of the region (UDA,2019). There are several possible areas that can be used and advancing in the urbanization through the urban sprawl and expansion of the development with regarding the tourism and the fishing industry. Figure 1 shows the Study area of this research

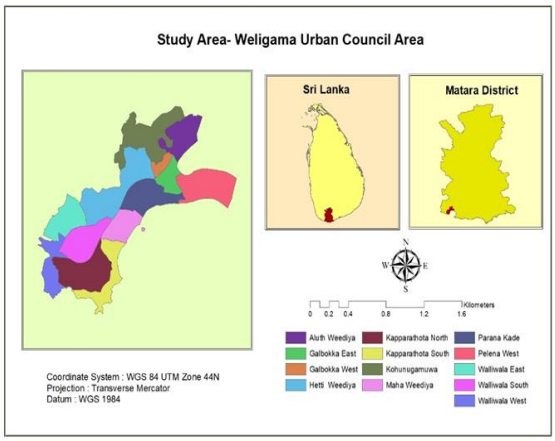

Figure 1. Weligama UC Area
Source: Urban Development Authority

II. METHODOLOGY

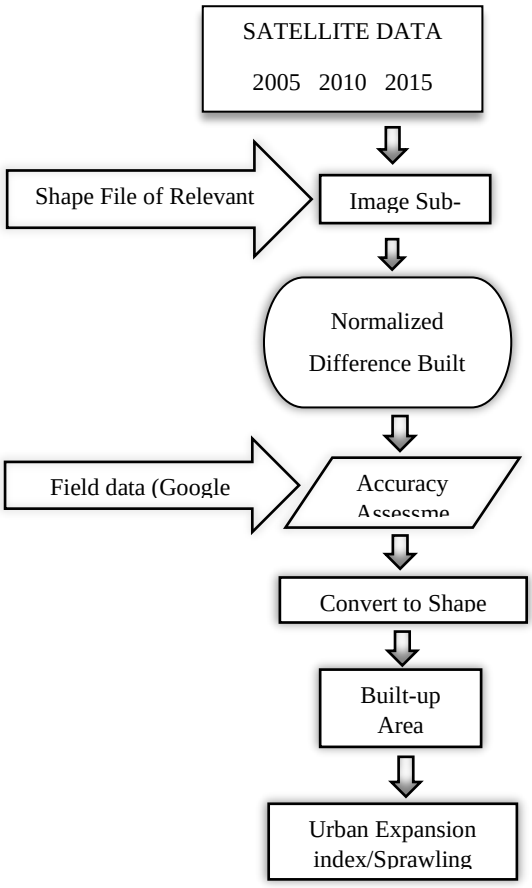

Figure 2. Flow Chart

For this case study and the methodology directly based on the raster base building extraction, building indices NDBI. The analysis of this case study is literally based on the Built-Up area changes in 2005, 2010, 2015, and 2020.

For this study using satellite images for the years of 2005, 2010, 2015, and 2020 as per the basic data source. Data including built up area investigation and recent built-up area from 2005 to 2020. Use data every year-end information. The resolution was 30m of the satellite images.

Table 1: Type of Data used

No.	Type of Data used	Resolution	Year
1.	Landsat 4,5 TM	30m	2005
2.	Landsat 4,5 TM	30m	2010
3.	Landsat 8	30m	2015
4.	Landsat 8	30m	2020

This table shows the type of satellite images and its resolutions by mentioning its respective years. The main source of the data were satellite images which were taken from USGS Earth explorer.

In this study, by using the NDBI formula (Shown in equation 1) we have to extract the built-up areas in the relevant area from the Landsat images from 2005, 2010, 2015, and 2020 respectively. After that need to detect the expansion of the build-up area of the study area and therefore by considering each five years in between 2005 to 2020. According to that process identify the urban expansion in three stages as 2005-2010, 2010-2015, and 2015-2020-years range.

By using the Google Earth, had to extract the build-up areas. Therefore, need to go through with the Google earth and detect the built-up areas as point vice. Generally, when collecting these point locations details at least have to collect approximately hundred points. For this study has to take nearly hundred-point details in respective years. After taking both of these relevant details and data, as for the next step need to investigate the comparison in between the NDBI extraction of the build-up area and the point data gather from the Google earth. NDBI can be calculated by the following formula. The figure 3, 4, 5 and 6 are shown the built-up area of respectively years.

$$NDBI = (MIR - NIR)/ (MIR + NIR) \longrightarrow 1$$

In Landsat 4-5 thematic mapper (TM), band 4 denotes the IR and band 5 denotes the MIR. In Landsat 8 respectively band 5 and 6 denotes to NIR and MIR.

Urban land expansion index (SI) was found by using below equation (shown in equation 2)

$$SI = ((UL_{(i+n)} - UL_i)/ nTUL) *100\ \% \longrightarrow 2$$

Where SI says sprawling index/urban expansion index, UL(i+n) and ULi represent the land area at the moment of i + n and i respectively, and TUL is the total land area (Tian et al, 2005). Table 2 and

figure 8 represent statically data of urban expansion.

III. RESULTS and DISCUSSION

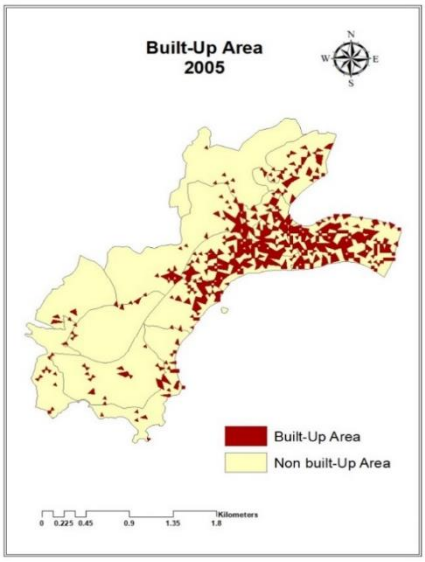

Figure 3. Built-up Area 2005

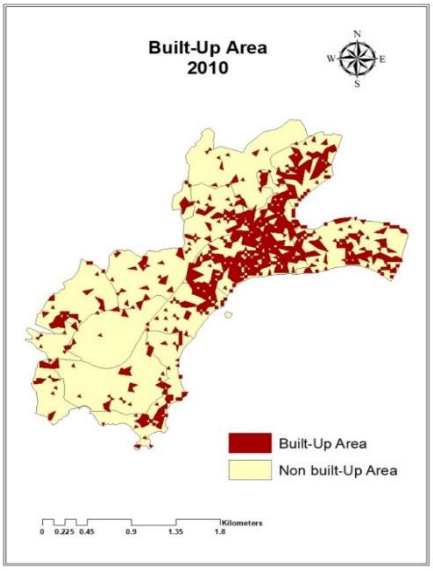

Figure 4. Built-up Area 2010

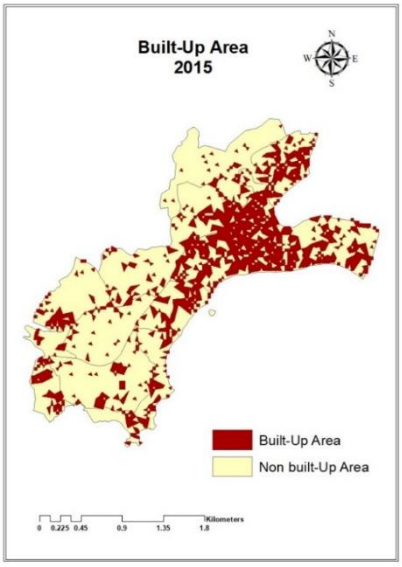

Figure 5. Built-up Area 2015

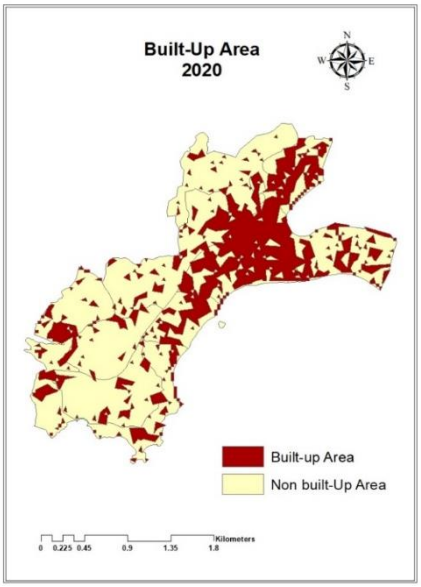

Figure 6. Built-up Area 2020

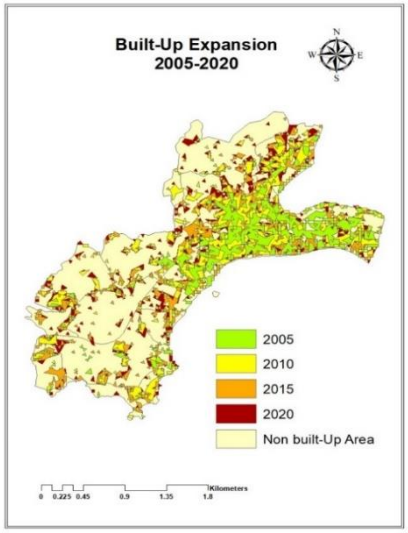

Figure 7. Built-up Area final map

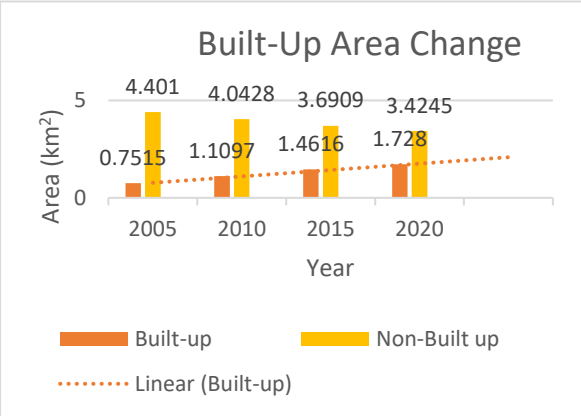

Figure 8: Built-up are change bar chart

Above figure 7 shows how the urban region was expended through the past years. Also, it shows the ratio difference in between built-up and non-built-up areas in the study area. By looking through that gradually the urban expansion is spread among the Weligama Urban Council area. However, the growth of built-up area and its expansion directly affected to the bare lands in the region according to the chart details.

Table 2: Urban Expansion Index / Sprawl Index

GN Division	SI(2015-2020)	SI (2010-2015)	SI (2005-2010)
Aluth Weediya	1.475	0.625	1.875
Galbokka East	1.504854369	0.873786408	1.844660194
Kohunugmuwa	0.510204082	0.233236152	0.626822157
Maha Weediya	0.868167203	0.996784566	0.675241158
Parana Kade	1.023454158	0.66098081	12.36673774
Pelena West	0	1.073825503	-1.040268456
Walliwala East	0.618556701	0.283505155	1.082474227
Walliwala South	0.218818381	0.525164114	0.10940919
Walliwala West	-0.503355705	1.845637584	0.570469799
Kapparathota North	0.141287284	0.737833595	0.266875981
Kapparathota South	0.108108108	0.567567568	1.162162162
Galbokka West	1.978021978	1.538461538	2.417582418
Hettiweediya	0.56372549	0.416666667	0.968137255

The urban expansion index between 2005 and 2010, According to the details shown in table the urban sprawling indexes of the Weligama Urban Council area land use have the following features between 2005 and 2010. In whole five years the area was taken middle speed expansions according to the relevant details. Only Pelena GN division area was the place that does not expand many more. Not only was that Parana Kade GN division expanded sharply in that era. Typically, in 2005 to 2010 Weligama urban council area does not try to make any unacceptable expansions during this period of time. The urban expansion index between 2010 and 2015, from the table it can be seen in Pelena west, Walliwala west and Galbokka west GN divisions were trying to reach the fairly rapid urban expansion. Rest of other GN divisions were slightly expanded during this 2010 to 2015 time period. The urban expansion index between 2015 and 2020.When considering the 2015 to 2020 five years of period Aluth Weediya, Dalbokka east, Parana Kade, and Galbokka west GN divisions were increased their expansion in fairly and rapidly. Pelena west and Walliwala west are the only GN divisions that were not any changes since in 2015. However other GN divisions were take their changes in middle speed expansion.

Table 3: Accuracy Assessment

Accuracy Assessment NDBI					
		2005	2010	2015	2020
Producer Accuraccy(%)	Built-Up	85.5522	90.4762	95.7143	90.35088
	Non Built-Up	92	93.0556	88	85.33333
User Accuraccy(%)	Built-Up	95.2381	96.8153	93.7063	90.3509
	Non Built-Up	83.1325	80.7229	91.6667	85.3333
Overall Accurcay(%)		90.4306	91.25	93.02326	88.3598
Kappa Coefficient		0.79681	0.80038	0.844989	0.75684

It measures how well a particular area is. This includes the acronyms for percentage of features observed on the ground that are not labeled on the map. The higher number of leakage errors shows the lower accuracy of the product. Calculated by dividing the number of pixels correctly categorized in either category by the total number of pixels in the corresponding column. User accuracy given by dividing the number of correctly classified pixels in each category, by the total number of pixels

Classify into that category. In overall accuracy takes the probability of an individual being correctly classified by the test. In here it was taken by both producer and user accuracy values.

According to this case study, it is able to reach over 85% in overall accuracy in all the years. Cohen's kappa coefficient, which is commonly used to estimate interrater reliability, can be used in the test-retest context. In the test-retest, the kappa coefficient indicates the agreement between the frequencies of two sets of data collected on two different occasions (Chong

Ho Yu,2005). Considering that by takeover 0.6 range of kappa coefficient while having good level of strength of agreement.

IV. CONCULSION

Built-up areas are considered as indicators of urban expansion phenomenon. In this study based on the built-up area therefore the use of NDBI effective to extract the urban expansion of the area. Commonly used urban expansion Metrix is called Urban Expansion Index/ Sprawling Index (SI) and it is used for measurement, quantification of urban sprawl and urban expansion phenomena in urban developed area.

Since the improvement and opening up, Weligama urban territory has expanded rapidly. Using satellite and remote sensing technology, we can quickly monitor, track and analyze urban expansion. However, this paper has studied the urban land expansion and sprawl in three respective stages of 2005-2010, 2010-2015 and 2015-2020 in Weligama urban council area and the land expansion state of each GN divisions in Weligama Urban Council can be easily seen according to the urban expansion index. Apart from the few decreased due to the changes in administrative divisions, and the territory of the Weligama Urban Council have expanded gradually in every five years. This indicates that the accelerated urbanization process promotes continuous urbanization land use in Weligama urban council area. The accuracy assessment showed that the overall accuracy is 90.76% with kappa coefficient of 0.79975 averagely. Finally, as per the result gaining from this shows that the direction of the urban expansion of the Weligama Urban Council area along the beach side to city center.

Urban planning authorities can take advantage of this techniques for extracting built-up areas and analyzing urban sprawl for effective city planning and sprawl control. there is a need for create innovative approaches and further refine existing methods and techniques in order to take full advantage of diversity from remote sensing data within urban areas.

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ID 514

Severity Classification of the Forest Fired Area by Utilizing Remote Sensing and GIS: A Case Study in Ella Sri Lanka

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Abstract— The burning of forest areas in Sri Lanka can be considered as one of the foremost issues that should be addressed. Human influence could be identified as the major cause of forest fires in Sri Lanka. Hence, identification, mapping, and taking necessary actions for forest fires are vital in the current context. The forest fire that occurred in the Ella area in 2019 was the focus of the case study. First, the burned location identification was the crucial part of the study due to the unavailability of a proper database of forest fires in Sri Lanka. Hence, with the use of newspaper articles and reports, the forest-fire area was identified at the beginning. Then by utilizing Sentinel-2 satellite images through the Normalized Burn Ratio (NBR) forest fire area was identified. Further, with occupying the difference of NBR (dNBR) mapped the severity of the fire by following the United States Geological Survey (USGS) fire classification scheme. The analysis was performed in Quantum GIS (QGIS) open-source software platform since the Semi-automatic Classification Plugin (SCP) provided the best framework for analysis. Even if immediate satellite images just after the incident were not present, mainly due to the cloud coverage, the analysis was able to obtain a considerable output. Consequently, owing to the study, 73.82 hectares of areas were identified as burned due to the wildfire and 15.65% of the area was highlighted as a high severity of the burn. In conclusion, the applied methodology could be used by any organization for forest scare mapping, and it is vital in future planning.

Keywords: *dNBR, forest fire, GIS, NBR, QGIS, remote sensing*

I. INTRODUCTION

Forest systems far could be considered as the heart of the ecosystem (United Nations, 2010) and provide invaluable service to nature. Hence, conservation of the forest areas is the accountability of all human beings subsequently we are all part of it. Deforestation, forest degradation, and forest fires might be identified as the biggest threat to the forest worldwide. In the fire ecology, burn severity is well-defined by the influence of fire on an environment (Peek, 1997). Thus, frequently occurring forest fires were the foremost environmental hazard in any ecosystem (Bajocco *et al.*, 2012; Erten and Musaoglu, 2018) mainly due to human influences (Gigović *et al.*, 2018). Hence taking necessary actions for the prevention is vital and could be identified as the major requirement in ecosystem conservation. Sri Lanka is a tropical island nation embraced with monsoon climate and the driving factors of the climate were wind and precipitation (Yamane, 2009). As per the evidence that is available (The Consortium of Humanitarian Agencies, 2016) approximately, two hundred forest fires occur annually contingent on the current weather conditions. Further, the fire hazards were often not in native forest areas and most of them were recorded in peak vegetation and woodlands of the south and central highlands (Series, 2009) and the study focused to investigate the forest fire occurred at Ella area in 2019.

Remote sensing usually defines as the remote monitoring features on the ground being without contact with it (Navalgund, Jayaraman and Roy, 2007). It is vital in the environmental-related analysis and hazard monitoring due to the spatial and temporal resolution characteristics and owing to the capability of monitoring remotely. The freely available satellite data integrate with open-source software platforms provide a better framework

for the experimental assessment (Van Westen, 2000). Freely available Multispectral (MS) Sentinel-2 satellites, at the medium-high spatial resolution, allow the advance of more detailed wildfire mapping (Filipponi, 2019). Sentinel-2 images were employed under investigation through the semi-automatic classification plugin (SCP) (Congedo, 2016) in Quantum Geographic Information System (QGIS). QGIS is a free and Open-Source Desktop GIS platform that permits map creation, edit, spatial analysis which is established on the Geographical Information Science (GIS) (Baghdadi, 2018). Further, the SCP plays a significant role in applied remote sensing analysis such as image downloading, preprocessing, classification, postprocessing, raster calculation etc.

Recognizing post-fire data is essential for post-fire administration activities and rehabilitation treatments. Hence, the main objective of the study is to map and quantify the burned area and demarcate the levels of burn severity. Further, the specific objectives express as follows.

- To identify the burned area by the forest fire
- To demarcate the fired area by using remote sensing techniques
- To map the level of severity of the fired area
- To quantify the correlation between NDVI, NBR, and dNDVI, dNBR.

Pre and post images are often used to distinguish the changes in every condition (Miller and Thode, 2018). Thus, pre-, and post-Sentinel-2 satellite images of the forest fire of the study area were implemented. Vegetation indices (Hayes and Sader, 2001) have been exposed to enhance detection of vegetation types, levels, etc., and further, ratio-based vegetation indices as well minimizing the topographic and atmospheric effects (Hayes and Sader, 2001).

II. METHODOLOGY

A. Study Area

Ella (6.8667° N, 81.0466° E) is a small town in the Badulla District. The Ella rock fire started on August 22nd and continued up to August 25th of 2019 as per the evidence from the news reported on the web since there is no proper forest fire database to access in Sri Lanka. Hence, identifying the correct location of the wildfire is one of the major concerns of the study.

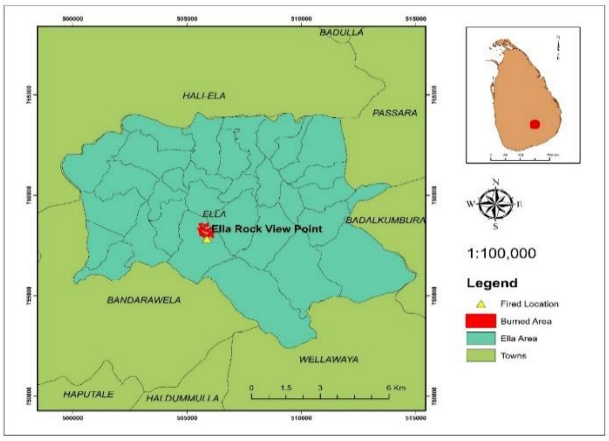

Figure 2: Study Area

B. Data

Sentinel 2 images downloaded from the Copernicus Sentinel Scientific data hub were utilized. The Pre and post Sentinel-2 images that were captured on 27th June 2019 and 10th September 2019 respectively were used since the incident occurred on 22nd August 2019.

C. Methodology Adopted

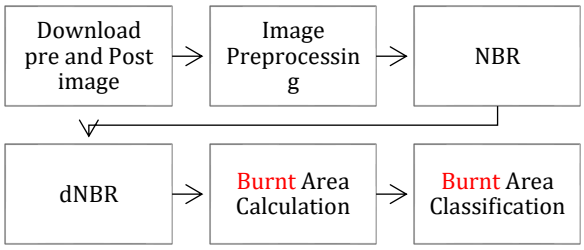

Figure 1: Methodology Adopted over the study

Google Earth images were used to identify the actual ground area by the forest fire subsequently it is difficult to find a database of the fire. Hence, news articles and reports regarding the forest fire were used as evidence. Then by using Google Earth, temporal images were identified the exact date and the location of the fire. The overall methodology implemented

over the investigation is stated in the above Figure.

D. Normalized Burn Ratio (NBR)

The raw Satellite image is compromised with a spectral band in spatial resolution and each spectral band has its way of interact with the features on the ground (Key and Benson, 2016) and the vegetation indices are defined based on the absorption and reflectance characteristic with the ground features and respective wavelength regions. The NBR has been developed to measure the burned areas efficiently by Key and Benson in 1996 (Key and Benson, 2016) and further, it's much similar to NDVI. NBR is a ratio-based vegetation index and can be stated as follows.

$$(\boldsymbol{NBR}) = (NIR - SWIR)/(NIR + SWIR)$$

Mostly, Mid Infrared upsurges from pre-fire to post-fire while the variation is utmost in extent related to other bands, and the discrepancy in between burns is greatest (Key and Benson, 2016). The ration-based indices benefit to remove within-scene topographic effects and between-scene solar illumination effects. This separates the actual reflective variances among the bands, which allows spatial and multitemporal assessment of the resulting NBR values efficiently. Change detection (Hayes and Sader, 2001) analysis is significant in measuring the changes that occurred due to particular incidence. Hence pre- and post-images are required to quantify the alteration. Consequently, to demarcate burned from unburned regions and to quantify the change that arises, the pre-and post-NBR images were subtracted. The delta NBR (ΔNBR) or dNBR (Key and Benson, 2016) can be stated as follows.

$$\boldsymbol{dNBR} = NBR_{Prefire} - NBR_{Postfire}$$

The pre-fire image contains high NIR values and low SWIR Digital Number (DN) values and further, the post-fire image contains low NIR values and high SWIR DN values comparatively. The levels of the burn severity were obtained by classifying the dNBR as per the United States Geological Survey (USGS) to decode the burn severity.

Table 1: Severity Level classification defined by the USGS Geological Survey

Severity Level	dNBR Range
Enhanced regrowth	–500 to –251
Enhanced regrowth	–250 to –101
Unburned	–100 to +99
Low severity	+100 to +269
Moderate-low	+270 to +439
Moderate-high	+440 to +659
High severity	+660 to +1300

III. RESULTS AND DISCUSSION

In the study area, nearly 73.82 hectares of area burned by the forest fire, and 63.92 % of the area was highlighted as burned severity while 15.65% of the area was highlighted as high severity as per the following Table 2

Table 1: Burned Area and the Percentage of coverage

Severity Level	Area in hectares	Percentage of Coverage
Enhanced regrowth high	00.07	00.06%
Enhanced regrowth low	00.12	00.10%
Unburned	41.49	35.92%
Low severity	36.12	31.27%
Moderate-low severity	19.63	17.00%
Moderate-high severity	18.04	15.62%
High severity	00.03	00.03%

The higher dNBR signifies more severe damage and regions with negative dNBR values imply improved efficiency after the fire (Key and Benson, 2016). The following Figure 03 illustrates the burn harshness level map of the study area. Due to the cloud cover and the unavailability of data, the post-fired image collected after two weeks from the fire happened nonetheless capable to obtain a sensible production.

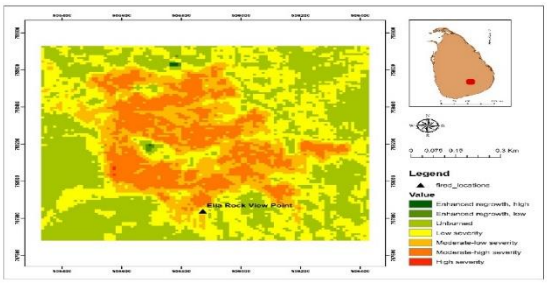

Figure 3: Burn severity classification of the Forest Fire

IV. CONCLUSION AND RECOMMENDATIONS

Remote sensing analysis plays a significant role in forest fire mapping and for better representation of the result required to integrate with the field measurements vital. Further, the freely available satellite images and the open-source platforms provide an excellent framework for scientific investigations. The NBR index was vital in forest fire mapping and recommends using in-field measurement when the physical approach gets disturbed or difficult. Even though the optical satellite images were providing better analysis, the cloud cover could be identified as a major drawback. Hence, integrated optical data with microwave data would be effective than a single type. As per the investigation, 73.82 ha were burned, and it is not a small value compared to our country.

Continuous measuring of the forest fires and maintaining a proper web-based fire management database are timely requirements of the country and it is better to change the manual bookkeeping to the database management system for storing and retrieving the forest-related data. That will help future forest management, policy development, awareness, and scientific instigations like predicting the future pattern of forest fire. Further, relevant authorities should take necessary actions to prevent forest fires since it is difficult to measure the damage that affects nature due to the forest fires.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

dNBR : difference of NBR

GIS : Geographic Information Sciences

NBR. : Normalized Burn Ratio

USGS : United States Geological Survey

QGIS : Quantum GIS

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AUTHOR BIOGRAPHIES

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Analysis of Sediment Accumulation and Decumulation Pattern by Means of Bathymetric Surveys: A Case Study in Beruwala Fishery Harbour

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Abstract – Hydrography is one of the main branches of surveying. In the modern world, the hydrography field plays a major role in safe navigation purposes and seafloor mapping. Bathymetry survey is the science of identifying and preparing charts about the behaviour of the ocean's floor. Also, bathymetric data provides an important foundation for the process of generating profiles of the seafloor, charts for safe navigation, coastal area erosion/accretion, sea-level variations, and so on. Due to the waves and currents, the sediments are transporting along the seabed and the seafloor may differ continuously. Therefore, hydrographers should collect hydrographic data for safe navigation purposes and other oceanographic requirements. The present study mainly focused on sediment accumulation and decumulation patterns utilizing bathymetric surveys in the Beruwala fishery harbour. The bathymetric data were collected by using a single beam echo-sounder in February 2012, September 2013, August 2017, and February 2019. Further, sand volumes were calculated by time series of bathymetric data using ArcGIS software with several tools (IDW, etc.) and results shows that sand accumulation is evident in February 2012 and February 2019. Further, sand decumulation is obvious in September 2013 and August 2017. Based on the obtained results, sand accumulation inside the harbour is evident during the northeast monsoon season and sand decumulation is evident during southwest monsoon season. So, this information is important for the maintenance of the harbour basin.

Keywords: *bathymetry, hydrography, monsoon, single beam echo sounder*

I. INTRODUCTION

Sri Lanka is an island in South Asia, located in the Indian Ocean to the southwest of the Bay of Bengal and to the southeast of the Arabian Sea. The nation has a total area of 65,610 km^2 and it belongs 64,740 km^2 of land area and 870 km^2 of water bodies. As an Island, it has a beautiful coastline around the country and its length is 1,340 km (830 mi).

The ocean provides an important act towards the growth of the economy of the nation. Moreover, it provides transportation around the ocean, helping to bind the various nations with import and export business, awareness of bathymetry as the primary basis for introducing practices related to structures in marine areas such as pipeline laying, infrastructure, oil drilling, port structures, dredging, aquaculture, management, fishing, etc. The determination of seafloor structural behaviour changes in sediments and planning of navigational bathymetric behaviour secure transport maps are also important and underwater depth information carries a similar significance.

Maintenance dredging to widen or retain navigable waterways or channels that owing to sedimented sand and mud, are threatened to become silted over time, likely making them too shallow for navigation. This is also done with a hopper dredge for cutter suction. Dredging land reclamation from the seabed to mine sand, clay or rock and using it to create new land elsewhere. Beach nutrition: underwater sand extraction and positioning on a beach to replace sand which are

eroded by storms or wave action. This is done to strengthen the function of the beaches for leisure and safety, which can be destroyed by human activities or storms. Sediment volumes can be estimated to determine the level of sediment accumulation in a navigation channel, given multiple sets of bathymetric survey data and the modelling of seafloor levels.

According to El-Hattab (2014), many ports and harbors have dredged channels, berths and anchorages, which suffer from siltation, thus reducing the depth of water usable for shipping. Ports work with a minimum under keel clearance that must be retained by a ship transiting to a port. Routine maintenance dredging refers to the excavation from channel beds of accumulated sediments to preserve the design depths of current public-use structures. The thickness of the layers that will be removed during maintenance dredging is fairly thin. According to El-Hattab (2014), accurate determination and modelling of the seafloor levels are essential to avoid unnecessary over-dredging and extra costs. Therefore, with a view to providing some of these kinds of facilities Ceylon fishery harbor was established. For conducting these types of facilities, the bathymetric survey should be conducted for an all over the country. That can materialize inside the harbor or navigational channel etc.

II. BACKGROUND OF THE PROBLEM

It is a well-known fact that Sri Lanka has a four different monsoon seasons during a year. Due to different types of monsoon seasons, the behavior of nearshore and offshore areas of the ocean is continuously changing those completely affecting to the country's' ocean related activities such as fisheries, transportation, recreation, tourism, etc.

Furthermore, the waves those are converts to currents after the breaker zone and those currents can be categorised as longshore currents and cross-shore currents. Mainly, the longshore currents are caused to sediment transport to inside the harbor basins. That is a huge problem of harbors in Sri Lanka.

For the efficient harbour operations, it wants to maintain a required constant depth (e.g., 2.5m–3.0m) in harbour basin mainly to safe docking purposes of ships and boats. That constant depth maintains by using dredging procedures with the help of bathymetric surveys. The bathymetric data of the harbour basin that can be used to calculate the sand volume by using existing volume calculation methods (using manual method and software like ArcGIS, Surfer etc.) Beruwala fishery harbour is located in southwest coast of Sri Lanka and the seasonal sand accumulation into the harbour basin experienced there can be identified as a main problem.

Moreover, this research mainly focuses on analyzing and calculating sand volume inside the harbour basin using existing bathymetric data and give recommendations to reduce accumulation of sand into Beruwala fishery harbour.

III. PROBLEM STATEMENT

Temporal sand accumulation and decumulation of fisheries harbors have severely affected to harbor operations and that has increased the cost of maintenance.

IV. LITERATURE REVIEW

Principle of Acoustic Depth Measurement

According to El-Hattab (2014), Depths are usually measured by echo sounders using either single-beam (SBES) or multi-beam (MBES). SBES is now the most common instrument used in port and port surveys and when used properly in a well-designed and conducted survey, will continue to provide accurate results.

According to Stephenson (1970), it is very important to realize than an echo sounder does not, and cannot, measure depth. For that echo sounders measure time taken for a pulse of sound to travel from a transmitter to the seabed and back this time interval is then converted to depth by multiplying it by the velocity of sound on water, thus

- Depth = ½ *v*t

D = Measured depth is between the transducer and some point on the acoustically reflective bottom.

v = Mean velocity of sound in water

t = time taken for pulse to travel to the seabed and back

Depth corrected to referenced water surface

- d = ½(v*t) + k + dr

If the velocity of sound propagation in the water column is known, along with the distance between the transducer and the reference water surface, the corrected depth (d) can be computed by the measured travel time of the pulse.

where:

d = corrected depth from reference water surface

v = average velocity of sound in the water column

t = measured elapsed time from transducer to bottom and back to transducer

k = system index constant

dr = distance from reference water surface to transducer (draft)

The parameters v, t, and dr cannot be perfectly determined during the echo sounding process, and k must be determined from periodic calibration of the equipment. The elapsed time, t, is dependent on the reflectivity of the bottom and related signal processing methods used to discern a valid return.

According to Bouwmeester and Heemink (1993), purpose of conducting a hydrographic survey is to obtain a predefined accurate insight of the characteristics of the sea bottom. Also, these activities fully depend on the information about the seabed. Those activities are Nautical charting, Maintenance and control of harbor approaches of deep draft shipping routes, Optimization of dredging operations, Scientific marine research etc. Not only that, from hydrographic data we can analyze and identify sediments volume that accumulated inside the harbor basin, sediments volume that decumulate from the harbor basin, monthly sediment transport rate along the coastal belt, etc.

Two fishery harbors, namely Beruwala and Hikkaduwa are located in southwestern coast of Sri Lanka. According to Samaranayake (2019), thirty-six sediment samples were collected systematically using a grab from Beruwala harbor for analysing grain size. The mean grain size of the Beruwala harbor varied from 1.83mm to 4.19mm and the average was 3.08 in phi scale indicating that most of them belonged to the fine to very fine sand range.

These sediments travel moving to the offshore due to the energetic cross shore currents. Normally during north-eastern monsoon period most of sediments come from offshore due to the calm weather condition. Also, during that period, the wave consists of low energy. Sediments around Beruwala harbor vary fine to very fine sand range. The mean grain size is varying from 1.83 mm to 4.19 mm. Therefore, the sand inside the Beruwala fishery harbor is traveling most recently from inside and outside of the harbor basin.

V. EXPERIMENTAL DESIGN

Study Area

The study area of research project is focused on Beruwala fishery harbor situated in the western province in Kalutara district, bordering to the Southern end of the western province. Entering position is given by 142089.2 N & 112124.9 E (National Grid Coordinates). Beruwala fishery harbor consists of 4.6 Ha of land area and the 11.99 Ha of the basin area. Also, this harbor maintains a constant depth like 2.5 m – 3.0 m for docking their boats.

Figure 1. Study Area

VI. METHODOLOGY

Table 1. Calculated sand volumes above the reference plane (-4.27)

Data Set	Calculated Sand Volume above the reference Plane	Sand Accumulate or Decumulate
February 2012	172150 m^3	Accumulated
September 2013	171234 m^3	Decumulated
August 2017	147589 m^3	Decumulated
February 2019	182885 m^3	Accumulated

Main objective for this research is assessing sand accumulation and decumulation pattern in Beruwala fishery harbor by means of existing bathymetric data. For that, author used four different bathymetry data sets which are collected in different monsoon time periods using single beam echo sounder. These four different data sets were collected according to February 2012, September 2013, August 2017, February 2019 respectively. In order to gain an understanding of the accumulation and decumulation pattern in fishery harbor, data were processed by using Arc GIS software.

Therefore, by using Arc GIS software create a unique polygon for all the data sets. Now all the data points are covered by that unique polygon. If not, the study area is going to change with different data sets. Because bathymetry data were not collected for a unique area. By using IDW tool we can convert those points into one raster image. Likewise, four different rasters were created four different data set.

Volumes were calculated with one reference plane. That reference plane is the plane that travels through the deepest point (-4.27) of all the data sets.

By using IDW tool in ArcGIS software and from that a raster surface may be interpolated from points.

For a raster, triangulated irregular network (TIN), or terrain dataset surface, we may generate contour lines. In here, contours created by using raster image and contour interval is 0.2 m. After running the surface volume tool, it measures the volume between a surface and reference plane. By analysing amount of sand volumes with different datasets, we can calculate monthly rate of sediment transport.

VII. RESULTS

The calculated sand volumes above the reference plane (-4.27 m) are as follows,

We can identify those sediments accumulated inside the harbor premises during February 2012 and February 2019. Also, sediments decumulated from the harbor basin during September 2013 and August 2017. With respective to February 2012 September 2013 provide that it was evident -916 m^3 sediment decumulate from the harbor basin. Furthermore, comparing with August 2017 gives -24,561 m^3 sediment decumulated from the harbor basin. Those data have been collected during the southwest monsoon period.

Finally, February 2019 data set provide 10,735 m^3 sediment accumulated into the harbor and belongs to the northeastern monsoon period.

Table 2. Monthly volume transport rates with respect to 2019

Data Set	Number of months between two datasets	Sand Volume (m^3)	Volume Transport rates with respect to 2019 (m3/month)
February 2019		182885	
	18		1960.889
August 2017		147589	
	47		179.246
September 2013		171234	
	19		127.798
February 2012		172150	

Above Table 2 shows, monthly volume of sediment transport rates during February 2019 to February 2012.

Above monthly volume transport rates calculated by difference between volumes with respective two data sets divided total number of months between those two data sets.

M.V.T.R =(Volume of 2019 – Sand volume of another dataset) (Number of months between two datasets)

Table 3. Volume transport rates with respect to 2012

Data Set	Number of months between two datasets	Sand Volume (m^3)	Volume Transport rates with respect to 2019 (m3/month)
February 2012		172150	
	19		48.210
September 2013		171234	
	47		372.136
August 2017		147589	

The Table 3 shows, monthly volume of sediment transport rates during February 2012 to August 2017. We are moving from February 2012 to September 2013 the monthly sediment transport rate is 0.48×10^2 m^3 per month. The sediment transport rate is given for 19 months. When we move from February 2012 to August 2017 the monthly sediment transport rate is 3.72×10^2 m^3 per month. This amount of sediment transport rate is given during 66 months of time period.

According to Chandramohan et al., (1990),Longshore transportation along the west coast of Sri Lanka occupies the south from January to March and the north May to December. The annual gross transport rate is lower all over the Sri Lankan coast and the southern portion of the coast is estimated to be lower.

VIII. DISCUSSION

A, Different monsoon changes around the coastal belt.

During southwest monsoon period the sea around western part of Sri Lanka is going to be rough. The currents and waves happen very frequently. Therefore, during this time there is no sediments deposition around coastal belt due to energetic waves and currents. All the sediments travel to the offshore area. But during Northeast monsoon we can see a calm sea around western part of Sri Lanka. During this time period sediments travel from deep sea to coastal areas with the help of waves and currents. During that time period sediments can be deposited and accumulated inside to the harbor.

B. Sediments accumulate from the Beiray river straightly to the harbor basin.

The small drainage river called Beiray river is situated in Beruwala Area. This is a type of drainage river which goes to the Beruwala fishery harbor. During Southwest monsoon time period, the average rainfall is high in Beruwala area. Therefore, sediment moves to the offshore due to the energetic waves. When the rain falls, the sediments come from the land and most of them move to the offshore due to energetic cross shore currents. Normally, low rainfall occurs during Northeastern monsoon time period. So, less amount of sediment come from the land side. But most of sediments come from offshore due to calm weather condition. Due to the low energetic wave's sediments coming from the offshore to the harbor basin. The sediments came from the land area also traveling through this process too. Therefore, sediments get accumulated during northeastern monsoon period.

C, Sediment characteristics of Beruwala fishery harbor.

According to Samaranayake (2019), the mean grain size of the Beruwala fishery harbor varied from 1.83 mm to 4.19 mm and the average was 3.08 in phi scale indicating that most of them belongs to the fine to very fine sand range. Sediments around Beruwala harbor can usually be transported by currents. Because those sediments are not very coarse or coarse. Depending different type of monsoon periods, the travelling process of sediments is going to change.

D. Due to waves, currents and tides.

Waves, currents and tides contribute greatly to the redistribution of the sediments supplied to the depositional inside to the harbor basin according to Saravanan & Chandrasekar (2010). Waves are found to provide the necessary energy for the movement of water and sediments within the nearshore zone. Depending on the energy of waves, currents and tides the sediment can be

easily accumulated and decumulated from the harbor basin. During north east monsoon time period the Beruwala area consists of a calm sea weather condition. Therefore, sediments accumulate inside to the harbor premises during that period. During southwest monsoon time period, the energy of waves and currents is high in Beruwala area. Therefore, most of beach sediments are traveling to offshore by energetic currents and waves.

IX. CONCLUSION

Mainly, there are four types of reasons for sand accumulation and decumulation in Beruwala fishery harbour. Those are; (i) Different monsoon changes around the coastal belt, (ii) sediments accumulate from the Beiray river straight to the harbor basin, (iii) sediment characteristics of Beruwala fishery harbor and (iv) due to waves, currents and tides.

To prevent sand accumulation inside to the harbor we can suggest some engineering plans for harbors. One of them is preparation of suitable break water. From that we can protect harbor from storm waves. Prepare some artificial harbor. From that harbor having no natural protection but artificial arrangement is made to protect the harbor from storm and wind. sand accumulation and decumulation of fisheries harbors and harbors have severely affected to harbor operations and that is increased the cost of maintenance. From these kind of construction projects, we can minimize sand accumulation and decumulation inside to the harbor. Accordingly, we can minimize the cost of maintenance of the harbors.

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The Impact of Cost Reduction Methods on Cost Overruns in the Sri Lankan Construction Industry

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Abstract — Construction Industry plays a major role in the development of a country. Cost is a basic criterion which measures the success of a project. Though the cost reduction methods are available in the industry, cost overrun has severely affected the status of the Sri Lankan construction industry. Thus, this paper aims to identify the impact of cost reduction methods which are currently used over cost overrun, on the identified management approaches in the Sri Lankan construction industry. This research was assessed through a detailed questionnaire survey and interviews. The number of distributed questionnaires were 60 and the response rate was 88%. Correlation and regression analyses were done with the use of SPSS software to analyse the collected data. The interview questions were assessed through the content analysis. The findings highlighted that there is a positive relationship between cost reduction and those identified management approaches (pre-contract, post-contract, human resource, material & change management). It is recommended to change the cost mitigation measures from traditional methods to new methods such as sustainable construction and value management strategies. Moreover, the implementation issues of these methods were identified and suggestions were made as making proper project planning with the use of actual project data and software skills. While this research focused on finding the impact of cost reduction methods, future research could develop and categorize the modern techniques to reduce the cost and time overruns in construction projects.

Keywords: *cost control, management, cost overruns, Sri Lanka*

I. INTRODUCTION

Construction Industry plays a major part in the development of a country. Construction Industry is one of the prominent sectors in Sri Lankan context which has contributed approximately 6.8% to the GDP (Annual Report 2018, Central Bank of Sri Lanka). Due to various reasons the main problem which Sri Lankan construction industry currently is facing is "poor cost performance". The cost management is a challenging task to Project Managers. To complete the projects within given cost parameters & timeline, corrective actions are needed whenever it's required (Ejaz, et al., n.d.).

In most of the construction projects, the final completed cost is almost always higher than the pre-estimated cost which is calculated at the initial stage. Factors for cost overrun differ from country to country depending on economic, political, cultural as well as internal & external factors of the industry. Cost estimated at the initial stage is the most important factor (Devi & Ananthanarayanan, 2017). Real cost estimate is a crucial factor because it determines financial competence of the project & provides a basic idea for cost control of the project.

There is a necessity for increasing the work of construction & decrease the cost at the same time. Experts in the industry have to have theoretical as well as practical knowledge on cost control techniques. There are plenty of various techniques & project control softwares available regarding cost optimizing, but still not accomplish the basic target requirements of a construction project. Even with various cost control techniques, cost overrun is not uncommon all over the world (Azhar, et al., 2008).

There are many reasons for cost overrun in the construction industry. The large the amount of cost overrun, there the same amount of cost control & reduction techniques available at industry. Though they were plenty but sill we face the problem of cost overrun means there is a need of finding modern cost reduction methods. To achieve those targets, this paper aims to get the base knowledge by identifying the impact of this cost reduction methods which currently practiced at projects over cost overruns, on selected management approaches (pre contract, post contract, human resource, material & change management) in Sri Lankan context.

II. LITERATURE REVIEW

A, Construction Cost Overruns

There is a need for understanding the factors affecting cost overrun & identify the mitigation measures that can be taken to reduce the loss. It has been observed that delay and cost overrun are habitually occurring in developing countries (Ejaz, et al., n.d.). Further Azhar, et al. (2013) confirmed the statement as the poor cost performance is a shared problem worldwide.

The cost overrun of a project will be depending on project size, type & location. The statement was emphasized by Baccarini (1996) as the requirement of proper management of projects is greater at large scale construction projects than the smaller. Cost & time are inseparable since the extension of time leads to the cost overrun (Dlakwa and Culpin, 1990). Malkanthi (2017) interpreted that the main problem is in reality not the techniques, but the familiarity regarding poor management of methods & moreover the inadequate control. “Without keeping an eye on the real costs while in progress, the successful completion will not be possible” (Memon et al., 2011). Cost overrun has been a topic discussed in numerous literatures, & there is a need to find cost reduction methods by identifying the impact of them on behalf of the industry.

B. Causes For Cost Overruns

There are different reasons for cost overruns in construction which depend on the type of the project. Cost overruns can be categorized into several groups for the easy of understanding & providing of better mitigation solutions. A study by Ramabhadran (2018) categorized cost overruns into two main as internal & external. External factors challenging to control than internal & also it has a low occurrence edge. He found out that only internal factors were extremely influencing the cost overrun. Karunakaran et al., (2018) categorized potential cost overrun factors in to 7 categories named project related, contract related, client related, contractor related, consultant related, labour related & external related factors. Memon et al., (2011) & Baccarini (1996) confirmed in general, causes for cost overruns can be recognized as political, economic, technical or psychological causes. Olawale and Sun (2010) separated causes into three main headings which in a more practicable way as mainly within the owner’s control, within the consultant’s control and beyond either parties control.

Consequent delays in construction, reworks and the practice of awarding the contract to the lowest bidder are the common causes for cost overruns which identified in non-infrastructural Indian projects (Devi & Ananthanarayanan, 2017). Malkanthi (2017) investigated that 25% of projects in Sri Lanka are over budgeted. Some of the reasons are lack of monitoring, price fluctuations of raw materials, cost of plant & machinery, improper planning & high interest rates. Hafez (2015) noted that the contractors in Egypt find difficulty in controlling project cost due to problems which include change orders, design errors, economic dropdowns. Communication barriers between parties also badly effect on cost Memon et al., (2011).

Kaming et al. (1997) expressed survey in Indonesia listed inflation, higher material cost & higher cost of labour supply while Karunakaran (2018) research on Malaysia revealed poor contract management as the most significant causes for delay & cost overrun.

It’s confirmed from the above literature that the causes of cost overrun vary from country to country based on the subjective matters. The experts in the industry could focus more common cost overruns & make efficient mitigation measures for the betterment of the industry.

C. Traditional Cost Reduction Methods

For the identified cost overruns there were reduction techniques which proposed through

different studies. Management should make necessary steps on controlling human resource. Further emphasized that the important of training about "Cost Management" & make proper management among the project (Ramabhadran, 2018). He further stated a well-defined plan is necessary for the effective completion of a project with less disputes.

The total cost should be carefully assessed at the initial stage before signing on a contract (Hedaya & Saad, 2017). The tight control among project can limit variations which directly affects to the cost overrun. Aljohani (2017) was suggested to control cost at projects by applying effective resources & improve proper communication between internal & external stakeholders. According to Tam (2011), cost control can be easily attained through recruiting the right person for the right job function which is a responsibility of project manager by delegating the responsibilities with proper understanding.

There were plenty of literature available on the causes of cost overruns & on the cost reduction methods (Ejaz, et al., n.d.). It's essential to access the impact of the current cost control practices on cost reduction. This paper aims to fill the gap by identifying the impact of cost reduction methods on cost overruns in the Sri Lankan construction industry by approaching identified management approaches.

III. RESEARCH METHODOLOGY

The research study is targeted to identify the impact of cost reduction on management approaches which practices in the construction industry Sri Lanka. To evaluate the impact of cost reduction, a large range of community which attached to the construction industry in Sri Lanka will be targeted covering with the professionals & stakeholders in the Sri Lankan construction industry. The research was completely evaluated through questionnaire survey & interviews with the concerned authorities. The combinations of qualitative & quantitative methods are highly appreciated because it gives a comprehensive picture & enhance the study about the research area (Ramabhadran, 2018).

A. Data Collection Methods

A web based detailed questionnaire (Google forms) was circulated among professional groups in construction industry, Sri Lanka sent through e-mails to the construction firms. Questionnaires were distributed among professionals in order to obtain suitable responses to the questionnaire & different viewpoints were ranked accordingly to the "Likert Scale". The total number of questionnaires distributed was 60 (selected by stratified random sampling), & the response rate was 88.33% including from 13 Contractors (C), 18 Quantity Surveyors (QS), 10 Engineers (Eng), 07 Consultants (CR) and 05 Project Managers (PM).

Semi-structured interviews provide the freedom to discuss about numerous areas widely (Le-Hoai, et al., 2008). A purposive sample was selected for the semi-structured interviews since the objective is to select the partakers who have better knowledge & industry experience in the area of research study. A total number of interviews conducted were 08 including 01 Contractor, 03 Quantity Surveyors, 02 Engineers, 01 Consultant and 01 Project Manager.

B. Conceptual Framework

According to the conceptual framework, there are five relationships can be identified.

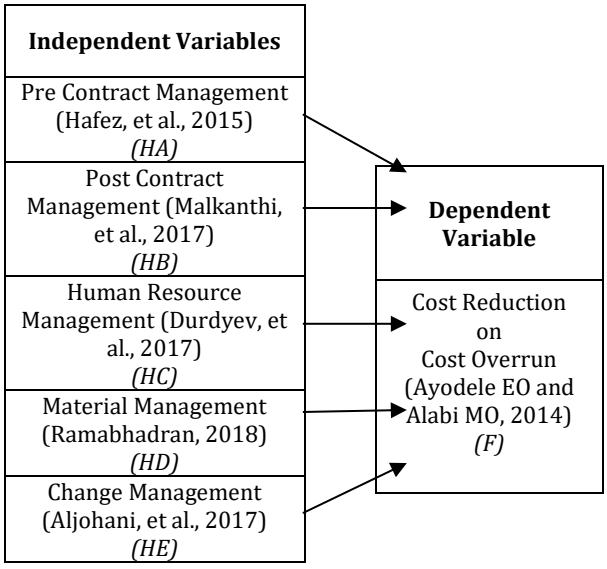

Figure 1: Conceptual framework

Independent variables are identified to find the effect of them against the main core of the study. Based on the framework, assumptions have been developed. In order to exam the agreement

among respondents on construction cost performances the hypotheses were developed as following.

HA1 –There is a relationship between Pre Contract Management & Cost reduction.

HB1 –There is a relationship between Post Contract Management & Cost reduction.

HC1 – There is a relationship between Human Resource Management & Cost reduction.

HD1 – There is a relationship between Material Management & Cost reduction.

HE1 – There is a relationship between Change Management & Cost reduction.

C. Data Analysis Methods

Primary data has been analyzed using quantitative techniques and secondary data has been analyzed using a content analysis. Statistical analysis helped to determine the relationships between the developed variables related to cost control & and their effect on projects (Devi & Ananthanarayanan, 2017). This is a best method for multivariable analysis. The relationship is hypothesized at the beginning & the statistical analysis were done accordingly. The analysis was done with the use of SPSS software which has a broad coverage of formulas, statistical procedures. Presentation was in the forms tables which were auto generated by the SPSS software itself. Most of the data converted in to information. A cording system used at the SPSS software is similar to the codes mentioned on variables (Refer Figure 1).

1. Correlation analysis: This helps to analyze the relationship between different variables in a multivariable analysis study. The correlation is used to validate the agreement or disagreement among parties (contractors, quantity surveyors, client representatives, engineers, project managers) on a common factor (Le-Hoai, et al., 2008). This aim to find the relationship between developed key factors effects on cost control (independent variables) & cost reduction (dependent variable).

In this study, correlation coefficient is measured by the "Pearson Correlation Analysis" which is analyzed with the use of SPSS software. The output value of analysis is always been -1 and +1. Correlation coefficient equals to -1 shows there is negative relation between selected two variables, correlation coefficient +1 shows there is positive relation between selected two variables & correlation coefficient 0 shows there is no relation between selected two variables. For this research the coefficient value is determined as "P" & the significance level is 0.05.

2. Regression analysis: Regression analysis was done for the same statistical data collected & analyzed through the use of SPSS software. This focused to find out which variable has the most impact on the cost reduction in the construction industry in Sri Lanka. For this study the linear regression is computed.

IV. DATA ANALYSIS

The Construction activity is a complex work item which needs the hand of different parties who specialized in different areas of profession. In the same way "Construction Cost", is a main item which affects through the life cycle of a project & every party must know the cost items in different degrees according to their job specification. So, it is important to get the idea of different parties who are involved in a construction project regarding "Cost" factor. 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 showed in Figure 2.

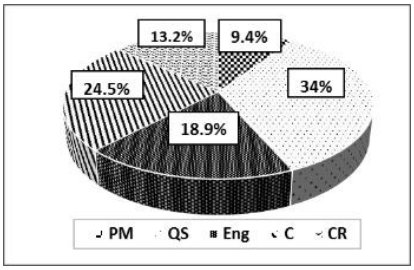

Figure 2: Respondent based on profession

Then targeted to find out whether these professionals, experienced project cost overruns. More than 90% of respondents have experienced cost overruns at construction projects which is highlighted as a serious problem in the construction industry and the need of actions to mitigate the cost overrun in projects.

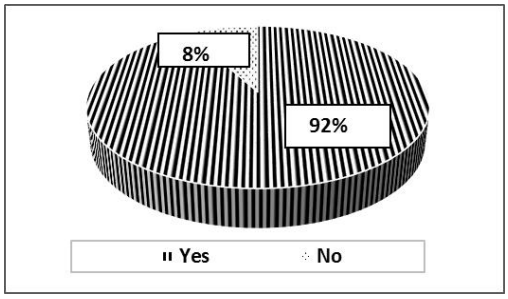

Figure 3: Experience in cost overruns

The dependent & independent variables were figured out according to the base literature survey. The main indicators which questioned from the respondents were tabulated below.

Table 1: Main indicators of variables

Variable	Indicator	Reference
Pre Contract Management (A)	Risk assessment	(Ramabhadran, 2018)
	Proper detailed estimation	(Sooriyaarachchi, 2007)
	Adequate contingency plan	(Ejaz, et al., n.d.)
	Pre-qualification assessment	(Ramabhadran, 2018)
	Most suitable bidder	(Hafez, et al., 2015)
	Tender documentation	(Aljohani, et al., 2017)
	Time allocation	(Durdyev, et al., 2017)
	Feasibility study	(Le-Hoai, et al., 2008)
Post Contract Management (B)	Contractors' financial status	(Aljohani, et al., 2017)
	Clients' financial status	(Le-Hoai, et al., 2008)
	Government intervene	(Hafez, et al., 2015)
	ICTAD guidelines	(Malkanthi, et al., 2017)
	Project monitoring	(Sooriyaarachchi, 2007)
	Decision making	(Karunakaran , et al., 2018)
	Update cost data	(Ramabhadran, 2018)
Human Resource Management (C)	Labor turnover	(Durdyev, et al., 2017)
	Project management methods	(Ramabhadran, 2018)
	Experienced professionals	(Sooriyaarachchi, 2007)
	Effective resources	(Aljohani, et al., 2017)
	Training & development	(Karunakaran , et al., 2018)
	Better communication	(Aljohani, et al., 2017)
Material Management (D)	Inventory control	(Ramabhadran, 2018)
	Minimize material wastage	(Tam, 2011)

Variable	Indicator	Reference
	Resource management	(Aljohani, et al., 2017)
	Supply agreement	(Devi & Ananthanarayanan, 2017)
	Local materials	(Durdyev, et al., 2017)
Change Management (E)	Client requirement	(Ramabhadran, 2018)
	Design team	(Hedaya & Saad, 2017)
	Design analysis	(Ramabhadran, 2018)
	Better visualization	(Aljohani, et al., 2017)
Cost Reduction (F)	Pre Contract Management	(Hafez, et al., 2015)
	Post Contract Management	(Malkanthi, et al., 2017)
	Human Resource Management	(Durdyev, et al., 2017)
	Material Management	(Ramabhadran, 2018)
	Change Management	(Aljohani, et al., 2017)

Key factors were developed (A, B, C, D & E) which the cost reduction (F) depends on. The professional idea is that cost control techniques can be used effectively at the post-contract stage & then in the pre-contract stage. The percentages are 23% & 21% accordingly which doesn't have a major difference between rates & confirmed that both these 2 stages are most critical for project cost control. The parties on the project are not much focused at the pre-contract stage regarding cost due to the limited time allocation. Most team members of the project are going for easy & short-term plans without predicting its risk when it comes to long term. The post contract stage is the lengthy period in a construction project where series of different complex activities happened. Controlling cost at that stage with appropriate strategies lead to reduction of cost overruns.

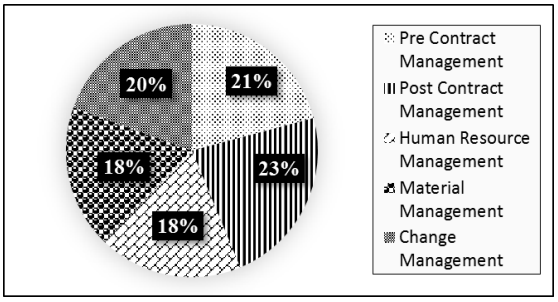

Figure 4: Effectiveness analysis of cost reduction

A. Correlation Analysis

Correlation analysis was 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 variable was tested with the dependent variable. Positive correlation represents, when one variable increases the other variable also increases & the negative correlation represents decrease of both. The correlation coefficient will be satisfied based on significance value (P) which,

P < 0.05 – The DV has a relationship with particular IV

P > 0.05 – The DV doesn't have a relationship with particular IV

Where:

N = No of respondents (53)

AVGA = Average of Pre-Contract Management *(IV)*

AVGB = Average of Post-Contract Management *(IV)*

AVGC = Average of Human Resource Management *(IV)*

AVGD = Average of Material Management *(IV)*

AVGE = Average of Change Management *(IV)*

AVGF = Average of Cost Reduction *(DV)*

The table 2 demonstrates the correlation between pre-contract management, post contract management, human resource management, material management & change management towards the cost reduction. The results of hypothesis testing were discussed below.

Table 2: Correlation coefficient analysis of variables (SPSS software generated)

Correlations

		AVGA	AVGB	AVGC	AVGD	AVGE	AVGF
AVGA	Pearson Correlation	1	.591**	.588**	.507**	.601**	.720**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	53	53	53	53	53	53
AVGB	Pearson Correlation	.591**	1	.566**	.523**	.608**	.550**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	53	53	53	53	53	53
AVGC	Pearson Correlation	.588**	.566**	1	.474**	.633**	.630**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	53	53	53	53	53	53
AVGD	Pearson Correlation	.507**	.523**	.474**	1	.480**	.646**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	53	53	53	53	53	53
AVGE	Pearson Correlation	.601**	.608**	.633**	.480**	1	.731**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	53	53	53	53	53	53
AVGF	Pearson Correlation	.720**	.550**	.630**	.646**	.731**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	53	53	53	53	53	53

**. Correlation is significant at the 0.01 level (2-tailed).

First variable is pre-contract management (A) & based on the aforesaid table, it has a positive & very strong relationship with a value of 72% & a significance level of 0.000 (P<0.05). That means can't reject the alternative hypothesis *(HA1)*, which there is a relationship between pre-contract management & cost reduction.

Second variable is post-contract management (B) & based on the aforesaid table, it has a positive & considerably strong relationship with a value of 55% & a significance level of 0.000 (P<0.05). That means can't reject the alternative hypothesis *(HB1)*, which there is a relationship between post-contract management & cost reduction.

Third variable is human resource management (C) & based on the aforesaid table, it has a positive & strong relationship with a value of 63% & a significance level of 0.000 (P<0.05). That means can't reject the alternative hypothesis *(HC1)*, which there is a relationship between human resource management & cost reduction.

Fourth variable is material management (D) & based on the aforesaid table, it has a positive & strong relationship with a value of 65% & a significance level of 0.000 (P<0.05). That means can't reject the alternative hypothesis *(HD1)*, which there is a relationship between material management & cost reduction.

Fifth variable is change management (E) & based on the aforesaid table, it has a positive & very strong relationship with a value of 73% & a significance level of 0.000 (P<0.05). That means can't reject the alternative hypothesis *(HE1)*, which there is a relationship between change management & cost reduction.

B. Regression Analysis

Regression analysis was done to identify the impact of developed 5 different variables on the dependent variable. This makes all the independent variables comparable & standardized.

Table 3: Regression analysis (SPSS software generated)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.071	.366		.195	.846
	AVGA	.397	.127	.338	3.125	.003
	AVGB	-.106	.124	-.092	-.852	.398
	AVGC	.121	.122	.108	.997	.324
	AVGD	.242	.079	.292	3.048	.004
	AVGE	.369	.110	.376	3.361	.002

a. Dependent Variable: AVGF

From the aforesaid table 3 explained the regression model is as follows,

$$Y = \alpha + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + Std.E$$

Equation 1: Linear regression

$$Y = 0.071 + \{[0.397*AVGA] - [0.106*AVGB] + [0.121*AVGC] + [0.242*AVGD] + [0.369*AVGE]\} + Std.E$$

Equation 2: Linear regression (Based on SPSS generated data)

It shows the beta value 0.397 & a significance value of 0.003 shows a positive relationship with 40% variance of cost reduction is affected by the pre-contract management. More elaborately, it states that cost reduction increase 40% with the increase of pre-contract management strategies.

It shows the beta value (-0.106) & a significance value of 0.398 shows a negative relationship with (-11%) variance of cost reduction is affected by

the post-contract management. More elaborately, it states that cost reduction decrease 11% with the increase of post-contract management strategies. The correlation for this particular variable was positive & had a considerably strong relationship. The currently practicing cost reduction techniques were questioned by this variable. With the negative value, it indicates that there is significant lack among those traditional techniques & need of modern new techniques were identified because the post contract stage was ranked as the top when considering the causes of cost overruns (refere Figure 4) mostly happened & have the most of need to control the cost.

It shows the beta value 0.121 & a significance value of 0.324 shows a positive relationship with 12% variance of cost reduction is affected by the human resource management. More elaborately, it states that cost reduction increase 12% with the increase of human resource management strategies. Here the productivity is discussed with the minimum cost overruns.

It shows the beta value 0.242 & a significance value of 0.004 shows a positive relationship with 24% variance of cost reduction is affected by the material management. More elaborately, it states that cost reduction increase 24% with the increase of material management strategies.

It shows the beta value 0.369 & a significance value of 0.002 shows a positive relationship with 37% variance of cost reduction is affected by the change management. More elaborately, it states that cost reduction increase 37% with the increase of change management strategies.

V. CONCLUSION

The main objective of the research was to identify the impact between cost reduction & pre-contract, post-contract, human resource, material and change management approaches. This was achieved through a detailed questionnaire survey. The collected data were analysed with the use of SPSS software. Independent variables & dependent variable were developed & the relationship between variables were analysed through correlation analysis. For this the hypothesis were defined initially. The positive relationship was existing only if the significance value is less than 0.05 as shown in table 2. The study revealed that the all independent variables have a positive relationship with dependent variable.

Then the regression analysis was done to identify the impact of the relationships based on above computed results which is shown in the table 3. If the variance value is positive, it determined that when the IV increases (decrease) the DV also increases (decrease) & if the variance value is negative it determined that when the IV increases (decrease) the DV decreases (increase).

From the interviews, the interviewees specifically comment on the implementation issues of cost reduction methods in the construction industry. There are plenty of new concepts in the industry regarding cost control but still experienced cost overruns due to implementing issues. Main issue is that the parties are not willing to changes due to the afraid of risk factor. Most of the time in construction projects the top level management are the old experienced professionals who are not interested on new method & go along with the traditional methods. So, the newcomers who have innovative ideas also proceed with the traditional methods which currently practicing because no one is there to get their modern ideas & persuade them. Normally people are lazy to adhere or to adopt new trends from conventional methods (Foster, 1989). No place for new generation ideas because old people run & tightly control the whole industry. An interviewee stated that,

"With the advanced development of the construction industry, it should go with new knowledge. The traditional methods which have being practiced a long period of time in the industry to control cost overruns must be the basic foundation, but modern cost reduction techniques need to implement for the development of the industry".

Poor planning strategies also an issue when implementing modern cost reduction methods (Ramabadran, 2018). Most of the planned schedules & programmes are not practical due to not having proper idea about the construction projects. Industry stakeholders don't have proper knowledge & don't know the importance of having cost reduction strategies on projects.

Simply they don't have any idea about cost controlling & also lack of innovative thinking. Even the industry professionals understanding and the ability to implement these modern cost reduction methods are questionable in the Sri Lankan construction market. Lack of expertise people on the industry & high cost for training people on among subjects are the main drawbacks for implementing cost reduction methods in the industry.

VI. RECOMMENDATIONS

The cost reduction strategies which questioned in the survey (refer table 1), are the traditional practices in the Sri Lankan context. Though these practices available in the industry, still cost overrun happens in every construction project. It is highlighted that the identification of modern, advanced, practical construction methods are needed to implement in the industry & interviewees recommended methods are listed below.

The main objective of the research analyzed & the impact of cost reduction methods over cost reduction. The impact is positive & the developed independent variables (management stratergies) have a relationship with the identified dependent variable.

Pre Contract management - *Selection of appropriate procurement strategy*; There are different types of procurement strategies for projects. Main procurement methods are Traditional, Design and build & Management. This selection must be done carefully because this step decide the success of the project (Otim, et al., n.d.). An interviewee said that, "Engaging for lump sum projects will somewhat keep the project on budget margins, because at the initial the contract sum is fixed amount & the construction works done up to the limited costs". *Risk management;* having a proper risk management at the initial is essential (Forster, 1989), by identifying all future unforeseen events & update the system up to the completion of the construction project. *Research & development (R & D) method*; Research & development is a new strategy to control the cost of a project. In this method, it's identified one activity of work & research on it to get the best option out of it with minimum cost by accessing the all-risk events.

Post Contract management - *Value management (VM);* Value management is a new approach of increasing the value of project by minimizing the additional unnecessary cost & reduce time for completion. *Sustainable construction*; with sustainable it can use more of natural energy resources which minimize cost to increase the use of renewable energy systems (Lowe & Zhou, 2003). The construction now-a-days go towards this concept by detecting the future advantages by analyzing the whole life cost of the project. *Modern construction technologies & software development*; with the advancement of technology there were modern techniques (Off-site construction, modular construction, precision manufactured construction, pre-manufactured construction & Digital/ Smart Construction), in building construction with complete project in lesser time. If the time of construction saved, the cost will be automatically mitigated. With the use of new softwares (Primavera, MS Project, ERP system & BIM), the project programme can update & can check the actual expenses of project along with the estimated project budget & can get the cost decisions along with. *Proper dispute resolution*; According to Baccarini (1996) disputes are a common phenomenon in construction due to its complexity & involvement of different parties. Dispute resolution is a process which consume a large amount of money & time. Better to mitigate arising of disputes by maintaining a better communication among members of the project.

Human Resource Management - *Proper labor control plans*; managing the human resource will be a challenging task at sites. Proper plans to be created to lower the labour turnover & have to make arrangements for settling the payments due monthly wise as they claimed. *Training & Development*; training programs must be conducted on behalf of lectures by giving the information of the importance of cost control with better communication processes.

Material Management – *Inventory control*; the material reconciliation must be done according to the payments requests & to be provided with the information of cost reports. *Supply Chain Management*; proper procedure have to be followed to the effective allocation of resources.

Change management – *Proper visualization*; the all stakeholders in the design team must co-operate when decision making is based on a situation to avoid arising of future disputes.

To overcome the implementation issues of cost reduction methods also discussed with the interviewees & some of their suggestions were discussed. Make proper project planning with the use of actual data & software (IT skill) facilities is an essential item. Establish a proper cost monitoring & cost controlling system during the construction period by using updated cost data will have positive impacts on project. The interviewee IP03 pointed out that,

"Involving the contractor at the design stage & optimize the project scope during project formulation make positive impacts on project cost. Conduct a proper waste management system & store management at site is required. Automated the project management system & should not over control the cost of essential items. On top of all this maintain update cost documents is very important to track cost overruns and idling".

Educate & make awareness of people about importance of cost control is a best strategy to implement modern cost reduction techniques in the construction industry (Hafez, et al., 2015). The interviewee stated that, *"Make proper training programmes & development states among people regarding those techniques including legal authorities related to construction like ICTAD & CIDA are essential"*. Educating people have to start from the academic level (relates to construction industry) itself. Improve knowledge of teenagers about value of money & important of cost control through academic programmes like in university course modules are a better option.

VII. RESEARCH LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

While this research focused on the impact of cost overruns on management approaches in Sri Lankan construction industry (Limited to Sri Lankan Context), a study can be done to identify the modern techniques to reduce the cost overruns in construction projects. Further studies can be done to categorize the most vital causes for cost overruns in construction projects.

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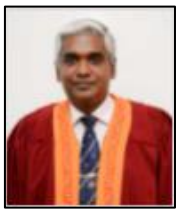

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Augmented Reality for Construction Project Monitoring: Challenges and Strategies for Adoption in Sri Lanka

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Abstract— Construction project monitoring, which is governing effective decision making and successful project completion, is a key process in every construction project. However, construction project monitoring is not free from barriers, which necessitate the need for technological implementation as a possible solution to overcome such barriers. Though utilising augmented reality leads to achieving immense benefits, but there are challenges identified in implementing augmented reality within the construction industry. Therefore, this study aimed to investigate the challenges and strategies for implementing augmented reality for construction project monitoring in the Sri Lankan construction industry. A qualitative approach was adopted and expert interviews were selected as the data collection technique. Ten experts with experience in both Information Communication Technology (ICT) industry and the construction industry were interviewed to facilitate the in-depth input to the study. The collected data were analysed using code-based content analysis with NVivo 12 Software. The study identified the challenges for augmented reality implementation as the lack of knowledge on hardware and software, lack of accuracy and reliability, higher initial cost, privacy issues, health and safety issues, and lower battery life. Further, providing knowledge on augmented reality through education, training and workshops, carrying out feasibility studies, providing reduced tax-free facilities, using access control methods, implementing proper guidelines, and taking safety precautions have been identified as the possible strategies to overcome the challenges. The paper concludes by mapping the identified strategies to the challenges in implementing augmented reality in Sri Lankan construction industry.

Keywords: *augmented reality, construction industry, challenges, strategies*

I. INTRODUCTION

The construction industry is dynamic in nature, due to the uncertainties in technology and budgets. Moreover, building projects are becoming much more difficult and complex. Therefore, the project teams are facing extraordinary changes due to this dynamic nature in the construction industry (Kalkofen et al. 2011). Therefore, the construction industry is demanding implementable strategies for successful completion of the projects. Bosché et al. (2015) and Chan, Scott and Chan (2004) signified that, effective progress monitoring in construction will ensure successful completion of the project.

Kazin et al. (2009) defined monitoring as collecting, recording, analyzing, and reporting information by concerning key aspects of project performance at the pertinent level of details required by project managers and decision makers. Bosché et al. (2015) have identified Construction Progress Monitoring (CPM) as recognizing the current project status easily, rapidly, and accurately in construction industry. CPM will facilitate to identify the disagreements among the as-built and as-planned progress and enables the construction industry professionals to make decisions on the necessary remedial actions (Golparvar-Fard et al. 2012). In the construction industry worldwide, CPM can be experienced in the forms of manual visual observations and traditional progress monitoring based on field personnel's explanations, which are highly time consuming and error prone (Navon & Sacks, 2007). Further, Roh et al. (2011) have evidenced that an analysis

of large amounts of as-built data and the subsequent manual estimation for construction progress monitoring is time-consuming and prone to error. Manual progress monitoring represents excessively high costs, or ineffective, or even both, due to the significant required workload of experts (Rebolj et al. 2017). To overcome above problems, investigation on new methodologies that allow automatic recognition of as-built performance and visualization of construction progress is dynamic (Lee and Peña-Mora, 2006). Visualizations in real world environments benefit from the visual collaboration between real and virtual imagery. Even though, compared to traditional visualizations, '*Augmented Reality*' (AR) is a very powerful technique to achieve effective visualizations (Kalkofen et al. 2011). Augmented Reality allows the real-time merging of the digital data through specific computer interfaces with data from the surrounding environment (Sungkur et al. 2016). Moreover, AR can provide major benefits on construction such as increased safety, improved collaboration and communication, real time visualization of projects, better-quality scheduling and budget-management, and greater implementation of Building Information Model (BIM) (Heinzel et al. 2017). The AR system has ability to display an immersive view right into the real environment, where the stakeholders stay, visualize the as-planned data into the as-built environment right in place, and alleviate the mental workload suffered by the participants. With this in mind, the difference between the current progress and the planned future progress are able to see and monitor by the workers (Wang et al. 2014). Shin and Dunston (2008) stated that, the project participants can comprehend the project more easily and a consistent shared understanding can be achieved more readily by visualizing complex construction information. Lee et al. (2006) stated that, Progress monitoring with augmented reality technology can improve the coordination process by reducing the time to inform the participants.

Nevertheless, several researchers identified the challenges that are hindering the successful implementation of AR in the CPM in the global context (Noghabaei et al. 2020; Smith et al. 2016; Berryman, 2012). Some of the major challenges associated with the AR implementation have been identified under the data collection, modelling and alignment barriers, hardware limitations, tracking and managing data categories in the previous empirical investigations in the global context. Considering the Sri Lankan context, efficacy of AR has only been focused in the previous studies in construction industry. Despite this, there is a lack on empirical investigations in the area of challenges of successful implementation of AR and strategies to overcome those challenges. Therefore, this paper aimed to investigate the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. The paper starts with presenting a comprehensive literature review on AR. Then a brief introduction to methodology is provided. The findings of the research will be then presented under challenges and strategies for AR implementation followed by the discussion of findings. Finally, identified strategies are mapped with the challenges for AR implementation.

II. LITERATURE REVIEW

A. AR as a New Technological Approach for Construction Progress Monitoring

Both civil engineers and computer scientists have drawn much attention in current practice in applying computer vision technology to analyse the recorded images and videos automatically in the sense of CPM. Associations between computer vision and civil engineering researchers (Yuen et al. 2011) and also several interdisciplinary efforts have enabled the measuring, detecting and tracking of civil infrastructure elements, equipment and workers. Consequently, this plays a critical role in construction performance monitoring applications including progress monitoring, quality control, operation analysis, safety monitoring and occupational health assessments (Gong et al. 2011).

From fixed camera viewpoints, time-lapse images can be collected to document the work-in progress (WIP) (Heinzel et al. 2017). These collected images are either compared with one another image or against a 4D BIM which represents the expected state of construction progress (Fard et al. 2009). Several visualization

methods are also proposed to highlight deviations in construction progress. These methods are color coded construction elements based on the metaphor of traffic light colors. (Fard and Peña-Mora, 2007). Further, some studies have highlighted the importance of using 4D Building Information Modeling (BIM) in CPM and laser scanners or image-based 3D reconstruction methods focus to generate 3D point cloud models (Dimitro and Golparvar-Fard, 2014). Further the authors have stressed the possibility of automated progress monitoring technique using the geometrical information. However, it has been identified that none of the above technological approaches would provide enough information on the current stage of construction progress without the real time material information (Golparvar-Fard et al. 2012).

Hence, AR has been emerged to the CPM through combination of a real and virtual objects, interactive in real time, and register the virtual imagery with the real world. More comprehensively, AR allows computer generated virtual metaphors to exactly overlay physical objects in real time (Yuen et al. 2011). AR using real objects in a seamless way, permits the user to interact with the virtual images (Zhou et al. 2008). Additional information of real world can be acquired by interpreting this mixed overlay in devices such as head mounted displays, handheld monitors and see-through glasses.

The application of AR can be comprehensively described through the reality-virtuality continuum, which highlights the "mixed reality" of real and virtual environment (Milgram et al. 1995) as depicted in the below Figure 1.

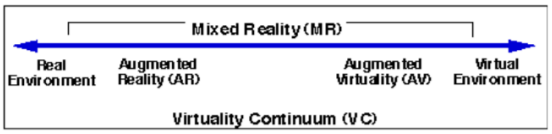

Figure 4: Simplified Representation of" Virtuality Continuum"

Source: (Milgram, Takemura, Utsum, & Kishino, 1995)

According to Figure 1, the real environment and virtual environment will be on the opposite ends of the scale. Two types of augmented environments exist between these two extremes: AR inserts computer-generated content and Augmented Virtuality (AV), taking the real world and real environments as its background and in which a computer-generated world serves as the background while real-world data is merged in and superimposed. (Milgram, et al., 1995). Accordingly, AR will be implemented within the construction environment to achieve the several purposes using the technologies along with AR such as Virtual Reality (VR), and Mixed Reality (MR).

B. Challenges in Implementing AR in Construction Industry

Despite the growing interest in the context of AR in construction environment, several challenges and issues exist, which is essentialy to be addressed to achieve the successful implementation. Some reseachers have categorised the challenges of AR implementation with resepect to the technological, social acceptance and usability aspects (Mekni & Lemieux, 2014). Further, Vakoms (2017) has emphasized that AR implementing challenges can be divided in to two categories namely social and technical challenges. However, several challenges of AR implementation within construction industry have been highlighted in various empirical investigations as described in the below Table 1.

Table 2: AR implementation challenges in construction industry

Challenges	**References**
Cost	[1], [7]
Privacy issues	[2], [3] [6], [8]
Social rejection	[3], [7], [9]
Poor experience	[1], [3], [4], [6] [8]
Lack of knowledge	[1], [3], [5], [8] [9]
Health and Safety Issues	[1], [4]
Battery life	[1], [3], [4], [6], [8]
Accuracy and reliability	[1], [3], [6], [8], [9]
Technological limitations	[1], [3], [4], [5], [7], [8]
References: [1] Smith et al. 2016; [2] Berryman, 2012; [3] Mekni and Lemieux, 2014; [4] Busel, 2017; [5] Azuma et al. 1998; [6] Fenais et al. 2020 [7] Vyas and Bhatt, 2017; [8] Wang, 2009; [9] Noghabaei et al. 2020	

As per the literature findings of Table 1, most of the literature sources have highlighted the impact of poor experience, lack of knowledge on technical aspects of AR, accuracy and reliability of the input data to the system, and the existing technological limitations within the construction industry. The unfamiliarity AR applications can be caused for the suffering of enough knowledge or experience on working with implementations. Further, enhanced tracking systems in the AR applications are needed to display the information in highly accurate and reliable way and the devices should contain well-functioning software and hardware to obtain, filter and retain the information and display the exact information (Mekni & Lemieux, 2014). Accordingly, accuracy and reliability are another major challenge that construction industry practitioners are facing with. Moreover, the impact of higher cost requirement, social rejection due to the unfamiliarity, and health and safety issues have been identified in the literature review. Hence, in order to proceed with the successful implementation of AR practices within the construction industry, the strategic solutions are essentially to be provided through an empirical investigation. In the Sri Lankan construction industry context, there is a dearth of research in identifying the challenges of AR implementation and as well as the possible strategies to overcome the challenges.

III. RESEARCH METHODOLOGY

The research problem, which is to identify the challenges in implementing AR and strategies to overcome the challenges in Sri Lankan construction industry needed an in-depth investigation whereas the respondent opinions regarding the challenges and strategies were also required to be collected. Therefore the qualitative approach was selected as the suitable research stance for this study (Naoum, 2007). Further, the study adopted the expert interviews using semi-structured interview guideline as data collection instrument for empirical data collection. The authors identified the importance of employing semi-structutred interview method to this study as interviewers have a structured flow ask questions from interviewees. In this study, data collection was conducted in two steps where initially five expert interviews with professionals in ICT industry and subsequently five expert interviews with construction industry professionals were conducted. Interviewees form ICT industry included Software Engineers, Software Developers and Computer Science Engineers who have more than 5 year working experience within ICT industry. The profiles of experts have been provided in Table 2.

Table 3: Profile of Experts

Industry	Code	Discipline	Experience
Experts from ICT industry	RI1	Software Engineer	> 5 years
	RI2	Software Engineer	> 10 years
	RI3	Computer Science Engineer	> 5 years
	RI4	Software Developer	> 5 years
	RI5	Software Developer	> 10 years
Experts from Construction industry	RC1	Planning Engineer	> 15 years
	RC2	Planning Engineer	> 10 years
	RC3	Civil Engineer	> 10 years
	RC4	Quantity Surveyor	> 10 years
	RC5	Project Manager	> 30 years

The collected data was analysed with code based content analysis using N-vivo software, which helped in organising and exploring a set of unstructured data.

IV. RESEARCH FINDINGS

This study investigated the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. Following sections elaborate findings of this study.

A. Challenges of Adopting AR in Construction Industry

The identified challenges of adopting AR in construction industry in literature review were validated during the interviews with experts. All the respondents from both ICT and construction industry highlighted the ***"lack of knowledge on software and hardware"*** as one of the main challenges of implementing AR within construction industry. Hence, the stakeholders of the construction may resist to adopt new

technologies such as AR. More comprehensively, RC3 stressed that people are tending more towards adopting the traditional construction methods rather than going for innovative technology because due to their nature of ***"unwillingness to change".*** Rather, RI2 highlighted the more adaptation of society towards the technological innovations in the daily chores. However, still the adaptation of construction industry practitioners for novel technologies is lacking than the expected level. Majority of the respondents from both the industries have highlighted the ***"higher initial cost"*** as a major challenge of AR adaptation in the Sri Lankan context. More comprehensively, RC1 stressed that ***"higher tax concessions"*** of government have directly affected the higher initial cost of acquiring the hardware and software essential in AR implementation within the Sri Lankan construction industry. Therefore, the investors in construction industry are not comfortable with investing on innovating technology due to its uncertainty of return on investment. Hence, higher tax concessions imposed by the government have also been indirectly impacted to successful adapatation of AR within Sri Lankan construction industry.

As per the view of RI5, it is essential to employ a skilled person, whom having the ability of handling and controlling the applicable hardware, software and 3D models using in AR practices. However, according to RC2, the ***"unfamiliarity on new technologies"*** lies within the traditional construction industry professionals would negatively impact in successful implementation of AR within construction industry. In accordance with the opinion of majority of respondents from construction industry, implementing AR will cause for the ***"health and safety issues"*** of the employees within the construction site. RC1 highlighted the ability of originating health and safety issues within construction site due to the utilisation of some hardwares related with AR technology such as smart headphones, smart phones etc. Further, mentioned by RC4, there will be health issues such as eye and ear related problems due to this. Further, real environment covered by 3D environment may increase accidents in the site.

Moreover, RI5 highlighted the possibility of ***"privacy issues"*** due to the implementation of 3D models associated with the AR implementation by entering valuable and confidential project information. According to RC2, any of the employee with access to the computer system of the site can access the model and it will be a security issue for the project details to some extent. RI4 and RC2 mentioned that mismatching between model and actual environment can cause more errors while tracking AR model with the real environment. Therefore, the necessity of hundred percent "accuracy and reliability" of input data have been highlighted by the majority of respondents. Hence, ***"lack of accuracy and reliability"*** can be identified as another major challenge in implementing AR in Sri Lankan construction industry. According to RC2, when implementing AR within construction sites, there should be a portable device to minimize the difficulty of handling. However, when adopting a portable device, ***"lower battery life"*** act as a critical barrier, which must essentially overcome.

B. Strategies to Overcome Challenges of Adopting AR in Construction Industry

In order to avoid the challenge of lacking accuracy and reliability, RI1 proposed to ***"implement AR for the small scale construction project"*** in the initial stage. Hence, it would allow the construction industry practitioners to conduct suitable testings beforehand and seeking the possible technological development in relation to the AR applications in mega scale construction projects. Further, RC2 highlighted the importance of upgrading the education system of the country by ***"including AR practices to the university level education"*** to overcome the challenge of lacking knowledge on software and hardware and unfamiliarity on new technologies. Moreover, RI3 stressed the importance of more ***"academic involvement in the research and development"*** on the area of AR and its practical implications in the construction industry of Sri Lanka. Hence, these studies will provide theoretical contribution in filling the existing knowledge gap related to AR implementation within the construction industry in local context comparative to the global context. RC4 mentioned that ***"conducting workshops and training programs"*** in the organisational level on AR implementation would support to

overcome the challenge of unfamiliarity on new technologies of construction professionals and fill existing knowledge gap regarding AR practices and unwillingness to change to new practices. Further, these programs would facilitate to minimise the control and handling issue in the technology and devices and enhance the awareness on novel technologies.

According to the opinion of RI1, RC2 and RC4, ***"carry out a feasibility study"*** before implementing AR in construction projects would be more suitable to identify risk and possible opportunities of adopting the technology in the Sri Lankan context. Conducting a feasibility study could reveal the possible forecast return on investment. This will address the issue regarding the higher initial cost of technology implementation. To overcome the challenge of higher tax concessions, some of the respondents highlighted the importance of the involvement of government in ***"providing reduced tax fee facilities"*** to motivate the construction industry practitioners who are involving in the AR implementation practices. ***"Using access control methods"*** such as fingerprints, passwords, and ID cards has been highlighted by majority of respondents in the sense of eliminating the privacy issues which can be occurred in the AR implementation. Hence access to data will be controlled and monitored. As mentioned by RI1, RI4, RC4 and RC5, ***"implementing a proper user guideline"*** and training construction industry professionals and workers to carry out proper site safety procedure to minimise on-site accidents and ***"take precautions to reduce health issues"*** that can arise due to negligence while handling the hardwares related to AR implementation are few steps to minimise health and safety issues regarding implementing AR in Sri Lankan construction industry. To overcome the challenge of lower battery life, RI4 mentioned the possibility of ***"using currently available devices to enhance the performance within the capacity".***

V. DISCUSSION OF FINDINGS

As the final step, the study mapped the challenges of implementing AR with the strategies required for overcoming those challenges in Sri Lankan construction industry. The Figure 2 presents the summary of findings. According to Figure 2, the study has identified several challenges of adopting AR in construction industry. Lack of knowledge on software and hardware, lack of accuracy and reliabilty, higher initial cost, privacy issues, health and safety issues, and lower battery life are some of the challenges identified in the empirical investigation, which can evidence in the literature findings as presented in the Table 1 above. In the empirical investigation, the authors have reworded some of the challenges identified in the literature synthesis such as lack of knowledge on software and hardware, lack of accuracy and reliabilty, and lower battery life as per the respondents' comments in the empirical investigation. Some of the challenges such as unwillingness to change, unfamiliarity on new technologies, and higher tax concessions have been highlighted by the respondents as challenges that Sri Lankan construction industry is facing in the implementation of AR in addition to the challenges identified in the literature synthesis. Further, the respondents have identified several strategies to overcome the challenges in AR implementation within Sri Lankan construction industry such as providing knowledge on AR implementation to the construction industry practitioner through university education, conducting workshops and training programs, and research and development procedures. Some additional strategies have also been highlighted, which can be implemented in the organisational, government and also the industry level such as providing reduced tax fee facilities and implementing a suitable user guideline.

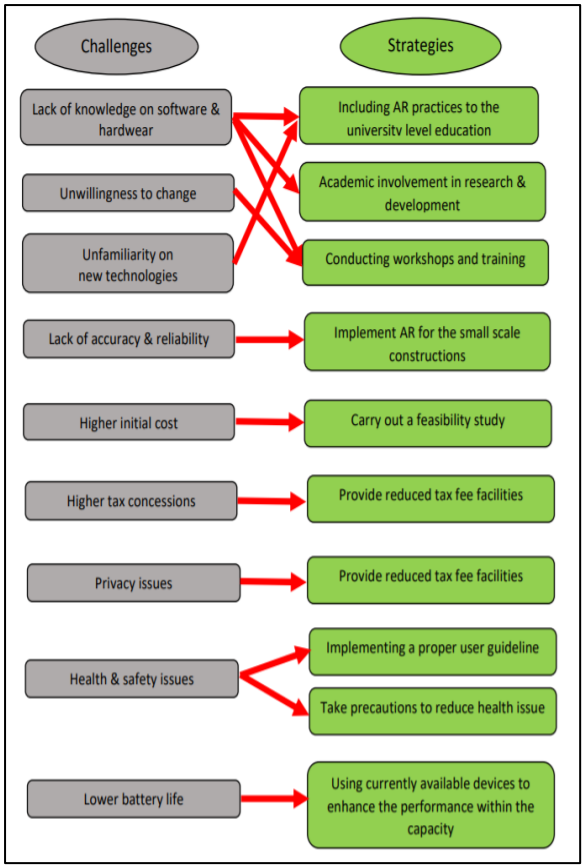

Figure 2: Research framework on challenges and strategies on AR implementation in Sri Lankan construction industry

V. CONCLUSIONS AND RECOMMENDATIONS

There has been a notable growth in application of novel technologies in construction industry practices. Due to the several barriers that construction industry practitioners faced in CPM, the utilisation of new technological approaches such as AR can be identified. However, utilising AR in construction industry is not free from challenges. Therefore, this study aimed to investigate the challenges of implementing AR and strategies to overcome the challenges in Sri Lankan construction industry. This study identified lack of knowledge on software and hardware, unwillingness to change, unfamiliarity on new technologies, lack of accuracy and reliabilty, higher initial cost, higher tax concessions, privacy issues, health and safety issues, and lower battery life as the challenges on AR implementation in Sri Lankan construction industry. In order to achieve the construction project success through AR applications, several strategies need to be practiced to overcome the AR implementation challenges within the Sri Lankan construction industry. Accordingly, the empirical investigation have identified the possible strategies such as providing knowledge on AR and it's applications, conducting workshops and training, carry out feasibility studies, provide reduced tax fee facilities, take proper safety precautions. The study will further guide the Sri Lanakn construction industry to understand the possible strategies to successfully implementing AR. The study contributes to the academic knowledge in the areas of challenges and strategies of implementing AR for CPM in Sri Lanka.

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An Overview of Various Techniques and Approaches of Concurrent Delay Analysis in the Sri Lankan Construction Industry

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Abstract— Concurrent delay is a very complex and controversial topic in the construction industry. Analysis of the concurrent delays became challenging due to the absence of clear provisions in the standard form of contracts. Meanwhile, project parties try to pass the contractual liability to the other parties and make the situation more problematic. The lack of knowledge on the concurrent delay analysis procedure among project parties would be another reason to increase the complications. Even though various delay analysis techniques and approaches are available in the construction industry, all of them cannot be used to assess any concurrent delay situation. Hence this study aims to investigate the adaptability of various techniques and approaches for concurrent delay analysis in the Sri Lankan construction industry. The research was conducted based on expert interviews by adopting a qualitative research approach. The collected data was analysed via content analysis using NVivo software. Research findings revealed that the lack of proper record-keeping, the ambiguity of concurrent delays, and the lack of advanced scheduling software as the main challenges of concurrent delay analysis in the Sri Lankan construction industry. Further, the time impact analysis method and window analysis method are the most recommended Critical Path Methods (CPMs) for concurrent delay analysis in the Sri Lankan context. However, in some cases, one CPM is not adequate to analyse the entire delay of a project and research findings recommended to use a combination of CPMs in such situations. Ultimately, the study concluded that the selection of concurrent delay analysis techniques depended on the type of construction schedule of the project and available project records.

Keywords: *concurrent delays, delay analysis techniques and approaches, critical path method, construction industry*

I. INTRODUCTION

In the construction industry, a delay is a time overrun either beyond the completion date specified in the contract or beyond the date that the parties agreed upon for delivery of a project (Shahsavand, Marefat & Parchamijalal, 2018). However, it is a very common feature in the construction industry that the projects are unable to be completed within a stipulated period and the consequences of the delays will lead to ineffective cost and quality optimisation (Tahir, Haron, Alias & Diugwu, 2017). Delays in construction projects are extremely expensive and result in severe damages to the involved parties (Dinakar, 2014). The main causes of construction delays are considered as conflicts and disputes among project parties (Braimah & Ndekugri, 2008). Kraiem and Diekmann (2002) classified construction delays into three major types based on the liability as compensable, excusable and non-excusable. Irrespective of a project being small or large in scale, a combination of the above delay types is very often seen in construction projects which can be recognised as concurrent delays (Baram, 2005).

There are no such standard or coherent definitions for concurrent delays, due to their complex nature. But Munvar, Mengistu, and Mahesh (2020) described that in concurrent delays, two or more independent delay events should occur at the same time, one being an

employer's risk event and the other one is a contractor's risk event. Concurrent delay analysis is an extremely complex task. Past researches identified various techniques and approaches to analyse concurrent delays in construction projects. Perera and Sudeha (2016) pointed out that delay analysts can either use one or a combination of delay analysis techniques to analyse concurrent delays since it is more complicated. Even though various delay analysis techniques are available in the industry, all of them are not suitable to analyse all of the concurrent delays (Al-Gahtani & Mohan, 2011). However, some analysis techniques and approaches are well-suited for concurrent delay analysis but most of the organisations are unable to use them practically since they are lacking with technical analysis facilities.

Therefore, it is necessary to review the requirements, essential records and process of concurrent delay analysis techniques and approaches specific to the Sri Lankan context to enhance the performance of construction projects. Hence, this study aims to investigate the adaptability of different techniques and approaches for concurrent delay analysis in the Sri Lankan construction industry. To fulfill the research aim, objectives were identified; critically review the popular concurrent delay analysis techniques and approaches in the construction industry, explain the current practices and challenges of concurrent delay analysis in the Sri Lankan context, assess the suitability of various concurrent delay analysis techniques and approaches to the Sri Lankan context and finally, appraise the significance of different contemporary records required by delay analysis techniques towards effective delay analysis in Sri Lanka.

II. LITERATURE REVIEW

A. Concurrent Delays

Concurrent delays can be considered as one of the notoriously problematic areas in construction law and the most complicated and controversial kind of delay dispute due to its nature (Bubshait & Cunningham, 2004). In concurrent delay claims, contractor party or other project parties can cause project delays and the impact and remedies vary from case to case (Bubshait & Cunningham, 2004). O'Leary (2014) addressed complications of concurrent delays such as no agreed definition of what is meant by concurrency and how it should be interpreted and applied.

B. International Protocols on Concurrent Delays

There are two published well-known international protocols for concurrent construction delays; (i) The Society of Construction Law (SCL) Delay and Disruption Protocol and (ii) Association of the Advancement of Cost Engineering International (AACEI)-International Recommended Practice No. 29R-03 Forensic Schedule Analysis Protocol. However, the Fédération Internationale Des Ingénieurs-Conseils (FIDIC) 1999 version was silent on this concurrent delays in construction projects but FIDIC 2017 version requires project parties to adopt rules and procedures to deal with concurrent delays through the special provisions.

C. Concurrent Delay Analysis

Construction delay analysis will be conducted to calculate the project delays and allocate responsibility among respective parties of the project. According to Rankin, Rosenberg, and Fick (2018) in the analysis of concurrent delays, the following three steps should be followed by analysts; i) Identify the critical path ii) Establish where it has been delayed and iii) Determine what events caused by these critical events. Hence this analysis process needs a general critical path delay analysis method. Eventhough various delay analysis techniques are available in the industry, mostly critical-path methods are popular among analysts and project parties (Yang, Huang & Lee, 2010). However, none of these techniques are perfect and have some limitations (Yang & Tsai, 2011). The below-discussed delay analysis techniques are most commonly used in the construction industry to analyse delay events (Yang, Huang & Lee, 2010).

1) As-planned vs. as-built method

This method can be identified as a traditional delay analysis method that reviews the change of work to determine where and how the revisions were incorporated in the schedule (Salunkhe & Patil, 2013). This method simply compares the activities of the as-planned CPM baseline schedule with the as-built schedule for a detailed assessment of the delay (Ndekugri, Braimah, & Gameson, 2008).

2) Collapsed as-built method/but-for method

This method uses an as-built schedule as a basis for analysis comparison and then eliminates delays from the as-built schedule to collapse the schedule (Yang & Yin, 2009).

3) Window-based delay analysis method

The window-based analysis method divides the construction period into discrete time increments called "windows" and examines the effects of the delays attributable to each project party.

4) Time impact analysis method

This method updates the as-planned programme by imposing each delaying activity in succession and disregarding any concurrency of delaying activities (Ng, Skitmore, Deng, & Nadeem, 2004).

5) Adjusted as-built method

This method can be implemented by only using the as-planned schedule. In this method, first create an adjusted as-built schedule by linking the delaying events to the relevant activities. Then it compares the completion dates in the as-planned schedule and adjusted the as-built schedule to decide the delay period to identify the difference between the two schedules (Alkass, Mazerolle & Harris, 2002).

6) Snapshot method

The snapshot method can be considered as one of the logical and accurate methods for delay analysis. This method is using the window concept and analyses delays by dividing the schedule for specific periods. Here, the as-planned schedule is used as a baseline schedule. After adding delays to the schedule and dividing it into specific snapshots and compare each snapshot with the original as-planned schedule (Al-Gahtani, & Mohan, 2011).

After calculation of the concurrent delay by employing the above CPMs, the next step is the allocation of responsibility of concurrent delays among project parties (Pappalardo & Spa, 2006). This can be implemented by referring to the contractual provisions of respective projects. Unfortunately, the contracts often do not include the relevant provisions specially in the Sri Lankan context and it becomes necessary to refer to the governing laws of the country. However, Gunarathna (2016) identified that, available concurrent delay analysis approaches which were used to allocate the responsibility of concurrent delays were developed through past case laws such as apportionment approach, first-in-line approach, but-for test, dominant cause approach, and Malmaison approach.

D. Contemporary Records

Contractors are submitting delay claims with an average of 60% success rate in Sri Lanka and the remaining 40% is unsuccessful due to inadequate documentation and failures due to the improper selections of the delay analysis techniques (Ramachandra, Rotimi & Gunaratne, 2014). The unavailability of contemporary project records may constrain the selection of the most appropriate delay analysis technique specially in analysing concurrent delays (Dinakar, 2014). SCL protocol and also some previous researches identified required contemporary records to analyse concurrent delays using different techniques (refer Table 3). As per the literature review, the updated construction schedule is the essential project record to analyse concurrent delays.

III. RESEARCH METHODOLOGY

The qualitative research approach was adopted in this research based on interpretivism research philosophy. Accordingly, literature synthesis was conducted to critically review the popular concurrent delay analysis techniques and approaches in the construction industry as a secondary data collection method. Further, appraisal of the significance of different contemporary records required to delay analysis techniques and approaches were partially revealed through the literature synthesis. Thereafter expert interviews were conducted to identify the current practices and challenges of concurrent delay analysis in the Sri Lankan context. Expert interviews were designed as semi-structured interviews conducted online for about 30–45 minutes. The reason to select the semi-structured interviews for expert interviews was to offer the freedom for interviewees to contextualise the data. Accordingly, six experts were interviewed who are having more than 15 years of experience and comprehensive knowledge of delay analysis of construction projects. Experts were selected using the convenient sampling method. The demographic data of the interviewees were presented in Table 1.

Table 1. Details of interviewees

Interviewee Code	Designation	Organization Type	Experience
ER-01	Company Director	Consultant	43 Years
ER-02	Senior Quantity Surveyor / Lecturer	Consultant	21 Years
ER-03	Quantity Surveyor / Lecturer	Consultant	19 Years
ER-04	Contract Specialist	Consultant	15 Years
ER-05	Contract Specialist	Consultant	18 Years
ER-06	Company Director / Claims Specialist	Consultant	45+ Years

The data collected from the expert interviews were subjected to content analysis using the NVivo software.

IV. RESEARCH FINDINGS

The analysis at a glance is presented in Figure 1.

A. Concurrent Delay Analysis

All the interviewees defined concurrent delay commonly as "a situation in a construction project where the impact of two different delay events occurs simultaneously whereas the employer/engineer is responsible for the one event and the other one by the contractor." The interviewees recommended that both CPMs and legal approaches should be employed for the successful analysis of concurrent delays, specially in the Sri Lankan context. The main reason for using a mix of techniques and approaches is due to the difficulty of analysing the ultimate responsibility in concurrent delays. However, this research confirmed that in the Sri Lankan context only 20% of concurrent delay cases are using CPMs for delay analysis. Further legal approaches can be prioritised when the construction programme are not standard and advanced enough to carry out a critical path analysis and when there are not available project records to analyse the impact on the critical path.

B. Challenges Encountered in Concurrent Delay Analysis

Based on the expert interviews results, six key challenges were identified in the concurrent delay analysis in the Sri Lankan context. The main issue faced by delay analysts was the unavailability of updated construction schedules of the projects. Further, interviewees argued that analysing concurrent delays require specialised and high-quality scheduling and programming software such as Primavera, Microsoft Project and etc. Unavailability of such advanced scheduling and programming licensed software in the Sri Lankan context also leads to complications of concurrent delay analysis. Interviewees further investigated that, even though all other requirements were fulfilled, it is not successful to analyse concurrent delays properly due to lack of sufficient analysis knowledge and skills of delay analysts. Similarly interviewees accepted that same definition for concurrent delay is always not applicable to each and every delay events in the projects and due to this ambiguity in concurrent delays also lead to analysis complications. Further lack of contractual provisions in standard forms of contracts becomes a key challenge in concurrent delay analysis.

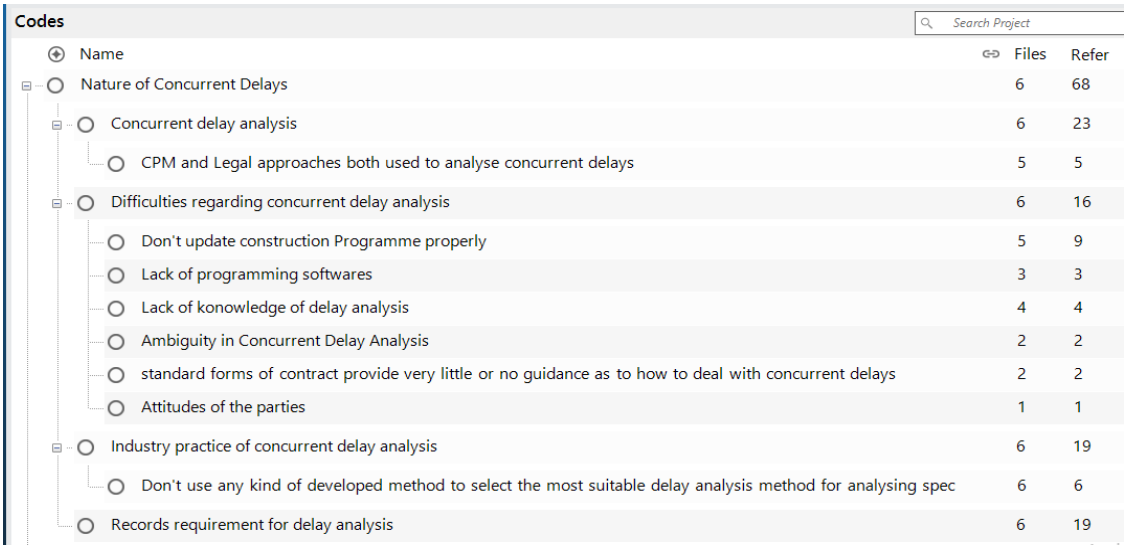

Figure 1. NVivo codes of expert interviews

C. Concurrent Delay Analysis Techniques

Past researchers who conducted researches on delay analysis and concurrent delay analysis, identified the most suitable delay analysis techniques specifically for concurrent delay analysis. Further, these selected techniques were contextualised via expert interviews to select the most suitable delay analysis techniques for concurrent delay analysis in the Sri Lankan construction industry. Table 2 presents the opinions of past researchers regarding the most suitable delay analysis techniques for concurrent delay analysis and expert opinion on the most suitable concurrent delay analysis techniques to the Sri Lankan context.

Table 2. Suitable Delay Analysis Techniques for Concurrent Delay Analysis in Sri Lankan context

	As-planned vs as-built method	**Collapsed as-built method / But-for method**	**Window-based method**	**Time impact analysis method**	**Adjusted as-built method**	**Snapshot method**	**Additional proposed methods**
Literature Review							
Kraiem and Diekmann (2002)							Easy rule and fair rule
Alkass et al. (2002)		✓			✓	✓	
Gothand (2003)			✓				
Ng et al. (2004)				✓		✓	
Kim et al. (2005)			✓				
Mbabazi Hegazy and Saccomanno (2005)							Moderated but-for analysis method
Adhikari et al. (2006)				✓			
Arditi et al. (2006)	✓			✓			
Menesi (2007)			✓				Moderated but-for analysis method and window methods
Al- Gahtani et al. (2011)		✓	✓			✓	Moderated but-for analysis method and window methods
Expert Interviews							
ER-01		✓	✓	✓		✓	
ER-02		✓	✓	✓		✓	
ER-03			✓	✓		✓	
ER-04			✓	✓			
ER-05		✓	✓	✓		✓	
ER-06		✓	✓	✓		✓	

Based on the literature survey results, out of six popular delay analysis techniques, only four analysis techniques were identified by the past researchers as the most suitable for concurrent delay analysis. Those are collapsed as-built method/ But-for method, window-based method, time impact analysis method and snapshot method. Out of these four techniques, the window-based method and time impact analysis method were identified as the most suitable delay analysis techniques to the Sri Lankan context through expert interviews.

The snapshot analysis method is a type of window analysis method and analysts are practically considering one to two months as one snapshot. Eventhough the snapshot method is extremely suitable for analysing concurrent delays, this is not popular among the Sri Lankan construction industry. The window analysis method was identified as one of the most suitable methods for analysing concurrent delays in the Sri Lankan context. Here, the new completion date will be compared with the as-planned completion date to determine the delay of respective windows of the construction schedule. Further, all experts recommended the time impact analysis method as the other most accurate delay analysis method to analyse concurrent delay events in the Sri Lankan context. Experts justified that, when incorporating each delay into an updated CPM baseline schedule sometimes they use a 'fragnent' or sub-networks. Further the experts witnessed that, the SCL delay analysis protocol also recommending time impact analysis for concurrent delay analysis. The collapsed as-built method/ but-for method was introduced as a method of choice when the contractor is lacking an acceptable construction schedule of the project or when the as-planned schedule was not required by the contract. This method subtracts all delays from the as-built programme and determines the earliest date that the contractor can complete the project, but for the delay, events relied upon.

In addition to that, experts recommended the Malmaison approach and apportionment approach as the most viable legal approaches for concurrent delay analysis in the Sri Lankan context for the allocation of delay responsibility. The Malmaison approach reflects on the allocation of risk agreed by the parties when they entered into the contract.

D. Contemporary Records Required to Analyse Concurrent Delays

Experts reviewed the construction schedules as the key records required for concurrent delay analysis which decides the analysis method based on the available types of construction schedules. Further construction schedule should be precisely updated and able to draft the as-built schedule from that. Contemporary records required by each analysis technique which were identified in the expert interviews were presented in following Table 3.

V. DISCUSSION

SCL and AACEI delay analysis protocols defined that, concurrent delays are comprised of two instances of delay events. Similarly, experts revealed that there should be two delay events in concurrent delays where those events should not be simultaneous but the impact sould be simultaneous. CPMs are the most scientific methods to analyse the impact of concurrent delays as recommended by the SCL protocol. But experts indicated that unfortunately in the Sri Lankan construction industry, there is a lack of record maintenance specially the updated project schedules. Project schedules are not detailed hence not advanced enough to conduct proper CPMs in the Sri Lankan context. As per the expert opinions, in most of the concurrent delay events, a basic schedule analysis was conducted to calculate the delay period and distribute the responsibility based on common sense and negotiation among project parties.

Table 3. Contemporary Records Required to Delay Analysis Techniques

	Time impact analysis method	**Window analysis method**	**Collapsed as-built method/ But-for method**	**Snapshot analysis method**
Literature Review				
Yang, Kao, and Lee (2006)	As-built schedule	As-built and As-planned schedule	As-built schedule	As-built and As-planned schedule
Yang and Kao (2009)		As-planned schedule, as-built schedule, and identified liability documentations		As-planned schedule, as-built schedule, and identified liability documentations
Yang and Yin (2009)			As-built schedule	
Construction Management Guide (2011)		As-built schedule and As-planned schedule	As-built schedule	
SCL (2017)	Logic linked baseline programme, Updated programmes or progress information required to update the baseline programme	Logic linked baseline programme, Updated programmes or required to update the baseline programme	Logic linked as-built programme	
Magdy, Georgy, Osman, and Elsaid (2019)	As-built schedule	As-built schedule	As-built schedule	
Expert Interviews	Latest adjusted schedule before delay events	As-planned schedule (Not essential logic linking to the schedule)	Logic linked As-built programme	Logic linked as-planned programme

However ER-03 and ER-05 revealed that, most of the time construction projects are using CPMs to analyse concurrent delays in the global context specially in the Middle Eastern construction industry but unlikely in Sri Lanka. Further, based on the experience, the experts highlighted that mostly a combination of delay analysis methods was used in concurrent delay analysis to investigate the impact on cost and quality. Moreover, literature and experts were identified that every CPM cannot assess the concurrent delays and only a few methods are well-suited for it. Even though literature interpreted that legal approaches are suitable to analyse concurrent delays, the experts highlighted that in the Sri Lankan context legal approaches are not very popular.

VI. CONCLUSION

Concurrent delay analysis is mainly consisting of two stages; (i) CPM analysis and (ii) assignment

of responsibility among project parties. There are several CPMs are available to analyse delay events in construction projects. The most recommended four CPMs by the past researchers to analyse concurrent delays are (i) the snapshot analysis method (ii) the window-based analysis method (iii) the time impact analysis method and (iv) collapsed as-built method/but for method. Further experts identified the most suitable two key CPMs to analyse concurrent delays in the Sri Lankan context as window analysis method and time impact analysis method. However, experts recommended using a combination of CPMs to analyse concurrent delays once it is not sufficient to use one CPM alone based on the nature of the delay event. According to the expert opinions, the most difficult task would be the assignment of responsibility of concurrent delay among parties and several legal approaches were developed based on the past case laws. However, the Malmaison approach was extremely useful in Sri Lankan projects. The collapsed as-built method is the only subtractive method that is proceeding to subtract delays from the as-built schedule and the remaining three methods are additive and starting with the as-planned schedule. Moreover, the window analysis method and snapshot analysis method evaluate the interim assessment of delay on updated schedule at a specific period of the project. However, the time impact analysis method is unique since it focuses on a specific delay or delaying event but not on periods containing delays or delay events.

In concurrent delay analysis, project parties faced some challenges in the Sri Lankan context such as lack of project records for analysis, lack of scheduling and programming software, lack of knowledge and skills of delay analysts, the ambiguity of concurrent delays, lack of contractual provisions in standard forms of contracts and attitudes of the project parties on concurrent delays. Lack of project records will be the featuring challenge among them specially in the Sri Lankan context. To promote effective concurrent delay analysis among the Sri Lankan construction industry, practitioners should come up with some strategies to overcome such challenges. Experts highlighted the requirement of contemporary records for concurrent delay analysis specially the schedule with updates. There are three types of schedules in concurrent delay analysis; (i) as-planned schedule (ii) as-built schedule and (iii) adjusted schedule. Moreover, the selection of delay analysis techniques depends on the nature and availability of these types of schedules. However, the success of the concurrent delay analysis always depends on the satisfaction of the project parties regarding the apportionment of responsibilities among them. Therefore to prove the responsibility and to argue on the decision, it needs comprehensive project records.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

- CPM - Critical Path Method
- SCL - The Society of Construction Law
- AACEI - Association of the Advancement of Cost Engineering International
- FIDIC - Fédération Internationale Des Ingénieurs-Conseils

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Contractor-related Cost Overrun Causes, Controlling Tools and Techniques: Study on Selected Building Construction Projects in Colombo District

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Abstract– Construction projects in Sri Lanka often fail completion within the specified time and cost allotted for the projects. Hence, cost overrun and delays are major problems that construction projects frequently experience. Many stakeholder-related causes affect cost overrun in construction projects despite their attempt to minimize cost overrun using various methods. Among them, there is a considerable proportion of Contractor-related causes. Therefore, this study attempted to find significant Contractor-related cost overrun factors and apposite cost controlling techniques that can be used to minimize the likely impact of cost overrun on building construction projects in Sri Lanka. This study primarily focused on completed or ongoing building construction projects between the years 2010 to 2019 located in Colombo District. First, a literature review was carried out and Contractor-related cost overrun causes and cost controlling techniques in general were identified. Then, a questionnaire survey was conducted among eighty professionals who worked in building construction projects in the Colombo district belonging to contracting companies with above C3 level Construction Industry Development Authority (CIDA) grade. Sixty-two of them were responded to and considered as valid for further analysis. The ultimate result was obtained through the Relative Importance Index (RII) technique, and the results revealed 'poor project management skills' as the most significant contractor-related cost overrun cause. Besides, the results disclosed the implementation of the labour controlling mechanism as the most prominent cost controlling method that can be utilized for minimizing contractor-related cost overrun causes.

Keywords: *cost overrun, contractor causes, cost controlling techniques, cost controlling tools*

I. INTRODUCTION

A. Background to study

The construction industry can be considered as the mighty pioneer of the country's economy which allocates a substantially higher percent for Gross National Product (Navon, 2005). Hence, the construction industry consists of a complex stakeholder network that defines the growing success of a nation worldwide. Similar to the other countries in the world, the Sri Lankan construction industry also contributes to the country's Gross Development Product by 7.1% (Jayasuriya, 2019). Hence, managing construction projects in Sri Lanka is extremely important in terms of economical perspective.

The fundamental controls required for managing a construction project are cost, time, and quality controls. According to the price indexes issued by the Institute of Construction Training and Development, a total construction project cost is increased by 12.2% annually, though it was 5.4% in 2011 (Jayamaha, 2019). Therefore, cost control is important for the success of every construction project. However, most of the construction projects suffer from budget overrun and the Contractors significantly cause the factors behind construction cost overrun (Zewdu and Aregaw, 2015). Mainly, the insufficient lowest bidding method used for the selection of potential Contractors affects project cost overrun in Pakistan (Azhar et al., 2008). As a result of poor planning for managing the construction projects,

Contractors often lead to many budget issues (Vafaiee et al., 2010). Therefore, it is required to keep the "S" curve, a monitoring tool for the construction projects, as it is without any major deviations for protecting the employer's requirements and project value.

All construction companies in the world attempt to provide profit from any project as their final objective. To successfully achieving this objective, all stakeholders should work within the employer's requirements and especially within the estimated project value. Moreover, the project should not be delayed (Polat et al., 2014). According to Doloi (2011), over-budgeting can be identified as one of the severe problems faced by civil and building projects at the time of their completion. Due to the excess stakeholder engagement, high administration cost also evident in construction projects (Doloi, 2011). Rahman et al., (2013) also state the cost overrun as one of the most regularly affected problems in global construction projects. Moreover, if the contractor or other stakeholders did not manage construction project cost without saving, it directly affects the construction project progress, changes the financial savings of the company, and abuse the national budget as well. According to Ali et al. (2010), if the stakeholders perform with the utmost care and provide clear advice and make correct decisions for the construction works, the employer's budget can keep at the expected margin. Cost overrun always affects the project progress and it is a common problem in almost all construction projects. Therefore, all stakeholders should be aware of the causes behind the cost overrun of construction projects and how to mitigate them in a practical situation.

This study mainly examines the causes behind the contractor-related cost overrun causes and tries to identify relevant cost controlling tools and techniques to mitigate the cost overrun issues.

In Indian construction projects, various factors affect cost overrun such as material shortage, shortage of labour, late delivery of materials and equipment, unavailability of competent staff, the low productivity level of labours, quality of equipment and raw materials, etc. (Tejale et al., 2015). Reddy, Raya & Prakash (2016) also mention lead factors of cost overrun such as; frequent design changes risk associated with projects, inaccurate evaluation of project period, tax liabilities, and the complexity of works and, further suggest the methods for mitigating cost overrun. Apart from the cost categorization, Subramani (2014) also studies mainly the leading cost overrun factors. Rathi & Khandve (2016) analysed time extension and cost overrun causes concerning Indian construction projects and further provides mitigation methods for cost overrun.

According to the literature review findings, various local and international researchers have identified numerous causes behind cost overrun, as cited in Table 1.

Table 1. Causes behind cost overrun

No	Cost overrun causes	Citations
1	Poor project management skills and practices	Malkanthi, et al (2017), Okpala and Aniekwu (2016), Mansfield et al. (1994), Memon et al. (2014)
2	Inaccurate Quantity Take-off (Lump sum /Design & build)	Ramabodu and Verster (2013)
3	Insufficient project planning and scheduling	Akram et al. (2017), Memon et al. (2014), Vaardini (2016), Nega (2008), Memon et al (2011), Wanjari & Dobariya (2016)
4	Poor time management	Sriram (2018), Ramabodu and Verster (2013)
5	Poor analysis of site condition	Alinaitwe et al. (2013)
6	Poor site management and supervision	Alinaitwe et al. (2013), Hoai et al. (2008), Mansfield et al. (1994), Vaardini (2016), Memon et al (2011), Memon et

		al. (2014), Okpala and Aniekwu (2016),
7	Obscurity in the contract documents	Ramabodu and Verster (2013)
8	Poor financial control on-site	Azhar et al., (2008), Vaardini (2016)
9	Wrong method of cost estimation	Akram et al. (2017), Gundaz and Maki (2017), Bekker and Baloyi (2011), Vaaedini (2016), Mansfield et al. (1994)
10	Not decided on the construction materials	Polat et al., (2014), Okpala and Aniekwu (1988), Nega (2008), Pirabahar et al., (2017), Salah and Shibnai (2015), Malkanthi, et. al (2017)
11	Lack of relationship between the management and labor	Memon et al (2011)
12	Shortage of skilled labor	Azhar et al., (2008), Gundaz and Maki (2017), Memon et al. (2014),
13	Services available on site not sufficiently exposed	Jackson (2002), Ramabodu and Verster (2013)
14	The fluctuation of prices	Mansfield et al., (1994)
15	Unplanned weather Conditions	Vaardini (2016)
16	Unnecessary storage of material, labour or machinery	Insaj (2017), Mansfield et al., (1994), Okpala and Aniekwu (1998)
17	Political instability	Alinaitwe et al. (2013)
18	Government legislations	Sriram (2018)
19	The high cost of transportation	Pirabahar et al., (2017), Gundaz and Maki (2017)
20	Variations	Nega (2008)
21	Mistakes during construction	Pirabahar et al., (2017), Memon et al (2011), Mansfield et al. (1994)

In addition, there are different types of cost controlling techniques that can use to mitigate cost overrun in construction projects as Earn value management, Cash Flow Forecasting, To-Complete index, Variance Analysis, and Performance reviews (Project Management Institute, 2004). Moreover, several records to be maintained such as unit cost sheets, subcontractor's payments, weekly statements of labour, and machines/ material cost for controlling the costs. Since cost controlling is somewhat difficult for professionals in the construction industry, they have to have a thorough understanding of cost controlling techniques (Malkanthi et al., 2017).

II. METHODOLOGY

The methodology includes investigation methods for objectives, research scope, research limitations, sampling technique, methods for data gathering, and analysis. Rajasekar et al. (2006) state that research methodology is the plan that introduces the researcher's actual work-study that explains and forecasts.

Data collection limited to a sample of 20 building construction projects in the Colombo district that belongs to C3 or above CIDA classified contractors. Snowball sampling technique was used for project selection. A detailed questionnaire was developed and distributed among 80 different construction industry professionals who worked on the selected projects. Out of them, 62 professionals were

responded and considered as valid for further analysis.

As a result of a detailed literature review, 25 numbers of contractor related cost overrun causes, 4 numbers of cost controlling tools, and 12 numbers of cost controlling techniques were identified and tested the same with the use of a detailed questionnaire concerning their applicability for building construction projects in Colombo district. The questionnaire consisted of four sections namely; demographic responses, Identification of contractor related cost overrun causes, cost controlling tools, and cost controlling techniques. As Ikechukwu et al. (2017) suggested, frequency values obtained to analyze demographic data.

Collected data referred to the subsequent sections of the questionnaire analyzed with the use of the Relative Importance Index (RII) method.

$$\text{Relative Importance Index(RII)} = \frac{\sum W}{AN}$$

W = Weight given to each attribute by the respondent

A = Frequency of response

N = Total number of responses

Here, "N" is constant since the total number of responses for this research equals 62. Besides, "A" and "W" are variables. A five-point Likert scale also used to support RII calculations as shown in Table 2.

Table 2. Likert Scale

Level of Importance	Scale
Extremely important	5
Very important	4
Important	3
Less important	2
Not important	1

III. RESULTS AND DISCUSSION

A. Demographic responses

The total number of respondents epitomized Client, Contractor, and Consultant categories as in Table 3. 85.5% among them represented contractors' party.

Table 3. Respondents' categories

Respondent category	Respondent %
Client	1.6%
Contractor	85.5%
Consultant	12.9%

According to designation categories, 50% of respondents were Quantity Surveyors (QS). Hence, it can be considered as a good rate of response since the QSs are the experts who directly monitor cost sequences of construction projects and who often use cost controlling tools and techniques. Besides, more than 60 % of them had a degree or more qualifications and, 64.5% of them had at least ten years of experience in the construction industry.

B. Contractor related causes behind cost overrun

Though there were other causes for cost overrun, this study was limited to contractor's causes behind cost overrun. Tabulated results of RII values and the rankings of contractor-related cost overrun factors are summarised as in Table 4. Accordingly, the most significant contractor-related cost overrun factors can be identified.

Table 4. Contractor-related causes behind cost overrun

Contractor-related causes behind cost overrun	RII	Rank
Poor project management skills	0.871	1
Inaccurate Quantity Take-off (Lump sum /Design & build)	0.823	2
Insufficient project planning and scheduling	0.816	3
Poor time management	0.813	4
Poor analysis of site condition	0.806	5

Poor site management and supervision	0.790	6
Problems with sub-contractors	0.777	7
Obscurity in the contract documents	0.774	8
Poor financial control on site	0.765	9
Wrong method of cost estimation	0.758	10
Not decided on the construction materials	0.739	11
Lack of relationship between the management and labour	0.735	12
Shortage of skilled labour	0.729	13
Services available on site not sufficiently exposed	0.703	14
Proposed services not fully followed	0.700	15
The fluctuation of prices	0.687	16
Unplanned weather Conditions	0.677	17
Unforeseen tasks	0.677	17
Late delivery of material and equipment	0.677	17
Unnecessary storage of material, labour or machinery	0.613	20
Political instability	0.603	21
Government legislations	0.590	22
High cost for transportation	0.587	23
Variations	0.529	24
Mistakes during construction	0.484	25

As per the tabulated RII values, the most significant contractor-related cause behind cost overrun was the poor project management skills though it is not significantly dominated by Malkanthi et al. (2017). Moreover, Mahawatte (2021) also indicated the impact of poor project management skills on contractor's cost overrun in Sri Lankan building construction projects and highlighted the skills improvement requirement in stakeholder management, schedule management and communication management areas of project management. Inaccurate Quantity Take-off (Lump sum /Design & build) reached the 2nd position of the causes list with the recording of 0.823 RII value. As Nega (2008), Memon et al. (2011), Jayamaha (2019), and Wanjari & Dobariya (2016) identified, insufficient project planning and scheduling can be considered as a highly prominent contractor relate cost overrun factor which was at the 3rd rank in this research resulted with 0.816 RII value. Moreover, poor time management reached 0.813 RII amount and positioned at 4th position among the top-rated contractor-related cost overrun causes. Also, poor analysis of site conditions and site management/ supervision hold 5th and 6th positions of the causes list respectively.

Though Omotayo et al. (2017) stated poor contractor-subcontractor relationship as a less prevalent factor to cost overrun; it was among the top ten causes with its 0.777 RII value in this research. The cause of poor detailed drawings and specifications was ranked among the uppermost three causes by Alumbugu et al. (2014) in their research. However, according to the tabulated results in this research, the cause of obscurity in the contract document was at the 8th position with a 0.774 RII value.

Poor financial control on-site was positioned at 2nd in Omotayo, et al.'s (2017) findings, though it was in the 9th position with a 0.765 RII value. According to Jayamaha (2019), poor financial status was not highly influenced to cost overrun, despite its importance in managing a construction project. As justified by Omotayo et al. (2017) and Malkanthi et al. (2017), the 'selection of wrong cost estimation methods' can be considered as somewhat influential contractor-related cost overrun factor due to its RII value of 0.758. 'Shortage of material, labour, or mechanical Plants' was the topmost cause identified by Malkanthi et al. (2017), though it was not a prominent contract-related cause in this research.

Besides, political instability, government legislation, high cost of transportation, variation, and mistakes during construction are the other factors that comparatively less prevalent due to their low RII values.

C. Cost controlling tools

As shown in Table 5, BOQ items, unit rates, S curve, and engineering estimate stated as significant cost controlling tools that can be used to mitigate contractor-related cost overrun causes.

Table 5. Cost controlling tools

Cost Controlling Tools	RII	Rank
BOQ items	0.884	1
Unit rates	0.865	2
S curve	0.794	3
Engineering estimate	0.790	4

Due to the highest RII value, 'BOQ items' can be considered as the topmost cost-controlling tool. Then, 'Unit rates' can also be deployed as a tool owing high RII value of 0.865 RII. Abobakr (2018) also indicated the importance of unit rate as a cost-controlling tool. Moreover, the S-curve was at 3rd place with a 0.794 RII value. Compared to the other cost-controlling tools, there was the least response rate for using engineering estimates as a cost-controlling tool.

D. Cost controlling methods

By considering the results indicated in Table 6, the most effective cost controlling method to mitigate contractor-related cost overrun causes was the labour control due to the highest RII value of 0.861. It was the 2nd best cost controlling technique identified by Malkanthi et al. (2017). Otim et al. (2011) also stated that work programming is the most widely used cost controlling technique with a 16.3% portion of responses. However, accurate work programming (including MS project work) and record-keeping equally shared 2nd highest value of 0.855 for RII in this study. Besides, 'regular inspection of Works' was at the 3rd place while 'cost value reconciliation' reached the 4th position with an RII value of 0.809. However, cost value reconciliation was the widely used cost controlling method in world construction projects (Abobakr, 2018). Otim et al. (2011) also exaggerated the importance of regular inspections and record-keeping as cost-controlling methods.

Variance analysis, as a method for cost controlling, was placed 6th in the list. Earned value management, Forecasting, and Evaluation of works carried out equally obtained RII value of 0.794. However, Earned value management was the 3rd highly responsive cost controlling technique in the research conducted by Malkanthi et al. (2017). Though Otim et al. (2011) stated the importance of evaluating works carried out for cost control purposes in Uganda; it was in the 7th position in this research. Though Site meetings, To-Complete Performance Index (TCPI), and performance reviews are important to mitigate cost overrun, those methods respectively obtained insignificant RII values in this research. Malkanthi et al. (2017) also denoted no significance of TCPI and performance reviews as cost controlling techniques. However, regular site meetings were somewhat influential for accurate cost controlling (Otim et al., 2011).

Tabulated results of cost controlling techniques can be summarized as shown in Table 6.

Table 6. Cost controlling methods

Cost controlling methods	RII	Rank
Labour controlling	0.861	1
Work programming	0.855	2
Record keeping	0.855	2
Inspection of works	0.813	4
Cost value reconciliation	0.810	5
Variance analysis	0.800	6
Earned value management	0.794	7
Forecasting	0.794	7
Evaluation of works carried out	0.794	7
Site meetings	0.781	10

To-complete performance index (TCPI)	0.690	11
Performance reviews	0.681	12

IV. CONCLUSIONS

Cost overrun is one of the critical issues associated with building construction projects in Sri Lanka. Though there are substantial ways and means available for cost controlling in present-day building construction projects, Sri Lankan contractors often experience cost-over run issues in their building construction projects. Therefore, this study primarily attempted to identify the actual contractor-related cost overrun causes, aiming to propose a mechanism to minimize the impact of cost overrun for the contractors. Among the prominent contractor-related cost overrun causes associates with building construction projects in the Colombo district, the study indicates poor project management skills substantially impact cost overrun in building construction projects. Therefore, it is apparent that thorough improvements of contractor side project management skills in areas such as stakeholder management, communication management, and schedule management are essentially required to minimize the contractor-related cost overrun issues. However, further researches need to be conducted, by covering different types of construction projects all over the country, to generalize the research findings.

The study further proved inaccurate quantity take-offs in lump sum/ design and build contracts as one of the prominent causes behind cost overrun in building construction projects. Meantime, theoretical and empirical investigations in this research suggested that the building contracting professionals extensively need to use BOQ items and unit rates as cost control tools. Hence, there is a crucial responsibility for contractor's quantity surveyors to minimize the cost overrun in building construction projects in Sri Lanka since they are the experts in quantity take-offs and preparation of BOQs and unit rates.

Moreover, improved labour controlling mechanisms and accurate work programs supported by modern project planning software can be utilized as effective cost controlling techniques to minimize the contractor-related cost overrun causes of building construction projects in the Colombo District. However, more research gaps still exist to investigate to produce a sound framework for minimizing the contractor's cost overrun issues. Taking this into account, the most effective cost control tools and techniques suit for each identified cost overrun cause are essential to be identified & analysed separately. Further, specific project management areas that need to analyse skills to be improved are also required to find in further researches. Besides, analysing the existing level of modern technology used for cost controlling purposes and required technology advancements are among the future research avenues.

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ID 630

Effectiveness of Online Architectural Design Teaching: Perspectives of Students and Teachers

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Abstract— Design teaching is an important process and the core of Architectural education. It reflects the theoretical knowledge as well as practical knowledge while enhancing the sensitivities and lateral thinking of the students. This pedagogy facilitates exploring, experiencing, creating and team work based on cognitive, technical and social skills. Architectural design teaching traditionally relies on the face-to-face classroom educational system. As Covid -19 pandemic has impacted every field of society including education, most of the educational institutions, universities and schools throughout the world have switched to online systems. Accordingly, architectural education also had to adapt to online systems to some extent even without having teaching methods specifically designed for online architectural education. This research was conducted to find out the effectiveness of online architectural design teaching in the Sri Lankan context according to the perception of students and teachers. Qualitative data were collected using a researcher made structured questionnaire distributed among teachers and students attached to Sri Lankan architecture schools. The questionnaire was made based on five design teaching and learning methods, i.e. group discussions, tutoring, critiques, field visits and group work. The purposive sampling method was used to select the sample considering the experience in both face-to-face and online architectural design teaching. The size of the sample was 175 including both students and teachers. The data were analysed by using the software OriginLab in order to assess the participants' perceptions. The overall results show that more than twice as many respondents perceive online teaching to be ineffective in comparison to those that are in agreement with its effectiveness.

Keywords: *architectural education, online architectural design teaching, effectiveness, perspectives of teachers and students, Sri Lankan context*

I. INTRODUCTION

Education is a field which is mostly affected by the current Covid 19 pandemic situation. Online teaching is becoming an essential part in every level of education from kindergarten to higher education due to the difficulty of relying on traditional teaching systems. However, it is uncertain that some of the areas of education which highly depend on face- to- face teaching such as Architecture, Dancing, Music, Drama, Painting, Sculpting, etc. could be effectively taught via online teaching. Most of the Architecture schools in the world have switched to online teaching even not having designed online teaching systems with them. After realizing that the education process cannot be further postponed, Sri Lanka also adapted to online systems in almost every field including Education.

All Architecture schools established in Sri Lanka have initiated online teaching without prior experiences or experiments of being totally online. Design is the core subject area in any Architecture degree course which is usually taught face-to-face in the studios. Therefore, an uncertainty about effectiveness of teaching and learning process arises regarding the core subject- Design.

The objective of this research is to find out the effectiveness of online architectural design

teaching in Sri Lankan context according to the perception of students and teachers.

II. BACKGROUND AND LITREATURE REVIEW

Online education has been widely spread all over the world. Sun, et al. (2016) has reviewed that online education has rapidly developed due to internet connectivity, advanced technology, and a massive market and specially for people who are unable to obtain education because of physical distance, schedule conflicts, and unaffordable costs. Most of the students choose online courses due to quality of course design, the creation of interaction and evaluation system (Tallent-Runnels et al.,2006). With emergence of Covid-19 pandemic situation, most of the countries focus on online education rather than the past. Suher (2020) states that Turky Council of Higher Education has decided to use distance educational methods as an emergency model to carry out educational activities without interruption in universities. Most of the Sri Lankan universities including architectural education institutions have also adapted to online teaching without any prior experiences and advanced technology.

Architectural design teaching is an important pedagogical process in Architectural education. Chen, et al.(2012) identifies design pedagogy as project oriented and the core in architectural education. According to Parsons (2007) Architecture and design are traditionally oriented towards studio teaching and project based learning. Architectural design teaching is an active and more practical pedagogy more than theoretical process as described by Steino, et al (2012). It is learnt through practise hence it simultaneously involves making, creating, seeing, reflecting, and forming habits.

Design studio is a physical space and learning environment where students interact with teachers. It is the place where students are able to learn from teachers as well as from each other (Steino.N et al, 2017). In physical design studios, the mode of the instruction is one-on-one supervision and teachers discuss design projects with students. Architectural design teaching and learning is reflected through action (Schon. D, 1981). Afacan, (2016) argues that the online or virtual studio as it is often termed ideally involves a 'community' rather than isolated, one-on-one communication. There should be an interaction and collaboration between learners and teachers to create online education effectively. (Sun, et.al, 2016)

Design studio education reflects visual, verbal, tactile, written assignments from various forms such as drawings, design reviews, group presentations and studio works. Teaching methods are individual critiques, group tutorials, and lectures. (Afacan, 2016). Design studio critiques helps to improve student's creativity, thinking process and techniques and optionally invites external jurors (practitioners and/or academics) to give their opinion and comments on the students' design work in progress (Ellmers, 2006; Krantz & Harris, 2013). The student should present precedents of architectural space and form, proposed design with plans, sections and elevations using appropriate scales, using of appropriate materials and construction techniques and physical 3D models in a design critique. (Afacan, 2016) Architectural design communicates through visual representations in the form of drawings, scale models and prototypes. These artifacts are traditionally physical – graphite and ink on paper, and models made from wood, cardboard, plaster and other materials – and therefore tangible (Steino, et al., 2017).

In the design studio, there are interconnections between the student and tutor. Design tutoring contributes to convey the implied knowledge to students through speaking, sketching and visual expressions (Boardfoot & Bennett, 2016). Socialization is another important aspect gained from physical design studio group works (Yurekli, 2003). Ke (2010) points out that "a group of students could dominate online discussion, thus intimidating others who were newcomers''. Thus, traditional design teaching is arguably unique as a form of educational teaching methods compared to many other disciplines (Boardfoot & Bennett, 2016).

Online design studios have become a more attractive alternative to traditional studio teaching (Boardfoot O & Bennett R, 2016). According to Afacan (2016), Online or virtual teaching is a challenge and more difficult than in traditional classroom teaching. Suher (2020) emphasizes that online studios create important

opportunities and challenges for studnts related to their presentation and expression of work. Virtual pedagogy may produce changes in teaching and learning patterns and practices (Lopez-Perez & Rodriguez-Ariza, 2011). However, there are many advantages of online pedagogy, such as pedagogic richness, flexibility and cost-effectiveness (Graham, 2004).

Field visits are one of most significant teaching devices in the architectural curriculum and practical platform to understand the scale and proportions of a design, critical and inseparable part of the design process which help to analyse the environment, cultural and social aspect of the site (Trivir,2016; Yurekli, 2003). Suher (2020) states that google earth or google map might have been easily supported for virtual site visits.

III. METHODOLOGY

The research was carried out using researcher made structured questionnaire distributed among 175 of participants who were selected using purposive sampling method considering the experience of both face-to-face and online architectural design teaching systems. Participants consisted of 114 students and 61 teachers including permanent teachers, visiting tutors, and examiners. Sample students were selected from three (03) leading architecture schools and other architecture related institutions since the students from one of leading architecture schools did not respond. Selected students represented all levels of study. The teachers/ tutors/ examiners represented all schools and belonged to different designations and groups of experience.

Table 01: Detailed summary of the total responses according to the institutions

Institute	No of Teachers	No of Students
Government University	18	36
Semi-Government University	12	60
Private University A	9	15
Private University B	16	-
Other	6	3
Total Responses	61	114

Table 02: Detailed summary of the students' responses according to the level of study

Institute	Students Level of Study					
	Level 01	Level 02	Level 03	Level 04	Level 05	Other
Government University	2	5	22	1	3	3
Semi-Government University	5	18	6	15	11	5
Private University A	4	1	8	1	1	0
Other	-	-	2	-	1	-
Total Responses	11	24	38	17	16	8

Table 03: Detailed summary of the teachers' responses according to the role

Teachers' Role in Architecture Education	No of Teachers' Responses
Teacher	22
Tutor	18
Examiner	2
Teacher & Tutor	3
Teacher & Examiner	2
Tutor & Examiner	5
Teacher, Tutor & Examiner	9
Total Responses	61

The questionnaire consisted of 20 questions presented under five sections named following the main design teaching methods i.e. group discussions, tutoring, critiques, field visits and group works. Part A of the questionnaire

included general information of the participants. All questions in Part B were 5-point Likert scale questions asking the agreement/ disagreement of the each participant on each statement offered. Questionnaire was generated as a Google form and sent to the participants as emails and WhatsApp masseges. the responses received were analysed by making use of the software OriginLab in order to assess participants' perception and viewpoint on the effectiveness of online teaching in architectural education.

IV.RESULTS AND DISCUSSION

Following the research design, and administration of the questionnaire, the responses received were analysed by making use of the software OriginLab in order to assess participants' perception and viewpoint on the effectiveness of online teaching in architectural education. The data obtained was evaluated by assessing the probability of responses to assess the overall agreement or disagreement of the effectiveness of online teaching, followed by a calculation of the score of the effectiveness of the same.

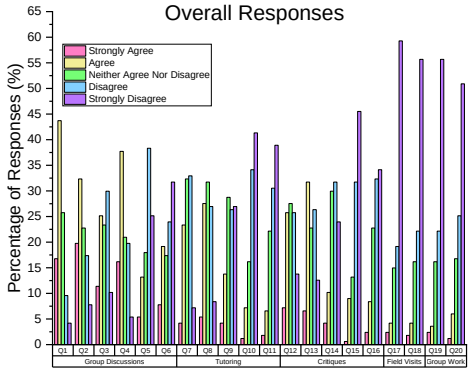

Figure 1: Overall responses

Figure 1 shows a graphical representation of the overall responses received through the questionnaire in terms of the percentage of responses received based on the total responses for each question based on the teaching method utilised. It can be seen that there is a general agreement for Questions 1,2, and 4, which asked whether participants felt like they could participate in online group discussions, whether they did not tend to pretend to participate, and whether they could easily share teaching material online, ranging from 32% to 44% of respondents stating that they agreed with the statements, and 15% to 20% stating that they strongly agreed with them. In contrast, it can be noted that Questions 15, and 17 to 20 received strong disagreement, ranging from 45% to 59%. It can also be seen that the teaching methods of field visits and group work have strong disagreement on effectiveness of online teaching, where participants' responses indicate that physical site visits and experience of architecture is necessary for effective teaching, and that group projects including the creation of structures and teamwork and soft-skill development require physical experience.

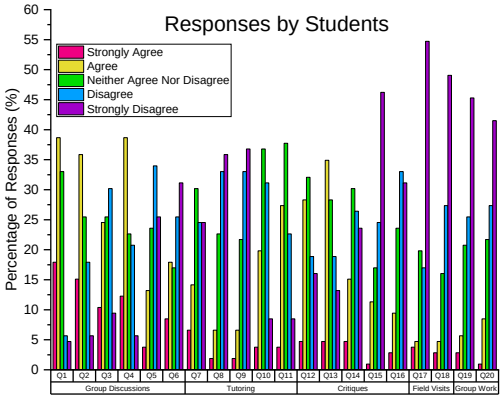

Figure 2: Students' Responses

Figure 2 details the results as analysed based on those received by students. A similar trend can be observed, where teaching methods of field visits and group work can be seen to be not effective when conducted online, however, some factors affecting effectiveness of group discussions are perceived to be effective online.

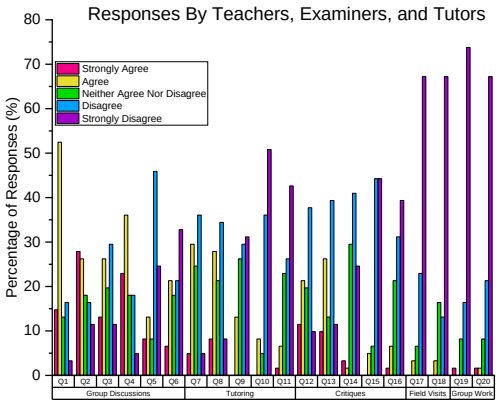

Figure 3: Responses by Teachers, Examiners, and Tutors

Figure 3 shows the responses received by teachers, examiners and tutors based on the method of teaching and question number. In comparison to Figure 2, it can be seen that less teachers, examiners, or tutors have a neutral

stance about the effectiveness of online group discussions as per Question 1, however more students (32.7%) have responded neutrally. In addition, teachers, examiners and tutors have a higher rate of positive responses (strongly agree and agree) of 67% to Question 1 in contrast to students (57%).

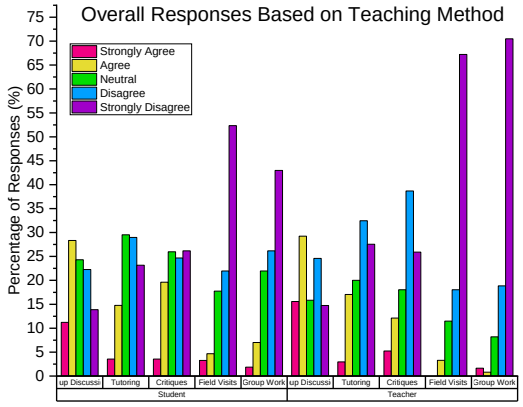

Figure 4: Overall Responses Based on Teaching Method

Figure 4 shows the overall responses obtained in relation to the type of teaching-learning method utilised online: group discussions, tutoring, critiques, field visits, or group work, for students and teachers (including teachers, examiners, and tutors) separately. It can be seen, as with the general trend of the previous graphs, that field visits and group work are generally perceived as ineffective, whilst group discussions are more effective, although only marginally, as 28.5% are generally in agreement, whilst 23.2% are in disagreement. In stark contrast, however, field visits and group work have strong disagreement rates of 57.5% and 53.3%, respectively, whilst strong agreement is at 2.1% and 1.8% for the two methods. Further, it can be noted that the rates of strong disagreement regarding the effectiveness of online field visits and group work are greater according to teachers (67.2% and 70.5%) than students (52.3% and 43%).

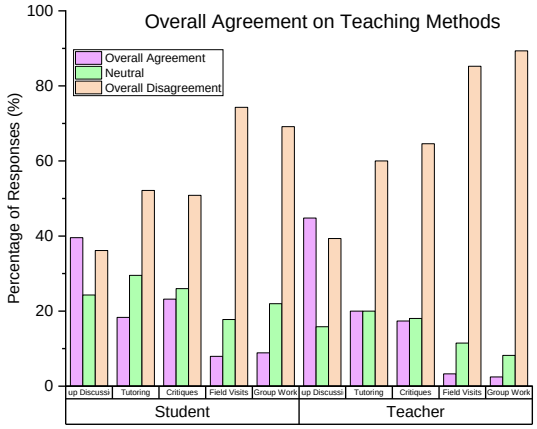

Figure 5: Overall Agreement on Teaching Methods

Figure 5 shows the overall agreement or disagreement based on each teaching method, categorised between teachers (including teachers, examiners, and tutors) and students, where all "Strongly Agree" and "Agree" responses were taken as overall agreement, and "Strongly Disagree" and "Disagree" responses were accounted for as overall disagreement; "Neither Agree Nor Disagree" was considered to be a neutral stance. In this, it can be seen that majority overall agreement is only found in online group discussions, where overall agreement was received by 41.5% of respondents. However, this should be compared with overall disagreement, which was 37.2%, where only 4.3% more respondents agreed that group discussions could be used effectively for online teaching. In contrast, overall disagreement is shown under all four other teaching categories, with disagreement ranging from 54% to 77%, compared against overall agreement ranging from as low as 6.6% to 21.2%. Further, it can be seen that overall disagreement in all teaching methods is higher for teachers than students, but overall agreement is also higher for group discussions in teachers as students have provided more general responses.

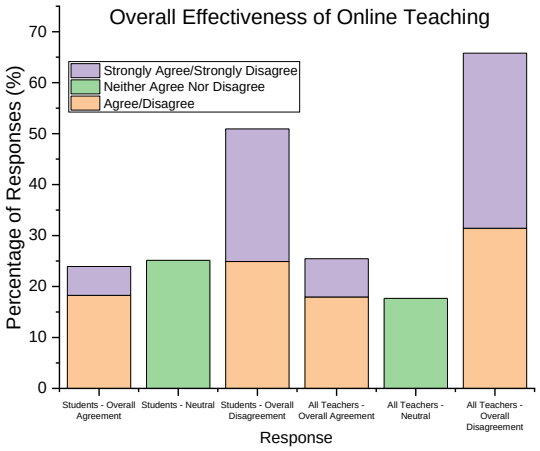

Figure 6: Overall Effectiveness of Online Teaching

Figure 6 shows the overall effectiveness of online teaching, which takes into account all responses received, where each factor is accounted for in equivalent weightage contributing to the concept of "effectiveness". The overall agreement responses are shown for students and teachers (teachers, examiners, and tutors) separately. It can be noted that students have a more neutral viewpoint on online teaching overall, marginally higher than overall agreement, in comparison to teachers, but overall disagreement is significantly greater than both. Neutral responses are lower in teachers than students. In addition, when considering the overall results for all roles, it can be seen that 23.8% of respondents are in overall agreement of the effectiveness of online teaching, whilst 54.2% are in overall disagreement, and 22% are neutral. This shows that more than twice as many respondents perceive online teaching to be ineffective in comparison to those that are in agreement of its effectiveness.

As a final analysis, a score of effectiveness was calculated to determine the overall effectiveness of online teaching. The concept would be represented by a value between -2 and +2, where +2 would be the maximum effectiveness that could be obtained (where all responses to all questions by all respondents would have been "Strongly Agree"), and -2 would be the lowest mark that could be obtained (where all responses to all questions by all respondents would have been "Strongly Disagree"). This calculation carried out by allocating a value of +2 for responses of "Strongly Agree", +1 for "Agree", 0 for "Neither Agree Nor Disagree", -1 for "Disagree, and -2 for "Strongly Disagree", in order to account for the weightage difference between strongly agree/disagree and agree/disagree responses. The total value obtained was then calculated as a ratio out of the maximum mark obtainable and converted to an average value for each response. The results from the calculation are shown in Figure 7. The overall score of effectiveness of online teaching in architectural education was found to be -0.52 suggesting overall ineffectiveness with general disagreement.

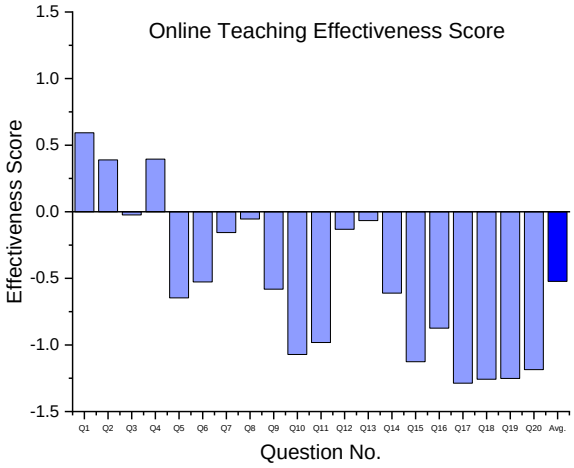

Figure 7: Online Teaching Effectiveness Score

V. CONCLUSION

This research was conducted to find out the effectiveness of online architectural design teaching in Sri Lankan context according to the perception of students and teachers. The qualitative data were collected from 175 participants comprised of teachers and students by conducting a questionnaire survey. 20 likert scale questions were included in the questionnaire in addition to the general information in the first part. Those questions were asked under the five sections namely, Group discussions, Tutoring, Critiques, Field visits and Group works which are main teaching learning methods of architectural design.

Analysis of the results can be summerized as following.

1. When considering the overall results for all roles, it can be seen that 23.8% of respondents are in overall agreement of the effectiveness of online teaching, whilst 54.2% are in overall disagreement, and 22%

are neutral. This shows that more than twice as many respondents perceive online teaching to be ineffective in comparison to those that are in agreement of its effectiveness.

2. When considering overall agreement on teaching methods, it can be seen that majority overall agreement is only found in online group discussions, where overall agreement was received by 41.5% of respondents. In contrast, overall disagreement is shown under all four other teaching methods including Tutoring and Critiques, with disagreement ranging from 54% to 77%, compared against overall agreement ranging from as low as 6.6% to 21.2%.

3. Among teaching methods used in design teaching, the field visits and group work are generally perceived as ineffective, whilst group discussions are more effective. Further, it can be noted that the rates of strong disagreement regarding the effectiveness of online field visits and group work are greater according to teachers (67.2% and 70.5%) than students (52.3% and 43%). It can be seen that overall disagreement in all teaching methods is higher for teachers than students, but overall agreement is also higher for group discussions in teachers as students have provided more general responses

4. The overall score of effectiveness of online teaching in architectural education was found to be -0.52 suggesting overall ineffectiveness with general disagreement in comparison with -2.0 (the maximum score obtainable for ineffectiveness)

Difficulty of finding participants with similar experience in both online and face-to-face architectural design teaching learning environments and different levels of knowledge in technology possessed by the participants are the limitations of this research which might have affected the overall results. This research only focused on five main teaching methods of design teaching and it can be further improved by including alternative teaching methods and other subjects closely associated with Architectural Design and enriching the sample.

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ID 181

Assessing the Impact of Urban Block Typologies on Solar and Photovoltaic Potential in the Tropical Urban City of Colombo, Sri Lanka

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Abstract— The increasing global energy crisis has brought about a shift towards the utilisation of renewable energy, particularly towards building-integrated photovoltaics. When considering the assessment of photovoltaics (PV) in urban regions, previous studies have focused on methods that take into consideration the urban block typologies, urban density, urban compactness indicators, or urban form. However, a requirement still exists to assess how the use of PV in tropical regions can be optimised via the use of facades. Coupled with the fact that semi-transparent PV implemented on windows can perform a dual role in generating electricity whilst minimising building cooling loads, it is imperative to understand how urban block typology can affect PV potential based on the shading effects caused within the block. This paper assesses four different urban block typologies in the urban and climatic context of Colombo, Sri Lanka and how they affect the total and average solar irradiation and the total photovoltaic generation capabilities of opaque and semi-transparent PV installed on building roofs and facades based on their orientation. It was found that although facades are unfavourably inclined towards tropical solar irradiation, they can generate higher amounts of electricity due to the more expansive façade area in high-rise buildings. Further, it was established that the building form in addition to the block typology affects the PV generation, especially when coupled with the building orientation, and that this can have a significant impact on the effectiveness of building envelopes for PV generation.

Keywords: *urban block typology, photovoltaic potential, building form*

I. INTRODUCTION

The growth in urbanisation and global conventional energy demand has brought about an increase in the cost of energy and carbon dioxide emissions (Poponi et al., 2016). Cities account for more than half of the world's population and 66% of the total energy demand. This has brought about a shift towards the utilisation of renewable energy resources. Photovoltaic (PV) technology provides a convenient method of onsite electricity generation and consumption with minimised transformation and transport losses, and it is imperative to account for the efficiency of PV systems when considering their implementation in urban environments. The utilisation of solar energy in urban environments, however, is not only dependent on the PV cell or system technology, which have also made significant advancements in recent years. Rather, the efficient utilisation of solar energy is determined by the intensity of solar irradiation present on the surface of the PV cell, which can be dependent on a variety of factors, such as the geographic latitude, climate conditions, urban context, and availability of installation space.

The installation of PV modules in high density cities face more challenges in comparison to low density cities when accounting for the shading and occlusion effect from neighbouring buildings and available area for panel installation. It has been found that different building blocks with varying building typologies but constant built density (Martin and March, 1972) could still have significantly varying effects on solar energy utilisation potential (Heng, Malone-Lee and Zhang, 2017). This brings about a need to

carefully assess the utilisation potential of solar energy in urban contexts based on different architectural or urban design plans (Ratti, Raydan and Steemers, 2003).

A further issue is brought about when taking into consideration high-rise, high density cities in tropical regions. In these regions, it is generally agreed upon that roof photovoltaics are the most feasible form of installation, as they are optimally inclined towards capturing solar irradiation (Mendis et al., 2020). However, the increase in high-rise buildings in these urban areas has brought about an increase in the building energy consumption relative to available roof area for PV deployment (Zhang et al., 2012). Thus, the installation of PV on high-rise building roofs may be unable to meet the building energy demand in tropical region), which brings about the next viable means of implementation – building facades. Although building facades are unfavourably oriented towards harvesting solar irradiation in these climates, it has been shown that photovoltaic integrated shading strategies can be a creative solution towards maximising solar energy utilisation potential in such contexts (Mendis et al., 2019; Hwang, Kang and Kim, 2012; Halawa et al., 2018). It is, however, necessary to obtain an understanding of the effects of neighbouring building shading effects on incident solar irradiation and corresponding PV electricity generation potential in tropical urban contexts.

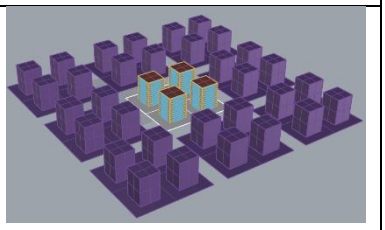
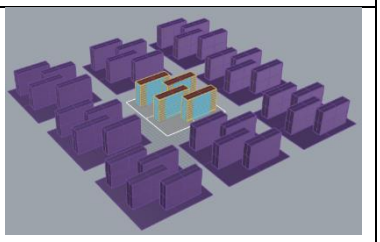
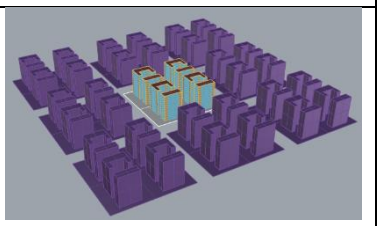
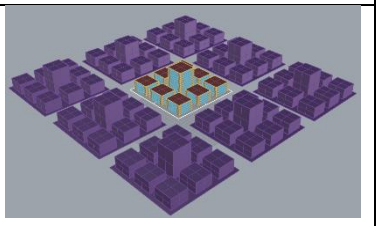
Given these, this paper makes an initial attempt into studying the effects of varying urban block typologies in Colombo, Sri Lanka on the solar and PV potential in order to determine optimised methods of PV implementation in high-rise, high density urban blocks in a tropical city.

II. METHODOLOGY

A. Urban Block Modelling

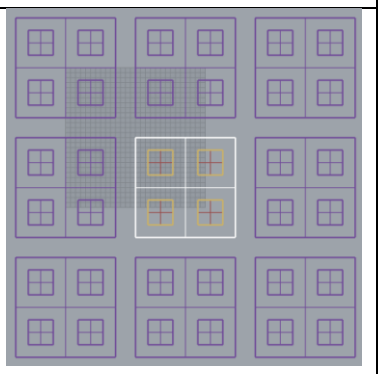
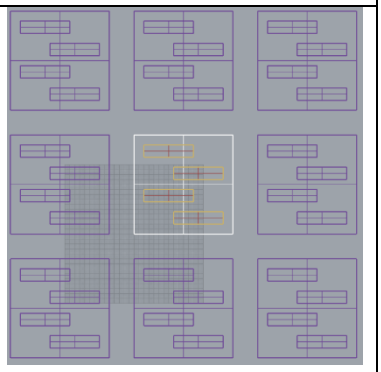
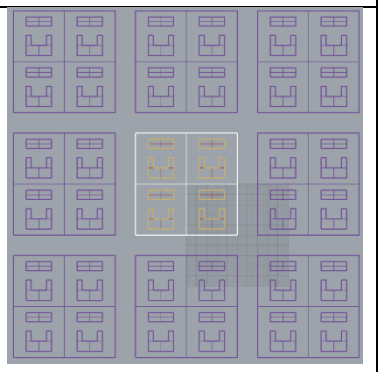
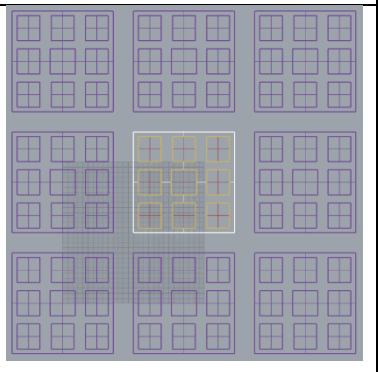
For the purposes of this paper, four urban block typologies were selected for evaluation. A survey was carried out to identify characteristic urban blocks in Colombo and their respective building forms, in order to determine the layout of each block. Through the survey, four generic urban blocks were identified in different typological categories: (1) regular tower, (2) staggered slab, (3) regular courtyard, and (4) regular centre block typology (Tables 1 and 2). The tower typology is considered to consist of standalone high-rise tower buildings with even spacing, whilst the slab typology consists of parallel rectangular buildings with even spacing. In addition, the courtyard typology consists of building(s) with a central courtyard, whilst the centre typology consists of low-rise buildings surrounding a central high-rise building.

Table 1. Perspective views of urban blocks used in the study

Block No.	**Block Type**	**Perspective View**
Block 1	Regular Tower	
Block 2	Staggered Slab	
Block 3	Regular Courtyard	
Block 4	Regular Centre	

Source: Author

Table 2. Plan views of urban blocks used in the study

Block No.	Block Type	Plan View
Block 1	Regular Tower	
Block 2	Staggered Slab	
Block 3	Regular Courtyard	
Block 4	Regular Centre	

Source: Author

Each urban block is considered to be the smallest unit in urban planning, surrounded by external roads. In order to maintain standardisation within the blocks, several parameters were kept constant. It is intended to assess the solar potential of the block in relation to the surrounding urban context which is mirrored by the block, i.e. the overall assessment was carried out in an array of 3x3 blocks with the assessed block being placed in the centre of the array, and the surrounding blocks being considered as shading elements in the overall urban context. This was done to evaluate the performance of the block in relation to a reflection of its own shading (references page 516). The parameters that were controlled include the maintenance of the site area of the block and the total built area within the block. For this, the site area was maintained at 10,000m^2 and the Gross Floor Area (GFA) was maintained at 30,000m^2, i.e. the plot ratio of each block would be 3.0, where the plot ratio is the ratio between the total built area within the block to the site area of the block. The window-to-wall ratio (WWR) of the facades of the buildings were maintained at 0.4. In order to represent a typical road, the spacing between blocks was set to 20m, and the distance between the edge of the site and the buildings was either 5m or 10m. Modelling of the urban blocks was carried out on Google Sketchup with the OpenStudio plug-in, along with importing the files to Rhino 6 in order run the solar irradiation simulation.

Although it is not perfect in recreating the real urban context, this method of homogenous simulation allows to derive at conclusions which are not context-specific, in contrast to other studies that are done in real urban contexts. By expanding the number of cases and block types in homogenous simulation, it is possible to arrive at conclusions for various block typologies which could be implemented in the real case.

B. Solar Irradiation Simulation

In order to run the solar irradiation simulation, Rhino 6 was used together with the Grasshopper plug-in, coupled with the Ladybug and Honeybee simulation tools. This method is capable of taking into account how time, location, climate, and shadows can affect the incident solar radiation. There are many validated models discussed in the literature, including Daysim, Radiance, ArcGIS Solar Analyst (Feitas et al., 2015), and it was found that Radiance is an accurate ray-

tracing software that has been validated multiple times through previous studies and is used as the simulation engine through the Ladybug and Honeybee tools. These tools help to investigate the environmental performance of buildings via a visual programming language and validated simulation engines. They make use of algorithmic modelling and neural networks to simulate building and environmental performance.

By making use of this method, the solar irradiation on the building surfaces of the central block were modelled on the individual facades – including the walls and windows individually, and the roofs of the buildings.

C. Photovoltaic Generation Calculation

In order to assess between the PV implementation feasibility of difference surfaces, it was necessary to calculate their PV generation capabilities. For this purpose, the following formula was made use of, where EPV denotes the total PV electricity generated; TSR denotes the total solar irradiation incident upon the surface; η denotes the efficiency of the PV module; PR denotes the performance ratio of the system; and A denotes the total area of the surface under consideration.

$$E_{PV} = \frac{T_{SR} \cdot \eta \cdot PR}{A}$$

The performance ratio is typically between 80% and 90% and was set at 85% for this paper (Kumar and Kumar, 2017), and the efficiency of semi-transparent PV was set at 5% and the efficiency of polycrystalline silicon PV was set at 15%. It was assumed that semi-transparent PV was made use of on the total surface area of the windows, whilst polycrystalline PV was used on the total wall area.

III. RESULTS AND DISCUSSION

The results from the simulation were analysed by considering for various aspects, two primary factors being the total solar irradiation and the average solar irradiation. The total solar irradiation represents the overall solar irradiation incident (kWh) upon the entire surface or surfaces under consideration, whilst the average solar irradiation accounts for the solar irradiation intensity (kWh/m²) on the surface, i.e. the energy present per square metre of surface area.

Figure 1 shows the overall total and average solar irradiation in each of the four blocks as an accumulation of all of the building surfaces (roofs, walls and windows). It can be noted that Block 3 (Regular Courtyard) receives the lowest average irradiation of 530kWh/m² in contrast to the highest average irradiation of 818kWh/m² received by Block 4 (Regular Centre). Further, the highest variation in total and average irradiation is present in Block 3, where it could be interpreted that although the building forms in the block provide for a greater envelope area, the compactness of the block is such that the overall shading effect on the envelope is increased, thus bringing about a decrease in the irradiation intensity on the surfaces. In contrast, Block 1 receives the second highest average irradiation (737kWh/m²) in comparison to the lowest total irradiation (1245700kWh). The opposite could be interpreted in this case, where the tower shaped building forms provide less surface area in comparison to Block 3, whilst minimising inter-building shading effects, bringing about an increase in the overall solar irradiation intensity on the surfaces.

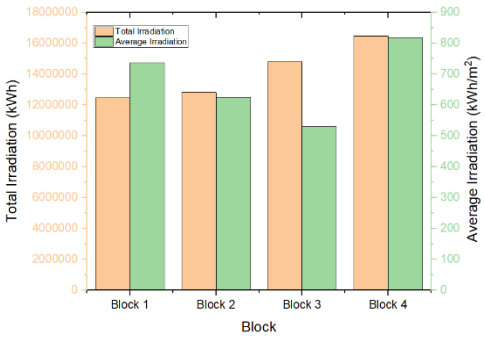


Figure 1. Overall total and average solar irradiation in each block
Source: Author

It can be seen that in Blocks 1, 2, and 3 (Regular Tower, Staggered Slab, Regular Courtyard), the highest total solar irradiation is achieved by the building facades, whereas in Block 4 (Regular Centre), the highest total irradiation is achieved by the roof (Figure 2). This could be assumed to be because although the compactness of Block 4 is increased, it is composed of many low-rise buildings surrounding a single high-rise building.

Since the plot ratio (and therefore, GFA) of each block is maintained at a constant, this means that the total building footprint – and hence, roof area – in Block 4 is increased, allowing for a greater area for total incident solar irradiation. However, when looking at Figure 3, which shows the average solar irradiation based on the building surface, it can be noticed that Block 4 receives the lowest irradiation intensity on the roof (1855kWh/m^2). This could infer that although a greater roof area is achieved through the building forms of Block 4, there is a greater shading effect from the high-rise building to the surrounding low-rise buildings, bringing about a decrease in the solar irradiation intensity on the roofs of the block. In contrast, Blocks 1, 2, and 3 all receive the same average solar irradiation (1934kWh/m^2) on the building roofs, since there is neighbouring building shading effect caused onto the building roofs. The average irradiation on the facades is highest in Block 1 (529kWh/m^2) and lowest in Block 3 (404kWh/m^2), which could confirm the results deduced from Figure 1 – where the tower shaped building forms in Block 1 create less shading on the building facades in comparison to the courtyard shaped buildings in Block 3, which create a greater façade surface area, but increase building-to-building shading effects.

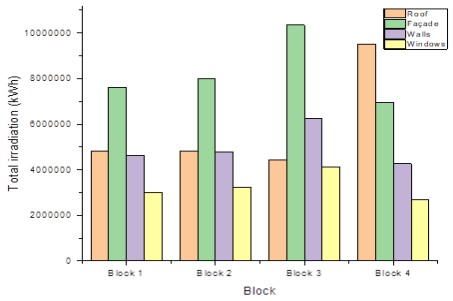


Figure 2. Total solar irradiation in each block based on surface; Source: Author

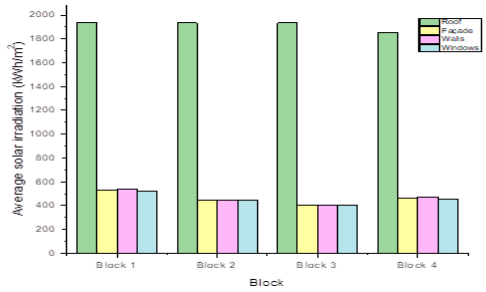


Figure 3. Average solar irradiation in each block based on surface; Source: Author

When looking at a more in-depth analysis of the total irradiation on the facades based on their irradiation as shown in Figure 4, it can be seen that Blocks 2 and 3 receive the highest total irradiation on the south façade. This could be because the building forms in these blocks are elongated in the east-west axis, and therefore the south façade has a greater surface area in comparison for solar irradiation capture. In addition, Block 2 receives higher amounts of total irradiation on the north façade as well in comparison to the east and west facades, although Block 3 receives the lowest amount of irradiation on the north façade in comparison to the other three facades. It can be deduced that this is due to the inter-building shading effect caused in Block 3 due to the compactness within the block. Blocks 1 and 4 appear to receive higher amounts of irradiation on the east and west facades in comparison to the south façade, which could be due to the effects of the sun path in the location and the constant shading caused on all surfaces due to the standardised nature of the building forms.

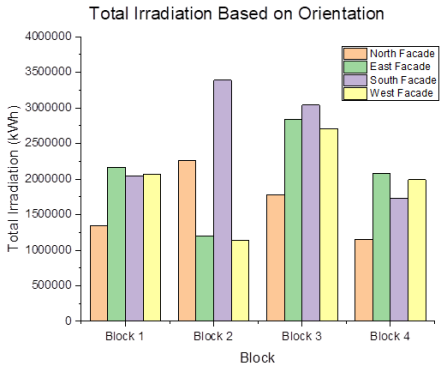


Figure 4. Total solar irradiation based on surface orientation in each block; Source: Author

Figure 5 represents the average solar irradiation based on the building surface orientation in each block, which includes the four facades and the roof. Understandably, the roof receives the highest average irradiation in all four blocks due to the favourable inclination angle, but it can also be seen that the north façade receives the lowest average irradiation in contrast, which could be due to the unfavourable solar elevation angle. Further, it is apparent that the east and west facades receive the highest average irradiation in all four blocks from the four facades, which is due

to the solar elevation angle and pathway based on the location.

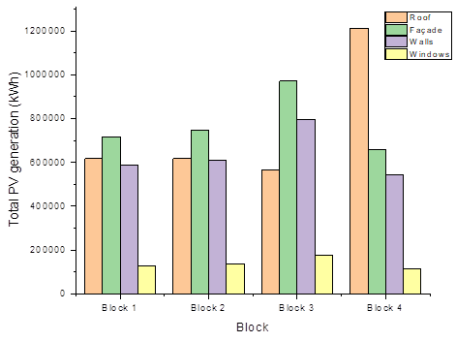


Figure 5. Average solar irradiation based on surface orientation in each block; Source: Author

Figure 6 shows the total PV generation based on the building surface in each block. This figure breaks down the overall PV generation capabilities of the roofs, walls, and windows separately of all buildings within the block. The facades account for the total average components of the walls and windows together. As described in the methodology, it was assumed the polycrystalline silicon PV of efficiency 15% was made use of for the roofs and walls, whilst semi-transparent PV of efficiency 5% was made use of for the windows. It is apparent that the windows generate the least total PV electricity due to the lower surface area for panel installation. In contrast, Block 4 generates the most PV electricity via the building roofs due to the expansive roof area whilst the total façade generation is reduced, presumably due to the reduced façade surface area caused by an increased number of low-rise buildings. Block 3 generates a significantly high proportion of façade PV in comparison to roof PV due to the increased façade area available. However, these values need to be compared with those shown in Figure 7, which represents the total PV generation based on the surface orientation in each block for the walls, windows, and both combined. This shows us that the south façade in Block 2 generates the most electricity, a major proportion of which is carried out by the walls. Further, the north and south facades generate more electricity in this block than the east and west facades. In Blocks 1 and 4, the east and west facades generate higher amounts of electricity, but are closely followed by the south facades. It can also be noted that the walls consistently generate more electricity than the windows due to the cumulative effects of higher panel efficiency and greater available surface area.

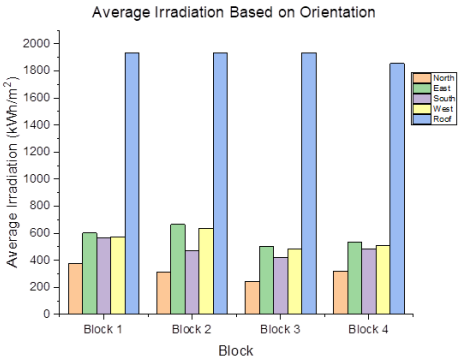


Figure 6. Total PV generation based on building surface in each block; Source: Author

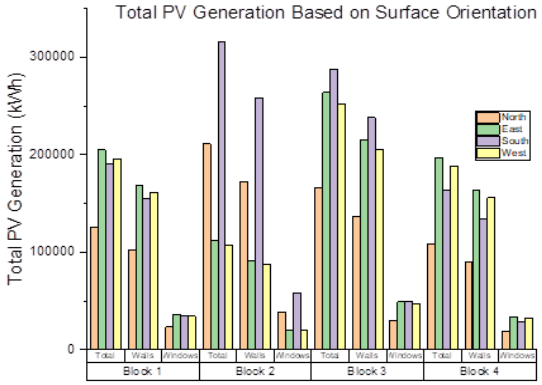


Figure 7. Total PV generation based on surface orientation in each block; Source: Author

IV. CONCLUSIONS

This paper looked into understanding the effects of urban block typology on solar and PV potential in urban contexts. Four distinctive generic urban blocks typologies were modelled for the location and climate of Colombo, Sri Lanka based on a homogenous form. The software, Rhino 6, was made use of coupled with the Grasshopper plugin, Ladybug and Honeybee tools, and the Radiance simulation engine in order to simulate the solar irradiation incident upon the building surfaces in each of the urban blocks. It was then assumed that photovoltaic panels were to be installed on the building envelope, with polycrystalline silicon PV (of 15% efficiency) being used for the building roofs and walls, and semi-transparent PV (of 5% efficiency) being used for the windows.

The results were analysed based on the total and average solar irradiation incident upon the

separate building surfaces, whilst also accounting for their orientations, after which, the PV generation capabilities of each surface was accounted for as well. From the results, the following deductions could be made:

i. Although the windows provide a greater surface area for PV installation in comparison to the roofs, the PV electricity generation capabilities of the roofs are greater than those of the windows due to the limited efficiency of semi-transparent PV panels and unfavourable inclination angle.
ii. Most blocks generate more electricity via façade PV in contrast to roofs due to the greater surface area available for installation.
iii. Due to the increase in the number of low-rise buildings in Block 4, and thus an increase in the building density and site coverage, the roofs are capable of producing more electricity via PV in comparison to the facades due to the expansive roof area available for panel installation.
iv. The south façades in Blocks 2 and 3 are capable of generating a greater proportion of electricity due to the elongated building form.

The above deductions open the way for more questions considering the effect of the urban block typology on PV potential. An interesting point to study would be whether a change in the orientation of Block 2 towards the east-west directions would bring about a greater increase in PV generation in comparison to its current form. Further, since semi-transparent PV installed on windows are capable of minimising the solar heat gains into the building, it could be studied on how this affects the overall building energy consumption when considering for cooling loads. Although this paper looked into the effects of four urban block typologies on solar and PV potential, more factors need to be taken into consideration in order to make this study more comprehensive, such as the effects of various WWR on both the PV potential and building energy consumption, and also the effects of different block typologies in various orientations. Further, a comparative assessment could be carried out considering the varying use of semi-transparent PV on windows in contrast to photovoltaic integrated shading strategies and their effects on minimising building cooling loads. Considering the developing context of a region like Colombo, it is also imperative to take into account the calculation of economic potential of these strategies, in order to ensure that the implementation methods studied are region-sensitive and feasible.

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Utilization of Cocowood for Affordable Engineered Wood Flooring in Sri Lanka

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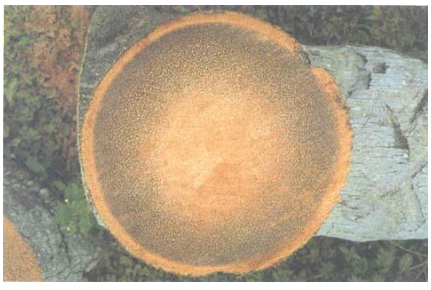
Abstract – Coconut wood or Cocowood has a long history of being utilized as a building material in Sri Lanka. Cocowood stem has three major parts from the inner core to outer skin such as; low-density wood, medium density wood and high-density wood based on the moisture content and the fibre bundle patterns. Cocowood is mainly used for roof construction and the utilizations are limited for certain lengths where timber logs less than 4'-0" in length are mostly abandoned in factory processes in Sri Lanka. The high-density stem fibre has properties similar to many hardwood timbers which are majorly used for luxury flooring products while the rest of the stems are under-utilized or used as firewood. Even though the utilization of Cocowood for flooring is practised in the international context, it has not been properly adopted in the local context. The objective of this research is to produce an affordable engineering flooring material that minimizes the material wastage of Cocowood by utilizing the medium density Cocowood stem and abandoned short length hard-density Cocowood logs. The research process identified the efficient use of Cocowood and the practical dimensions for an affordable Cocowood flooring material. Experiments resulted in 0'-6"x 0'-48" sized, ¾" thick, glue-lamed, aesthetically pleasing, engineered Cocowood tile that can be utilized as an alternative economic flooring material. The introduced tile is economical compared to the other timber flooring materials available in the current market.

Keywords: *cocowood, building construction, moisture content, density, efficient use, glue-lam, engineered wood, dimensional stability, affordability, colour variation, texture variation*

I. INTRODUCTION

Coconut palm (Cocos nucifera) is an endogenous tree which produce special wood named Cocowood or coconut wood. It is an agricultural crop widely spread throughout the tropics. Economic lifespan of a coconut tree is around 60 years and afterwards the trees are used by saw millers. By that time the dimensions of the tree would be as follows: Maximum Diameter (Butt) - 30cm, Top Diameter - 15cm, Average height - 20m, Gross volume per stem - 0.9m^3 (Killmann, 1996). The anatomical features of Cocowood results non-homogenous distribution of physical properties both over cross-section and height, so is a very non-homogenous raw material. The dry density of the stem fibre decreases towards the centre of the stem and over the height. The higher density wood or hard area (700 Kg/m3) is deposited in the outer periphery of the stem which has properties similar to many hard woods (Bailleres, 2010). Central area of stem consists of low-density wood (<500 Kg/m3) and the area in-between consist of medium density wood (500–700 kg/m3) (Killmann, 1996). Thus, the density rapidly varies approximately by 200Kg/m3 within a 150cm stem radios where approximately 25 % of the millable portion of coconut stem consists of low-density wood.



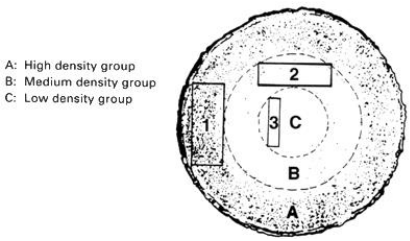


Figure 5: Cross section of coconut palm stem with density zones
Source: Sulc, 1984

The moisture content is high in raw coconut wood compared to exogenous wood. It is negatively correlated with the basic density of coconut wood. The moisture content decreases with increasing basic density and vice versa. The amount of moisture in coconut stem increases with increasing stem height and decreases from the core to the cortex. The moisture content ranges from 50% at the bottom portion to 400% at the top core portion of the stem (Killmann, 1996). According to another research no significant difference in moisture content has been found between periphery and core portion of a 40 years old coconut stem (Rana et al., 2014). The dimensional stability of the wood is determined by its shrinkage or swelling. Shrinkage and swelling cause drying defects such as checks and split. Unlike conventional wood where tangential shrinkage is almost twice the radial shrinkage, the tangential and radial shrinkage of Cocowood are not significantly different (Killmann, 1996). Seasoning is essential for coco timber before using due to this high moisture level. Air drying using an open ended and roofed shed is the most economical practice of seasoning coco timber (Romulo & Arancon, 2009).

The utilization of coconut tree varies with the height. Average length of the millable log of the tree is 8.4m. The top most part of the stem (from top edge of the millable log up to the level of first nut) has an average length of 6.6m and is considered as unusable as the percentage of low-density wood increases. Thus, that part of the stem is utilized as wood for charcoal and firewood. (Killmann, 1996). Accordingly, 44% of the total length of coconut stem is not used as millable wood.

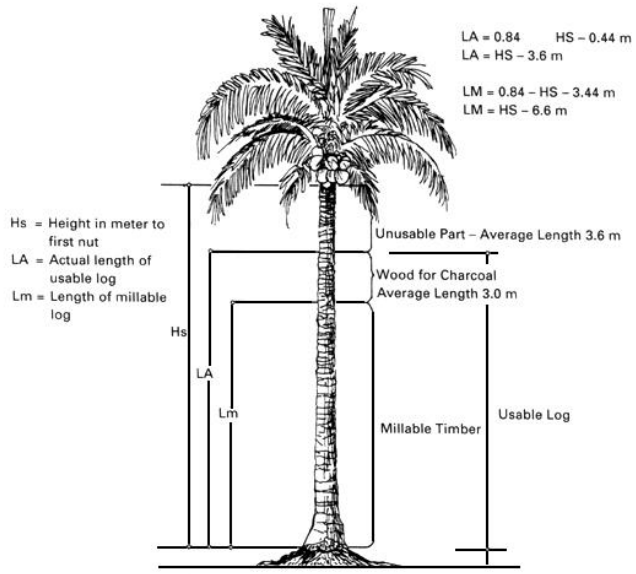


Figure 6: Use of the coconut palm stem
Source: Jensen and Killmann, 1981

One of the primary uses of Cocowood is building construction. In building construction Cocowood is used for making trusses, purlins, walls, joists, doors, windows, wall panelling, and cladding and also as a flooring material. However, around 90% of above mentioned Cocowood end use in building construction require high density and medium density wood materials (Killmann, 1996). As per the literature, approximately 25 % of the coconut stem is not used in building construction due low-density wood. When considering the complete stem of a fully grown 60-year-old coconut tree, overall 54% of Cocowood consist low density portion. Thus, only around 46% of an average coconut stem is possible to be utilized in building construction. Therefore, maximum utilization of this 46% is important to minimize wastage.

Cocowood in local context;

Coconut is a popular agricultural crop in the country. There are three main verities of coconut found in Sri Lanka namely tall (typica), dwarf (nana) and thambili (king coconut - aurantiaca) (Mahindapala, 1989). In Sri Lanka generally after 60 years, palm trees are uprooted (Mahindapala, 1989). As a tropical country Sri Lanka has many historic records proven that Cocowood has been used in many construction works. Coconut can be classified as a "traditional" wood under "non-forest wood resources" group in Sri Lanka. The utilization of coconut timber is increasing in the country as an alternative to solid wood. In fact,

Cocowood is popular as a building material in Sri Lanka in the form of structural members such as rafters, reapers and purlins (Mahindapala, 1989). According to available statistical data from year 1986 to year 1990, 102000m^3 of Cocowood has been utilized in Sri Lanka and had been predicted that it would be around 235000m^3 by year 2020. Therefore, unless the use of coconut wood is developed, the demand will have to be met by imported wood.

Only 20% of the saw log quality Cocowood logs are used mainly for hand-hewn rafters and surplus is likely to be used as fuel wood (Mahindapala, 1989). Thus that 20% has to be the high-density portion of the coconut stem as they are utilized as structural members which need high strength. As aforementioned data, from the 46% of useable middle density and high-density wood available in an average stem, it can be presumed that the remaining 26% of middle density usable wood for construction is underutilized in the local context.

Although Cocowood is popular as structural members in Sri Lanka its utilization as a flooring material is not very common. But it is internationally popular where countries like Australia is manufacturing export quality Cocowood flooring. (Romulo N. Arancon J. , 2009) The aesthetical appearance of the Cocowood created by bundle pattern increases its suitability as a floor finish. According to the data published by Australian centre for agricultural resources high density Cocowood and medium density Cocowood is suitable to manufacture flooring products (Bailleres et al., 2010). Thus, the main objective of this research to incorporate medium density Cocowood for flooring products by maintaining durability and dimensional stability to maximize the underutilized Cocowood and reduce the wastage of Cocowood. The final outcome of this research will serve the purpose of economise coconut wood use and find an alternative to expensive timber flooring.

II. METHODOLOGY

As mentioned the experimental research was conducted with the aim of utilising the underutilized medium density Cocowood and to reduce the wastage in Cocowood industry, aiming a product development; Cocowood flooring, which is economically feasible in local context. Main objective of the product development process was to utilize the existing cocowood related technology, techniques and machinery in the local industry.

A. Selection of materials and primary processing

For the study, 50 number of fallen trees with an average length of 60' were selected which are ready to process for timber. The top most part of trees of approx. 16.4' average length were removed due to the high proportion of low density wood. The rest approx. 49.2' long usable logs were bucked in to 8', 7', 6' and less than 5' Lengths. All logs were counted and measured after bucking. In the sawmill selected logs less than length of 5' were processed into 2"X4" lumbers by standard sawmilling equipment as 2"x4" is the common timber size of Cocowood which are used as rafters in roof construction. Afterwards a visual grading was done on physical defect and colour by an experienced timber technician to select medium density and high density lumber out of the lot.

B. Construction of The Flooring Material

Once sorting the lumber based on density they were dipped in a boron-based wood preservative commonly available in market as the preservative chemical to avoid stains and moulds as accelerated drying was not utilized in the process. The used preservative is a water born preservative suitable for timber use for internal applications. Boron is poisonous to wood-boring insects and wood-destroying fungi but safe for human (Romulo and Arancon, 2009). Lumber was dipped for 02 to 03 minutes in the Boron solution and stacked 04 to 05 weeks following the standard stacking methods to avoid boards contacting with the ground or direct sunlight, either before or after dipping.

Process of air drying was done in an open sided roofed shed. Since the product development was aimed to be an economical flooring material for the local market air drying alone was identified to be sufficient. Air-drying in tropical environments can achieve moisture contents between 15% and 18% because of the ambient conditions. This moisture content is proved to be feasible for non-airconditioned environments (Bailleres et al., 2010). Therefore, logs were kept inside a protected shed for air drying and the moisture content was monitored using resistant meter until 15% moisture content was achieved which took six weeks.

C. Construction of Timber Floor Tile

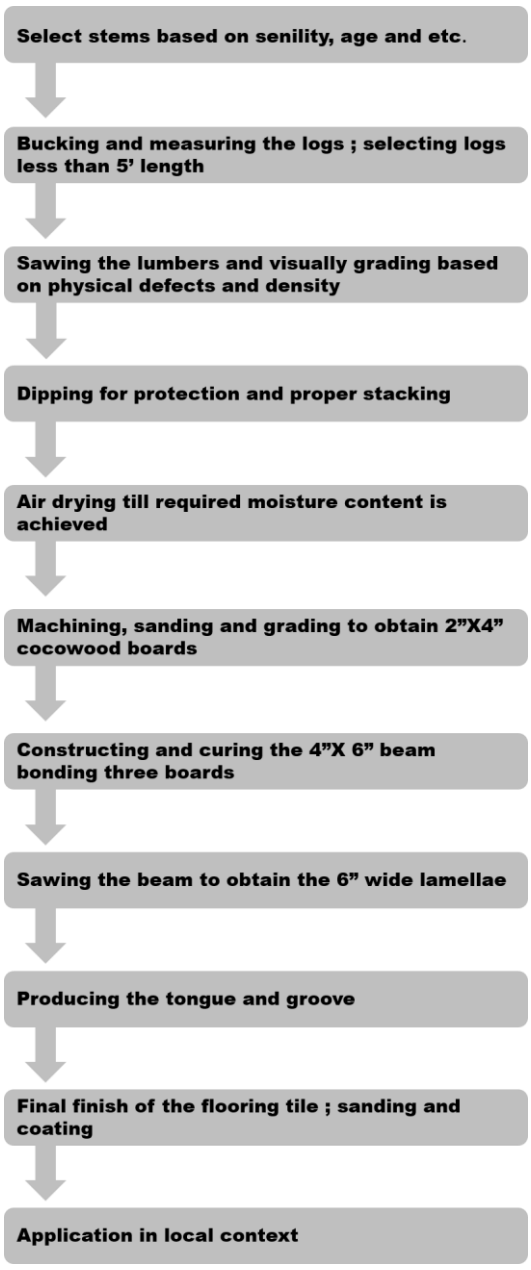


Figure 7: Production process followed in developing the Cocowood floor tile in local context

Seasoned 2"x4" Timber sections were glued using epoxy wood adhesive in the way that high-density lumber and low-density lumber are placed in alternate rows to produce a 6"x 4" beam (figure 4). This method is called as glue lamination or glue-lam. This method prevents the deformation of the final product due to case hardening and improve the dimensional stability. Further, this alternative use of high and medium density lumber influences the appearance of the tile by creating a visual variance which otherwise is monotonous.

Based on the technology and machinery available in the current industry the thickness of the beam was limited to 6". This was due to the reason that the possible maximum depth of the sawing table blade is 6". Glued boards were kept for 08 hours to ensure adhesion. After 08 hours glued timber beams were cut along its longitudinal axis in to in to ¾" thick timber tiles to obtain 05 tiles of equal thickness.

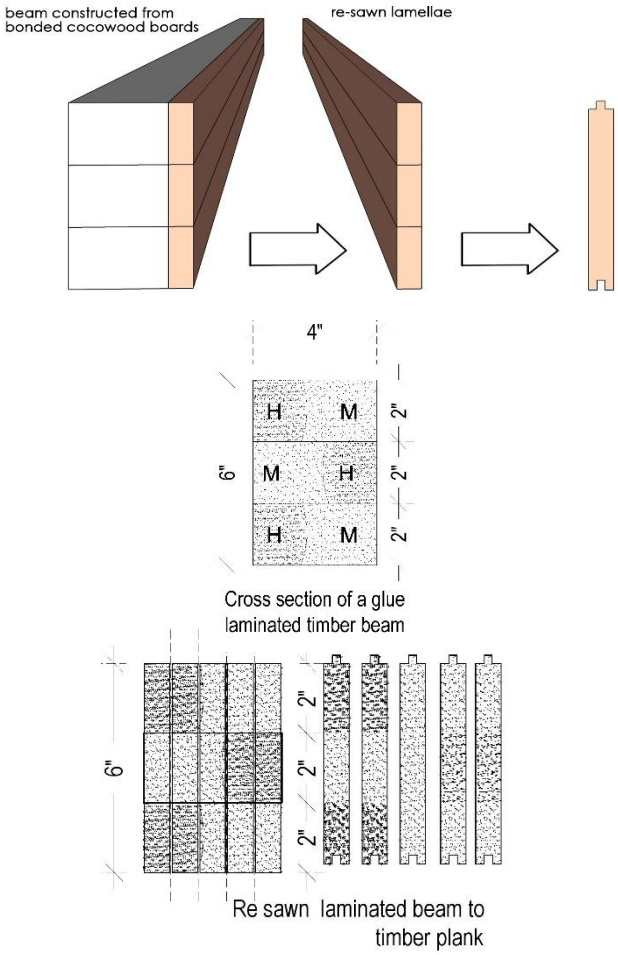


Figure 8: Constructing the Cocowood tiles

The thickness was decided based on the minimum wastage requirement and recommended minimum thickness. Afterwards those ¾" thick timber planks were trimmed in to a 4' of lengths. One engineered timber tile consists of 02 high density timber pieces and one medium density timber piece or vice versa. The final size of the engineered timber plank is 6"x48" and ¾" in thickness. Subsequently tongue and

groove joints were made on each engineered timber tile.

Surface Finishing

Wood planks were sanded to get the smooth finish following the standard sanding procedure. One coat of wood stain and three coats of water-based wood top coats were applied to get the desired finish (Figure 5).

Cost comparison

Market Prices of a leaner foot of 2"x3" Cocowood lumber of 8'-0" 18'-0" and less than 5' lengths were recorded based of 05 large scale sawmills. Manufacturing cost of the Cocowood tile flooring was calculated and compared with the market prices of conventional hardwood flooring and parquet flooring to determine the economic feasibility and maximum utilization of manufactured product.

Figure 9: Processing of Cocowood tile

III. RESULTS AND DISCUSSION

Using the measurements of 45'-0" long usable logs taken by 50 selected coconut trees, the length comparison of different log lengths produced by an average coconut tree was calculated and given in the table 01. 13% Log length is less than 5'0" according to the results.

Table 01: different log lengths produced by an average coconut tree

Log length	% of total length of the log
Less than 5'	13%
5'-0"- 10'-0'	28%
10'-0"- 15'-0'	42%
15'-0"- 18'-0"	27%

Price of a linear foot of 2"x4" coconut timber for different length were compared and given in the table 02. According to the table 02 the price of a 2"X4" coco wood lumber increases by 20 LKR per every additional linear foot of a specific length.

Table 02: Price comparison of 2"x4" Cocowood timber for different lengths

Log length	Price per 1ft. (LKR)
Less than 5'	70.00
6'-0"	100.00
8'-0"	140.00
10'-0"	180.00
12'-0"	220.00
14'-0"	260.00

Manufacturing cost breakdown of 05 number of ¾" tk. 4'-0" x 0'-6" engineered coconut timber tiles is given in the table 03.

Table 03: Manufacturing cost breakdown of 05 number of ¾" tk. 4'-0" x 0'-6" engineered coconut timber tiles

Description	unit	Rate (LKR)	Total (LKR)
4'-0"X4"X2" coconut wood lumber	12ft.	70 per ft.	840.00
Epoxy resin glue lamination	4sq.ft	38	152.00
Preservative treatment	0.2l	150 per litre	28.50
One coat of water base wood stain	8sqft	8 per sq.ft	64.00
three coats of water base top coat	8sqft	17 per sq.ft	136.00
Labour and equipment		100	825.00
			Rs.2045.50

According to the aforementioned figures the manufacturing cost for 05 number of ¾" thick 6"X4'-0" engineered coconut wood tile is 2045.50 LKR. So, the cost per square foot of coconut wood flooring tile is 204.55 LKR. Based on the market

survey, installation cost of the conventional hardwood flooring system was found as LKR.250.00 per sq.ft. The rate calculated to Cocowood flooring system introduced through the research is considerably lower than the conventional hardwood flooring. Based on this data, the rate for supply and installation cost of laminated Cocowood flooring system is LKR.454.00 per sq.ft with added 25% of profit margin referring the rule of thumb in current market. Based on these figures price comparison of the coconut wood laminated tile with other hardwood flooring systems is in table 04.

Table 04: Price comparison of the coconut wood laminated tile with other hardwood flooring systems

Cocowood	Burma teak hardwood	Burma teak parquet	Local teak hardwood	Local teak laminated
Rs.566	Rs.2250	Rs.1750	Rs.1650	Rs.950

IV. CONCLUSION

The research was conducted to construct an affordable engineered timber floor tile using under-utilized local Cocowood stem. Thus, 0'-6"x 0'-48" sized, ¾" thick, gluelamed, aesthetically pleasing, engineered Cocowood tile was produced using short length (less than 5'-0") Cocowood logs combining high density and medium density Cocowood lumber. Cocowood logs less than 5'-0" lengths are not utilized in the industry as shorter lengths are not adequate to get the required roof spans. Thus, offcuts of the Cocowood logs which got shorter lengths (less than 5'-0") have no economic value in the market. Further, medium density Cocowood is not utilized for structural timber members and rarely used for other purposes in Sri Lankan building industry. Therefore, the under-utilized medium-density Cocowood was combined with offcut high density Cocowood to manufacture the engineered Cocowood floor tile through the research process. Standard methods of timber floor installation were used for the installation of the Cocowood tile as well. Adopting a unique installation method was not in the scope of the research. Dimensional stability of the tile was expected by Alternate combination of medium density wood and high-density wood. The developed product and the findings of the research indicated following advantages in economical, sustainable and architectural point of views;

- Economical with reduced cost compared to local teak laminated timber flooring solutions as the tile is engineered by an underutilized parts of coconut stem.
- sustainable due to utilization of probable waste of the coconut wood; 13% of usable wood from the coconut stem is under-utilized due to medium density and short length.
- Aesthetically pleasing than monotonous colour and texture of conventional Cocowood as colour and texture variation of the engineered tile due to batch variation of timber and alternate fibre bundle pattern of medium density wood and high-density wood.
- Available for mass production as coconut is an agricultural crop, a forestry wood and abundance of underutilized parts of coconut stem in local context.
- Potential for exporting due the demand from foreign market

Further studies;

The mechanical properties and the durability of the tile has to be measured in further researches. Mass production possibility of this product and potential of exporting should be analysed further. Moreover, it is needed to further research on maximizing the utilization of Cocowood as flooring and to further economize the product by reducing the costs by developing the Cocowood floor tile combining a different base material suitable for local context and bonding the Cocowood as the top lamellae instead of homogenous Cocowood tile.

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Perceptions of Civil Engineering Undergraduates on Using Learning Management System (LMS) and Zoom Platform for Online Design Studio Teaching

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Abstract— As the COVID-19 pandemic continues, 'online teaching and learning' became the only possible solution to continue the education programmes at universities. Though there are multiple solutions presented in the educational literature, many of the universities were not prepared to carry out complete online-based educational models in their degree programmes. Therefore, converting the teaching process; mainly studio base design teaching from physical to online was a whole new experience to most of the academia in developing countries. Further, it is a challenge to run these virtual teaching processes with limited technological resources for a long time. This study was conducted to investigate the perceptions of online based education using the Learning Management System (LMS) and Zoom platform for a studio base module. Thus, the methods were adopted to evaluate influencing factors of the online learning experience of the subject. Quantitative analysis was used where unstructured and structured questionnaires were conducted among students. Finally, the students' perceptions of online learning experience for a studio base module were presented.

Keywords: *online teaching/learning, Moodle, Learning Management Systems (LMS), Zoom, studio teaching, project-based learning, student perceptions, civil engineering curriculum*

I. INTRODUCTION

Studio teaching and project based learning are the traditional disciplines of teaching programs associated with architecture and design. Architectural design education highlights on achieving technical, technological, cultural and social aspects together with studio teaching (Afacan, 2016). It is emphasized on creative methods where it basically deal with the arrangement of physical form and space for fulfilling criteria related to the avenues of use, construction and aesthetics. Consecutive involvement of making, seeing, reflecting and forming habits via practice has been identified as the fundamental of designing process (Daalhuizen *et al.*, 2019). Therefore, these subjects are basically communicated through visual representations such as artefacts in the form of drawings, prototypes and scale models. Traditional artefacts included graphite and ink on paper, objects made of plaster, cardboard and wood which were tangible. However, with the arrival of computer-aided design (CAD), immaterial artefacts such as digital images, movies and models are been used (Steinø and Khalid, 2017). Therefore, these design subjects typically involves learning and working on "architectural space and form, using of appropriate materials and construction techniques and presenting of drawings and 3D models"(Afacan, 2016). Similarly, in architecture and design studies, predominant approach of instructing students is one on one studio supervision, where design ideas are shared by supervisors with students through individual or group discussions. Furthermore, academics or invited guest practitioners provide their opinions or comments to the students, by observing their work in progress which is technically known as 'Critique/ critic'. This is also another major path of traditional studio learning format in architectural design study (Ruangvanich, Nilsook and Wannapiroon, 2019).

As an alternative to education at traditional university model, online design education has emerged as a method of perusing education which provides flexible, high quality learning experiences to location independent audiences at

a relatively low-cost (Cavanaugh and Jacquemin, 2015). Similarly, experimental learning through online platforms has become an important pedagogical approach in higher education because of the integration of Learning Management Systems (LMS) and other web platforms such as Google, Zoom, Scopus, You tube and etc. It has been identified that online learning has enabled the interaction of students with online learning assets such as video and text references, unlike traveling physically and also it has allowed the communication among peers and instructors without physically being at the same location at the same time. Similarly, it has allowed the collaborative learning and evaluation by sharing work in progress across space and time. Therefore, these three aspects of online education has enabled to practice architectural design education in online platform (Steinø and Khalid, 2017). Moodle is one of the prominent platforms of learning management system adopted by many higher educational institutes in the world to fulfil the requirement of online education. It has centralized the academic information services, online contents and learning applications and simplified the management and administration of teaching and learning through e-learning (Cabero-almenara, Arancibia and Prete, 2019). One of the main advantages of using Moodle is its open source or having open source facility allowing the users to program their knowledge to modify and adapting the environment according to their own needs. Similarly, it assures the distant learning process by having reachable interface for students, academics and administrators which allow them to plan their learning and teaching processes and it enhances the ability of working together (Kerimbayev, Kultan and Abdykarimova, 2017). In the functional perspective, it has configured features which allow the formation of student assessment processes, and the management of their learning activities. Similarly, it has enabled the enriching of learning process by allowing to insert open source learning materials and also it has the features of providing automated adaptive educational assessments (Lopes, 2011). However, teaching of studio design subjects entirely through e-learning platforms have been limited and remained understudied. In design education, theory lectures are important to explain the underlying theories and methods. In terms of experiential learning, these lectures guide to abstract the concepts and generalizations of underlying theories. In the e-learning platform this can be applied in the form of an online lecture or recorded video of the lecture which typically includes background theory and a specific method the students were to use for the design exercise (Scagnoli, Choo and Tian, 2019). The presence of references or benchmarks of the designs of other students and the examples and feedbacks of a teacher are key features of design education in a studio environment. Providing a benchmark video through open sources in online platforms allow the students to compare their design work with qualified professional works of the same design exercises. Similarly, providing expert videos as supplementary reference materials via open sources allow students to gain advanced visions into the specific step they used and to identify methods they applied in that step. Furthermore, these references allow to trigger the reflection of the course content and the experiences of the experts in a wider sense (Daalhuizen and Schoormans, 2019).

This study was conducted to investigate the perceptions of students on online base education using Learning Management System (LMS) and Zoom platform for the 'Building Design Process and Applications' (BDPA) module which was conducted to year one undergraduates who are following bachelor of civil engineering degree in University of Moratuwa, Sri Lanka. The objectives of this module are mainly achieved through studio based teaching, project based learning and end semester exams. BDPA is a three (03) credit elective subject which covers 150 notional learning hours per semester (06 calendar months). Thus the lesson plans were prepared to achieve the four (04) learning outcomes (LO's) such as LO 1: Articulate an appreciation of the roles of different professions in the design team, LO 2: Apply building regulations to residential, commercial and public buildings, LO 3: Apply basic building planning concepts for activity spaces and means of circulation, LO 4: Produce building drawing using computer tools, for 14 weeks on LMS platform. Table 1 shows the particular delivering and assessment methods prepared for weekly lesson plans given under the subject.

Table 1: Particular delivering methods (DM) and assessment methods (AM) prepared for 14 weeks of lesson plans given under the subject.

Week	Topics covered in lesson plans of BDPA
W-01	Introduction Lecture
DM	Lecture notes, Open source video references, Zoom session for face to face discussion
AM	Forum discussion#01
W-02	Practicing Pictorial Drawing Types
DM	Lecture notes, Open source video references
AM	Assignment #01- Drawing of perspective, orthographic, isometric and oblique views
W-03	▪ What is "creativity" and why "creativity" is important? ▪ Architectural "concept" and space-making
DM	Lecture notes, Open source video references
AM	Forum discussion#02,Assignment #02 – Building review
W-04	▪ Pre-design services ▪ RIBA Plan of Work 2007 ▪ RIBA Plan of work 2013 ▪ Responsibilities as a matrix of design team members as accordance with the RIBA Plan of Work
DM	Lecture notes, Open source video references, Zoom session for face to face discussion
AM	Quiz, Assignment #03
W-05	▪ Introduction to planning and building regulations ▪ Importance of anthropometrics and ergonomics in building design
DM	Lecture notes, URL#01 – external references, Zoom session for face to face discussion
AM	Forum discussion#03, Assignment#04
W-06	Elements of a Building - Introductions of different types of foundations in buildings
DM	Lecture notes, URL#02 – external references
AM	Assignment#05- Group 01 – Zoom session for face to face discussion (Student presentations)
W-07	Elements of a Building - Introductions of different types of walls and floors in buildings
DM	Lecture notes, URL#03 – external references
AM	Assignment#05- Group 02 – Zoom session for face to face discussion (Student presentations)
W-08	Elements of a Building -Introductions of different types of Roof structures, Introductions of different types of doors and windows in buildings
DM	Lecture notes, URL#04 – external references
AM	Assignment#05- Group 03 – Zoom session for face to face discussion (Student presentations)
W-09	Elements of a Building - Steps, Stairs and Elevators/ Lifts, Building Services, Finishes of buildings
DM	Lecture notes, URL#05 – external references
AM	Assignment#05- Group 04 – Zoom session for face to face discussion (Student presentations)
W-10	Introductions of construction site management
DM	Lecture notes, URL#06 – external references
AM	Assignment#05- Group 05 – Zoom session for face to face discussion (Student presentations)
W-11	Green concepts and sustainable building design strategies
DM	Lecture notes, Open source video references, Zoom session for face to face discussion
AM	Forum discussion#04, Assignment#06
W-12	Developing a basic building plan –Stage-I
DM	Open source video references for manual and AUTOCAD/Revit lessons, Zoom session for face to face tutoring session
AM	Forum discussion#05, Scheme Design
W-13	Developing a basic building plan –Stage-II
DM	Zoom session for face to face tutoring session
AM	Forum discussion#06, Design Development
W-14	Developing a basic building plan –Stage-III
DM	Zoom session for face to face tutoring session, URL-external reference for arrange portfolio
AM	Forum discussion#07, Detail Design submission
****For all the continues assessment (Assignment 01,02,03,04,05 and 06) : 30% of total marks	
****End Semester Examination (Open book paper based exam) : 70% of total marks	

Source: Author

In order to conduct the evaluation of the learning activities, formative quizzes, automated assessments and peer and self-assessments can be incorporated with the Moodle LMS. Similarly, the grading for such assessments can be used as a strategy to motivate the participation of the students in online education. Online discussion forums is one of the pedagogical technique often used in e-learning platforms (Seethamraju, 2014). Student's abilities such as critical thinking, problem solving, and decision making, written communication skills, organizing and analysing information are often enhanced through forum discussions. Similarly, combining online forums with case studies have been widely adopted by the academics and this technique encourage students to relate theory to practice. Furthermore, these combined activities enable the independent learning and knowledge construction and enhancing critical thinking skills of the students (Wong *et al.*, 2015). In the other hand, peer reviewing is a common pedagogical approach which can be more significantly blended with online learning platforms as well as in design studies. Peer reviewing enables students to receive evaluations of their work by their peers. This allow students to discuss the steps taken in developing the design work, assess the ideas and insights, exploring the various paths of the same design and finally the quality of the individual work with true reviews (Ruangvanich, Nilsook and Wannapiroon, 2019). In order to identify the success of delivering design subjects through e-learning platforms, various evaluation techniques can be utilized. Course evaluation feedbacks, demographics of the LMS with the number of student enrolments and their consistency, work performance metrics, information posted by students on course forum discussions and by assessing the students' experience through pre and post course surveys are some of these techniques which can be used to emphasize the success of the delivering and learning processes (Berga et al., 2021).

II. METHODOLOGY

A comprehensive literature review was done, and an unstructured and structured preliminary questionnaire was designed to evaluate the perception of the students who followed the module for entire semester. An informal/ casual discussion was organized with the students and the students were tutored before setting the final questionnaire. Pre-validity testing was carried out with 10 respondents and the feedbacks was taken into further consideration. Data were collected by considering the students' demographic features, perceptions, preferences, drawbacks, and suggestions. The statements were presented on a five-point Likert scale (05 being strongly agreed and 01 being strongly disagreed). The data and the statements were categorized in to five (05) sections as follows;

Demographic features (Gender, Region, Status of the internet connection)

Perception of the online learning experience of the subject

Perception of the online learning experience in terms of the designing aspect

Perception of the online assignments and exams

Feedbacks for future development of the module

III. ANLYSIS AND DISCUSSION

A. Selected sample profile

Civil Engineering undergraduates were chosen as the sample for this study. "Building Design Process and Application" (BDPA) subject was offered them through the university Learning Management System (LMS) in their second semester of the first year. There were 131 students registered and 126 of them have submitted valid responses. SPSS (version 23) was used to analyse the collected data. The selected sample consisted of 96 male students and 30 female students. Figure 1 shows the demographic information according to the region.

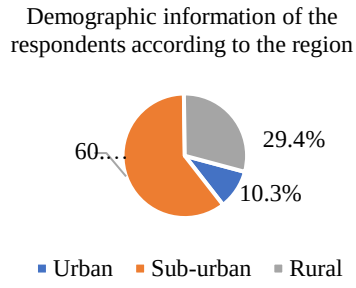

Figure 10: Demographic information of the respondents (N=127)
Source: Author

The majority of the sample were males (76.2%) and the percentage of the female respondents was 23.8% of the sample population. The students have connected to the online sessions from their homes because of the country was lockdown due to the COVID-19 pandemic. The majority of the respondent students were from sub-urban areas (60.3%). 29.4% of the respondents were connected from the rural areas and 10.3% of the respondents were living in the urban areas.

B. Reliability Test

Table 3: Reliability of the variables

Variable	Cronbach's alpha	Number of questions
Perception of the online learning experience of the subject	0.760	07
Perception of the online learning experience in terms of the designing aspect	0.714	06

The reliability test interprets the internal consistency and measured the properties of the scale (Hair et al., 2005). The reliability of the data set was measured by Cronbach's alpha, which is commonly applied in Likert scale-based surveys. Table 3 shows Cronbach's alpha values for each of the categorized variables separately.

The Cronbach's alpha value between ±0.41 and ±0.70 represents moderate reliability of the measuring scale and values greater than ±0.70 represent higher internal consistency (Sekaran and Bougie, 2009). As shown in Table 3, Cronbach's alpha value is 0.760 and 0.714 which interprets that the internal consistency of the collected data is good and can be used for further analysis. The question statements were ranked according to the mean rank derived by Friedman's test using SPSS software. The formula used for Friedman's testing is as follows:

$$\text{Mean Rank} = \frac{12}{n_r k(k+1)} \sum R_i^2 - 3n_r(k+1)$$

Here, n_r = number of rows; k = number of columns; R_i =Sum of the ranks.

This students' perception study has mainly depended on the given questionnaire. Insights can only be stated on the statements in which answers been recorded. This issue is overcome by using content analysis. Content analysis was done to analyze the conventional open-ended questions. Content analysis stands for a statistical generic name that analyzes a set of textual data that usually involves contrasting, comparing, and categorizing (Schwandt, 1997). The objective of performing a content analysis is to identify the students' perspective of online learning for building design and applications related subjects. Two authors were investigating the open-ended questions' responses. The categories and subcategories were created after testing the interrater reliability by using Kappa Co-efficient. The Kappa coefficient was estimated and resulted as 0.74 which interprets significant agreement between the investigators.

The questions were presented in a five-point Likert Scale which was ranging from 1: "Strongly Disagree" to 5: "Strongly Agree". "Strongly Agree":5 and "Agree":4 was combined to create one positive response which denotes "Agree". "Strongly Disagree":1 and "Disagree":2 clubbed to create one negative response which denotes "Disagree". "Neutral" was kept as it is.

C. Perception of the online learning experience of the subject

The variables of perception of the online learning experience (OLE) of the subject shown in the Table 4.

The analysis of the percentages of the perception of the online learning experience of the students is shown in Table 5. 69% of the students agreed that learning the subject online, provided the platform to access more Open Educational Resources (OER) that leads to high-quality education (OLE_3). 66% of the students agreed that active learning strategies such as group projects, discussions, case studies, debates are more advantageous during online lessons than in classroom sessions (OLE_1).

Table 4: Variables of the perception of online learning experience of the subject

Code	Variable
OLE_1	Active learning strategies are more advantageous in online learning
OLE_2	Learner-centered approach was encouraged than in traditional class room sessions
OLE_3	Provided the platform to access more Open Educational Resources (OER)
OLE_4	More convenient to participate in lessons online
OLE_5	Same subject guidance as in traditional class room sessions
OLE_6	Perfect alternative to education in the traditional university mode
OLE_7	Quality of the distance-education course is higher

Source: Author

Table 5: Percentages of perception of the online learning experience of the subject (N=126)

Code	SD % (1)	D% (2)	Total% 1+2	N% (3)	A % (4)	SA % (5)	Total% 4+5
OLE_1	0	6	6	29	60	6	66
OLE_2	0	2	2	39	59	0	59
OLE_3	0	2	2	29	61	8	69
OLE_4	0	2	2	42	48	7	55
OLE_5	0	6	6	37	56	1	57
OLE_6	0	4	4	37	53	6	59
OLE_7	0	11	11	40	46	3	49

Source: Author

59% of the students agreed that the learner-centered approach allows one to grab more knowledge than in traditional classroom lessons and learning the subject online is a perfect alternative to education in the traditional university model (OLE_2, OLE_6). 57% and 55% of the students agreed that the subject guidance given to them in the online lessons was the same as the classroom session and students feel more convenient to participate in lessons online than in traditional on-campus lessons because they are location independent and low cost accordingly. 49% of the students agreed that the quality of their distance-education courses in comparison with traditional classroom education is higher. Also, 30%-40% of students shown neutral perception on the variables which is a specific percentage. According to Friedman's testing, the average mean rank of the perception of the online learning experience of the subject is 4, which denotes "agree" in the Likert's scale (Table 6). According to the analysis, students had a better online learning experience of the "Building Design Process and Application" subject.

Table 6: Mean Rank Value of OLE according to the Friedman's testing

Code	OLE_1	OLE_2	OLE_3	OLE_4	OLE_5	OLE_6	OLE_7
Mean Rank	4.00	3.95	4.60	3.96	3.73	4.15	3.63

Source: Author

D. Perception of the online learning experience in terms of the designing aspect

The variables of perception of the online learning experience in terms of the designing aspect (DA) are shown in Table 7.

Table 7: Variables of the perception of the online learning experience in terms of the designing aspect

Code	Variable
DA_1	Allowed them to learn and perform different design activities
DA_2	Had more opportunity to reflect their own experiences through design
DA_3	Had the opportunity to experience all of the basic activities and the main phases of the design process
DA_4	Allowed to apply design theories in different areas
DA_5	Boosted the confidence and allowed for innovative activities towards designing
DA_6	Had more supervisory guidance for designing activities

Source: Author

Table 8: Percentage of the perception of the online learning experience in terms of the designing aspect (N=126)

Code	SD % (1)	D % (2)	Total% 1+2	N % (3)	A % (4)	SA % (5)	Total % 4+5
DA_1	0	86	86	13	2	0	2
DA_2	0	54	54	44	2	0	2
DA_3	0	60	60	38	2	0	2
DA_4	0	10	10	89	2	0	2
DA_5	0	64	64	34	2	0	2
DA_6	0	33	33	63	4	0	4

Source: Author

The analysis of the percentages of the perception of online learning experience in terms of the

designing aspect shown in Table 8. 86% of the students disagreed that the students are not limited to the tutor's ideas and it allows them to learn and perform different design activities (DA_1). 64% and 60% of the students disagreed with the statement that online learning boosts the confidence of the student (DA_5) and allows for innovative activities towards designing and the students have the opportunity to experience all of the basic activities along with the main phases of the design process (DA_3) accordingly. 54% of the students disagreed that the students had more opportunity to reflect their own experiences through design when doing the subject online (DA_2). 89% and 63% of students stayed neutral on the statements of the online subject allowed them to apply design theories in different areas rather than focusing on one specific problem (DA_4) and the students could take more supervisory guidance for designing activities during online lessons than in on-class sessions (DA_6).

Table 9: Mean Rank Value of DA according to the Friedman's testing

Code	DA_1	DA_2	DA_3	DA_4	DA_5	DA_6
Mean Rank	2.14	2.47	2.33	3.10	2.31	3.24

Source: Author

According to Friedman's testing, the mean rank of the perception of the online learning experience in terms of the designing aspect mostly denotes "disagree" in the Likert's scale. According to the analysis, students haven't had a better online learning experience in terms of the designing aspect of the "Building Design Process and Application" subject (Table 9).

E. Perception of the assignments and exams

The variables of perception of the assignments and exams (PA) are shown in Table 10.

Table 10: The variables of perception of the assignments and exams

Code	Variable
PA_1	Satisfied with the time taken to post back the grades and scores
PA_2	Activities and assignments increased the motivation towards the subject
PA_3	Evaluating the work-in-progress of the students has not been limited during the online learning period

Source: Author

Table 14: Percentages of the perception of the assignments exams

Code	SD % (1)	D% (2)	Total % 1+2	N% (3)	A% (4)	SA % (5)	Total % 4+5
PA_1	2	4	6	32	58	5	63
PA_2	4	11	15	8	66	11	77
PA_3	0	0	0	40	50	10	60

Source: Author

The analysis of the percentages of the perception of assignments and exams shown in Table 11. 66 % of students agree that the activities and assignments increased the motivation towards the subject. 58% and 50% of the students agree that they are satisfied with the time taken to post back the grades and scores of the student Assignment/exams and evaluating the work-in-progress of the students has not been limited during the online learning period accordingly. An average of 58% of students has shown positive perception about the assignments and exams given and an average of 7% of students shown negative perception about it. An average of 26.6% of students stays neutral of the perception on assignments.

F. Feedbacks for future development of the module.

One of the main issues the instructors faced during the online classes were responding to students' questions when they having technical difficulties such as audio echo, webcam or audio not working, zoom lags or freezes, zoom crashes, or unavoidable background noises. A rank answer question was designed to get feedback for finding the most convenient responding other medias (Table 12).

Table 15: Mode of most convenient media for response to the questions specially when students face a technical difficulty during face to face Zoom sessions (post-session responses)

		Rank_1	Rank_2	Rank_3	Rank_4
N	Valid	126	126	126	126
	Missing	0	0	0	0
Mode		3	1	2	4

Source: Author

Question: When having a technical difficulty with a component of your online course, how would you like your instructor to respond your question after the session?

1: Through e-mail

2: Through Moodle forum

3: Through social media chat room

4: Through phone call

A frequency analysis test has done to find the most convenient media. According to the analysis, the most preferable communication media when in a technical difficulty is through the social media chat room and the second most preferable media is sending an email. The least preferred communication method is through a phone call. The feedbacks were collected in terms of pacing the online course, how often should new content be available. According to the analysis, 67% of students prefer to receive the new content weekly and 26% of students prefer to receive the new content every two weeks. Only 2% of students preferred to receive the new learning materials more than once per week.

IV. CONCLUSION

This study identifies the perceptions of year one - BSc civil engineering undergatuate students who followed the design studio module, 'Buidling Design Process and Application' (BDPA) which was delivered through Moodle (LMS) and Zoom platform. Every year, 95%-100% of students per a batch are following this module though this an optional subject in curriculum. In 2020, the module was totally offered through online due to COVID-19 pandemic situation. Thus, the majority of the students were joined from urban and sub-urban areas (70.6%) and 29.4% of the respondents were connected from the rural areas. According to the analysed data, 59% of the students agreed that the learner-centered approach allows one to grab more knowledge than in traditional classroom lessons and learning the subject online is a perfect alternative to education in the traditional university model. Further, 51% of the students agreed that the quality of traditional active class room teaching is effective than online distance-education. However, 60%-65% of students not confident enough to handle online design projects because they lost the opportunity of experiencing basic physical design development activities. In addition, 66 % of students agree that the activities and assignments were given in online module was increased the motivation towards the subject. An average of 58% of students has shown positive perception about the assignments and exams given and 07% of students shown negative perception about it. According to overall student perceptions, coupling Moodle (LMS) with Zoom platform is efficient enough to deliver a subject module though it is not fully effective to handle design based assignments in a studio base module of a BSc civil engineering degree. However, a few positive aspects were identified such as students do more self-learning within the online delivering system than in a physical class room teaching. Most of the students are familiar with the virtual technologies/communications and most preferable communication media for answering their questions in post-sessions is through social media chat room or sending an email. Although the workload involved in setting up, monitoring and assessing the online learning materials, forum discussions and tutoring sessions are significant, it is possible to reduce the work load by preparing the weekly plan, because 67% of students prefer to receive the new content weekly. One senior lecture and four (04) assistant lectures were continually monitored online tutoring sessions and the forum discussions to solve the design related matters of students. The critiques were handled via face to face zoom sessions. That strategy was effectively captured by most of the students and it confirmed the human experience/input is an essential component for studio based teaching. Thus the study should improve to make effective connections between human interaction and online education platforms in studio teaching and project based learning in a civil engineering curriculum.

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Study on Development and Implementation of Safety Inspection Drones with Machine Learning Algorithms to Improve Construction Safety in Sri Lanka

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Abstract- Most of the construction sites in Sri Lanka work under unsafe conditions due to limited resources. Due to these unsafe conditions, human lives are in danger at times. The construction industry holds a major position in the development process of Sri Lanka, as it significantly contributes, not only for Gross Domestic Product but also for Gross National Product. Unfortunately, the Health and Safety factors have become a secondary concern though the construction industry holds a major portion in the economy of the country. The traditional inspection methods currently practised in the industry seem to be outdated, time-consuming, less efficient, less effective, and increase the workload of safety officers. It is impossible to perform observations in multiple locations at the same time by a single safety officer because some locations in the sites are hard to reach, and there may be blind spots too. This study proposes an automated safety inspection method to increase the safety levels of construction sites. For this, the study reveals a comprehensive experimental discussion on how to blend image processing techniques with unmanned aerial vehicles. Image processing is the technical analysis of images by using complex algorithms, and in this scenario, unmanned aerial vehicles (drones/quadcopters) act as a flexible image providing source that can fly over the construction sites by providing real-time videos for the algorithm to analyse for safety hazards. The study was concluded by achieving two objectives, developing an algorithm with YOLO v3 architecture to detect safety hazards through drones, and measuring the accuracy and reliability of the automated detections.

Keywords: *construction safety, Image processing, unmanned aerial vehicles*

I. INTRODUCTION

In Sri Lanka most of worksites are in under unsafe conditions, due this behaviour many pay from their lives every year. According to Department of labour Sri Lanka, annually 500,000-man days are wasted because of occupational health issues (Dissanayake, 2016). Moreover, Sri Lankan orthopaedic service of national hospital have records of 102,321 accidents treated in 2015. Among them 12% has been reported due to occupational health hazards. Within 12% of accidents, 50% fatalities are recorded from construction industry and most of them are preventable (Darshana, 2017). The construction industry owns a major role in development of Sri Lanka, it significantly appears not only in gross domestic product (GDP) but also in gross national product (GNP) of the Sri Lankan economy. The industry contributed 6.6% in 2009 overall GDP and 9% in 2019. Therefore, it contributes a considerable impact to the economy of Sri Lanka. While it is representing that much for the economy, one of essential factor, the health and safety has become the secondary concern in the industry. Managing a successful project means not only performing the construction operations within given time inside the budget but also considering the safety on site (Belel and Mahmud, 2012).

In Sri Lanka qualified safety officer will be employed for maintaining the occupational safety and health (OSH) performance in the site, but a study found that only 42% of construction sites are only able to employ a suitable safety officer to maintain the regulation inside the site. And the study also shows some barriers as high expenses and lack of qualified safety officers in the local industry (De Silva and Wimalaratne, 2012). Currently most of construction sites in Sri Lanka are still using traditional manual inspection methods. A study by Toole (2002) identified eight factors that result construction accidents. Absence of personal protective equipment (PPE), lack of proper training, lack of enforcement of

safety, unsafe procedures, unsafe site conditions, poor attitude toward safety, lack of safety equipment and sudden deviation from prescribed behaviour. One of keyword used in his study to overcome above factors was "Observation", the safety officer has duty to frequently observe employees, compare actual methods and sequencing and current actual site condition (Toole, 2002).

We can define this task of observation as one of the main duties to frequently walk around the site and getting real time data on the ground through direct interactions and direct observations. The data gathered on observation are used as safety officer's decision-making process (Jalaei and Jrade, 2014).

These traditional methods are time consuming; it is sometimes impossible to make observations in multiple locations within the site at the same time and some locations are hard to reach. And there may be blind spots. As considering these facts, it is suitable to get assistance from other sources to increase the efficiency.

When it comes to assisting to the safety officers, we can utilize new technology to the construction grounds, drones are a very good flexible and cost-efficient option (Irizarry et al., 2012). Moreover, this study focusses on to implement safety inspection drones which are using machine learning algorithm to identify most common safety issues and provide assist when inspections going on. This will provide the construction safety managers to increase their quality of their duties reducing the workload within the site and the productivity will be improved by saving the time.

Machine Learning can be defined as a process of building computer systems that automatically improve with experience and implement a learning process (Zhang, 2012). This machine learning can learn theories automatically from data, through a process of model fitting, inference or learning from examples (Zhang, 2012). It has special reason to choose drones to use this developed algorithm, because instead of using closed-circuit television (CCTV) systems, drones are superior endurance, intelligence and flexible to fly over every aspect of the construction site and have ability to provide real time video feed to the decision making sever that running the algorithm.

The study includes a case study performed in a high-rise building construction site in Colombo 08, Sri Lanka. The following objectives were achieved during this case study.

(1) Develop a suitable algorithm to provide an artificial analysing capability to the program for an automated safety inspection process.

(2) Perform an experimental analysis consisted of using the drone as a tool to inspect real time videos from a typical worksite and measure the accuracy of hazard detections.

The study presents the abilities of the drone, what are the issues arisen when performing inspections. While these new technologies take the construction to new level, there are some flaws that attention needs to be given.

In near future, drones will take over the more complex tasks in massive construction projects. Contractors who rely on drones will get more benefits and involve in more ambitious projects and finish work on proper time in Sri Lanka with minimized construction hazards.

II. LITERATURE REVIEW

Construction safety on project site should pay significance high priority due to the hazardous nature of the construction industry. Construction industry is one of unpredictable industries that cause more deaths and injuries on worksites, construction industry is known as a hazardous industry that many components that are possibly risky to labours (Osei-Kyei *et al.*, 2019).

Safety has a secondary concern in a market driven society where the main objective is to obtain quality within minimum time and cost. This trend can be identified in most developing countries. Comparing to developed countries, Sri Lanka has less output of construction rather than developing countries but the magnitude of the accident rate is still large as reported in other developed countries such as United Nations of America (National Safety Council, 1997, cited in Chau et al., 2004; Bureau of Labour Statistics, 2008a, b), the United Kingdom (Health and Safety Executive, 2010; Bureau of Labour Statistics, 2008a, b; Sacks et al., 2009) and Singapore (Kartam and Bouz, 1998, cited in Chau and Goh, 2004; (De Silva and Wimalaratne, 2012).
Zhou, Goh and Li (2015) identified six research areas that should pay more attention to conduct in order to improve the safety on sites as follows,

(1) Lack of unsafe behaviour monitoring. Most of studies show that the priorities should pay to fatalities/ injuries occur from workers' unsafe behaviour (Choudhry and Fang, 2008).

(2) Lack of utilizing safety climate to improve construction safety. Safety climate and its relationship with safety performance has been

revealed in construction safety research (Siu et al., 2004; Mohamed et al., 2009).

(3) Ignorance of quantitative relationship study between project/company scale and safety of construction. Some of researchers have done research studies about construction safety in the perspective of scale of the project or the company. The results show that accident rates in small projects is higher than large scale projects (Jeong, 1998; Kheni et al., 2010).

(4) Lack of research studies about task level, as mentioned in 3rd point, more than 90% of research articles aimed on project or company level, task level studies are very rare, but tasks provide to build basic components of a specific project.

(5) Immoderate priority on building projects and lack of studies carried out for non-building projects, such as road projects, bridge, canal etc.

(6) Lack of usage of innovative technology in construction sites to overcome problem encountered and minimize the workload from safety officers (Zhipeng et al., 2013).

All above facts are relative to Sri Lankan construction industry. This study is based on the first and sixth factor that mentioned above as "Lack of unsafe behaviour monitoring" and "lack of innovation technology applications in construction sites".

Due to the massive development of drone technology and real-time monitoring technologies, they are capable in assisting construction industry professionals to implement in house mass civil infrastructures capturing real-time images and videos and the most valuable benefit is the reachability of wide area of a site (Dastgheibifard and Asnafi, 2018).

One of study carried out by (Yong and Yeong, 2018) used a drone to human object detection with deep learning and deployed to forest surveillance purposes. This allowed to detecting existence of humans in forestry environment by saving time and cost. And the image detection results were categorized into three items as True Positive, False Positive, False Negative and tested them using F-score method. Hung (2020) performed another study using same F-score method, in his study he used Faster R-CNN deep learning module to detect pedestrian and searching for missing persons and illegal immigrants. In his results shows Faster R-CNN deep learning module was able to achieve acceptable decisions with 98% F1 measure.

III. METHODOLOGY

A comprehensive experimental case study was performed based on a high-rise building in Colombo. In this construction site, able to perform the sample tests to examine the hazard detection accuracy of the drone.

Also, in this scenario the accuracy of the drone was tested using F-score method. The F-score generally using in evaluation of information retrieval systems, machine learning models. The result is a value between, 0.0 for no F score and 1.0 for full or perfect F score.

The F-score also known as F1 score is a method of measuring model's accuracy on a specific dataset of an algorithm. This method is ideal for classifying data into "negative" or "positive". This method is ideal to evaluate binary classifications. F score or F1 score consists of "Precision" and "Recall". And the harmonic mean of the algorithm is defined by the F score or F1 score (Goutte and Gaussier, 2005) (F-Score Definition | DeepAI, 2020).

In machine learning, pattern recognition and information retrieval, Precision (Also known as Positive Predictive Value) is the fraction of true positive cases among the combination of true positive and negative cases. Recall (also known as sensitivity) this is the fraction of True positive among the combination of true positive and false negative (Sokolova, Japkowicz and Szpakowicz, 2006).

Following confusion matrix shows the relation between the positive and negative identified data using algorithm.

		Predicted	
		Negative	**Positive**
Actual	**Negative**	True Negative	False Positive
	Positive	False Negative	True Positive

Figure 1: Confusion matrix

A. Precision

Precision factor reveals the relevant result percentage among all positive predictions. The fraction of true positive predictions and the combination of true positive and the false positive is the precision value.

$$\text{Precision} = \frac{True\ positive}{True\ positive + False\ positive}$$

Equation 1: Precision equation

Where:
True positive = Number of true positive predictions categorised by the model.

False positive = Number of false positive predictions categorised by the model.

B. Recall

Recall factor reveals the percentage of all relevant predictions correctly categorised by the algorithm. Recall is also known as sensitivity. The fraction of true positive by the combination value of true positive and false negative is the recall value.

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negetive}$$

Equation 1: Recall equation

Where:

True positive = Number of true positive predictions categorised by the model.

False negative = Number of false negative predictions categorised by the model.

C. F score/ F1 Score; (Sokolova, Japkowicz and Szpakowicz, 2006)

$$\text{F-score} = 2 \times \frac{Precision\ x\ Recall}{Precision + Recall}$$

Equation 2: F-score equation

IV. ANALYSIS AND DISCUSSION

The research concludes the data analysis done from the experimental case study and the assessment of the suitability of the algorithm in real world. The two objectives which are defined in the introduction were critically analysed on this chapter.

A. Experimental Case Study

Figure 2: Assessment area, 6.9104069,79.8837379
Source: <https://earthexplorer.usgs.gov/>

The core of this study is to design a suitable algorithm that can self-identify health and safety hazards by flying over construction job sites. For this scenario, a case study was carried out within a randomly selected high-rise building in Borella, Colombo area. The building was in structural stage at 11th floor when the study was initiated. The perimeter and the area of the enclosure is shown here,

B. Objective 01: Algorithm development

Machine learning inside the Computer Vision is a pair breakthrough that continues to energize the curiosity of start-up entrepreneurs, computer scientists and engineers for decades. It aims various application platforms to solve advance life problems basing algorithm from the human biological vision (Fullscale.io, 2019).

Both machine learning and computer vision anticipate bringing the human capabilities of sensing of data, understanding and processing data and take necessary actions based on previous and contemporary results into computers (Khan and Al-Habsi, 2020).

Solutions establishing from machine learning revolve around data obtaining, training the data set and make predictions using trained dataset (trained model) (Khan and Al-Habsi, 2020).

Development stage: In this case, the algorithm was developed and checked its capabilities according to following steps (an open-source python code was aided on following process under GNU General Public Licence v3.0),

1. Gathering data
2. Converting to YOLO V3 format
3. Setting Training Pipeline
4. Training model
5. Exporting weights file
6. Checking algorithm competences

1. Gathering data

Data gathering done through OpenImageV5 application, this was initially launched in 2016. It has high volume of image pool, about nine million images annotate with their labels which comprising of real-world object groupings.

On this study perimeters, 3 types of objects were downloaded (smoke, fire, PPE).

2. Converting to YOLO v3 format

"oid_to_pascal_voc_xml.py" was initiated for convert images into XML file format. After that "OIDv4_toolkit" used to perform conversion between XML files to YOLO v3 format.

3. Setting Training Pipeline

This stage's main purpose was to define the classes.

4. Training model

Training the data set (model) is the main step in an algorithm. Below were the computer specifications which were the model was trained.

Table 6: System specifications

GPU	NVIDIA GeForce GTX 1650 (4GB)
GPU Overclocking	N/A
CPU	Intel Core i5-9300H 2.4GHz
CPU Undervolted	N/A
Cooling	Stock Cooling (Nitro Sense Coolboost™ at max fan speed)
RAM	16GB DDR4
OS	Ubuntu 18.04

Data model testing stage: To understand the neural network accuracy, training epoch vs accuracy curve is an ideal method.

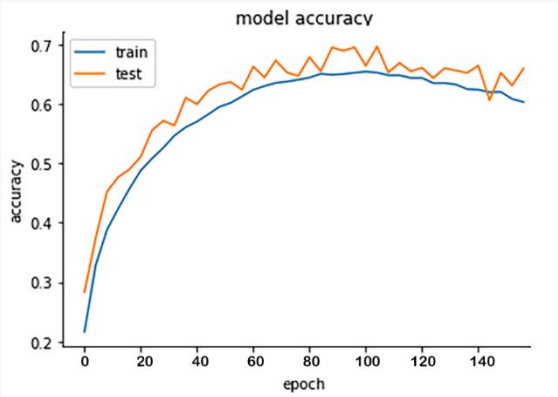

Figure 3: Accuracy vs epoch graph

This model consumed nearly 7 hours to train four objects with 100 epochs. (100 cycles through the full training datasets.)

5. Transferring the trained weights file to darknet format

After training of the specific model, final weight file needed to be converted to "darknet" format to test run.

6. Checking algorithm competences

Testing objects includes smoke, fire, and personal protective equipment presence. All below tests are executed after the special permission granted by the Assistant Operational Engineer of the site and collaboration with the Safety Officer on site.

Python code: The complete programming work has been uploaded to google drive, since it is open source, anyone has permission to modify it under GNU General Public License v3.0.

Use QR code to see above content.

Inside lab testing stage: The training has completed 100 epochs and gained a decent result as figure 3 for the internal testing purpose, the training model were examined with photos that took from construction personnel in the site, below are the results showing that the algorithm detects hardhats with higher rates of over 80% of accuracy.

Figure 4: Hard- hat detection accuracy

C. Objective 02: Accuracy of hazard detection

(1) Smoke detection accuracy test: To validate the smoke detection capabilities of the algorithm, the drone was tested on the site with artificially controlled smoke on 14th slab of the building, while performing these, precautions were taken to prevent any other damage can occur to construction personnel or equipment. The selected area has approximately 200 m^2. The drone flew 0.4 m/s on a straight line holding 10 m of latitude from the 14th floor of the building and above the tower crane, parallel to the routine straight lines covering the waypoints that planned before the flight. And 10 tests were carried out with maximum of six smoke points and minimum of zero. The test is as follows,

The control test: Manual count of the artificially made smoke points. (Accuracy 100%)
The experimental test: Count taken from the drone on smoke points.

Table 2: Smoke test- Drone counts vs. manual counts.

	Drone data	Manual data=actual data	True positive	False positive	False negative
Take 1	0	0	0	0	0
Take 2	3	3	3	0	0
Take 3	3	4	3	0	1
Take 4	6	6	6	0	0
Take 5	6	5	5	1	0
Take 6	2	3	2	0	1
Take 7	4	4	4	0	0
Take 8	5	4	4	1	0
Take 9	6	6	6	0	0
Take 10	4	5	5	0	1
	39	40	38	2	2

True positive =38
False positive =2
False negative =3

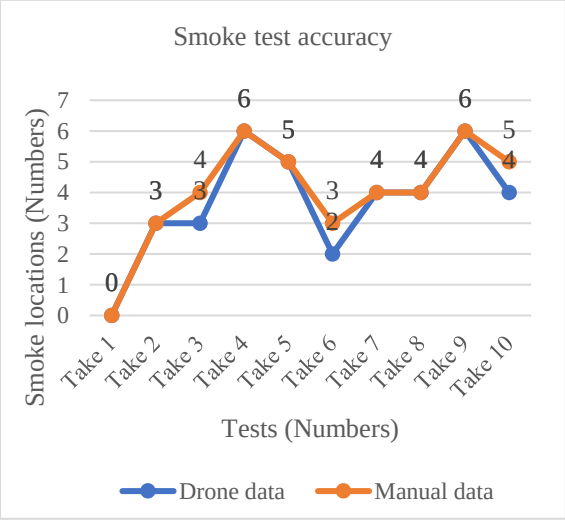

Figure 5: Smoke test accuracy test results

Using F score; (Rahman and Devanbu, 2013)

$$\text{Precision} = \frac{True\ positive}{True\ positive+False\ positive} = \frac{38}{38+2} = 0.95$$

Equation 4: Precision equation

$$\text{Recall} = \frac{True\ Positive}{True\ Positive+False\ Negetive} = \frac{38}{38+3} = 0.92$$

Equation 5: Recall equation

$$\text{F-score} = 2 \times \frac{Precision\ x\ Recall}{Precision+Recall} = 2 \times \frac{0.95x0.92}{0.95+0.92} = 2 \times \frac{0.87}{1.87}$$

$$= \underline{0.93}$$

Equation 6: F-score equation

(2) Fire detection accuracy test: To demonstrate the Fire detection capabilities, the drone had to be tested with artificially controlled fire on safe parts of the construction site. The selected area has approximately 200 m^2. The drone flew 0.4 m/s on a straight line holding 10 m of latitude from the 14th floor of the building, parallel to the routine straight lines covering the waypoints. And 10 tests were carried out with maximum of six fire points and minimum of zero. The test as follows,

The control test: Manual count of the artificially made fire points. (Accuracy 100%)
The experimental test: Count taken from the drone on fire points.

Table 3: Fire test- Drone counts vs. manual counts

True positive =37
False positive =1
False negative =3

	Drone data	Manual data=actual data	True positive	False positive	False negative
Take 1	0	0	0	0	0
Take 2	4	4	4	0	0
Take 3	3	3	3	0	0
Take 4	5	6	5	0	1
Take 5	3	5	3	0	2
Take 6	4	4	4	0	0
Take 7	4	3	3	1	0
Take 8	4	4	4	0	0
Take 9	6	6	6	0	0
Take 10	5	5	5	0	0
	38	40	37	1	3

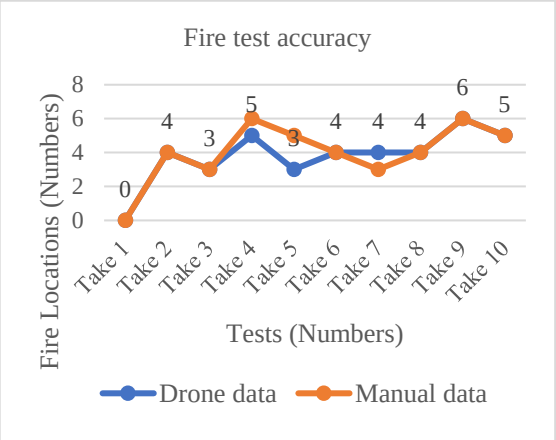

Figure 6: Fire test accuracy test results

Using F score; (Rahman and Devanbu, 2013)

$$\text{Precision} = \frac{True\ positive}{True\ positive + False\ positive} = \frac{37}{37+1} = 0.97$$

Equation 7: Precision equation

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negetive} = \frac{37}{37+3} = 0.92$$

Equation 8: Recall equation

$$\text{F-score} = 2 \times \frac{Precision\ x\ Recall}{Precision + Recall} = 2 \times \frac{0.97x0.92}{0.97+0.92} = 2 \times \frac{0.89}{1.89}$$

$$= \underline{0.94}$$

Equation 9: F-score equation

(3) PPE detection accuracy test: In this case hard hat detection accuracy was measured as for the PPE presence criteria. To test PPE presence capabilities, the drone was deployed on the construction site to detect PPE equipped construction personnel and alert on construction personnel who are not wearing hard hats.
For this scenario ten people were tested, two people from each colour as white, green, blue, yellow, red hard hats were deployed on the site in random places for ten times. The selected area was approximately 200 m^2.

The drone flew 0.4 m/s on a straight line holding 10 m of latitude from the 14th floor of the building, parallel to the routine straight lines covering the waypoints. The maximum count of hard hat is ten and the minimum count is zero.

The control test: Manual count of the labourers with hard hats. (Accuracy 100%)

The experimental test: Labourer count taken from the drone.

Table 4: PPE test- Drone counts vs. manual counts

	Drone data	Manual data=actual data	True positive	False positive	False negative
Take 1	0	0	0	0	0
Take 2	9	10	9	0	1
Take 3	6	9	6	0	3
Take 4	7	8	7	0	1
Take 5	10	10	10	0	0
Take 6	10	9	9	1	0
Take 7	10	9	9	1	0
Take 8	5	7	5	0	2
Take 9	8	8	8	0	0
Take 10	5	5	5	0	0
	70	75	68	2	7

True positive =68
False negative =7
False positive =2

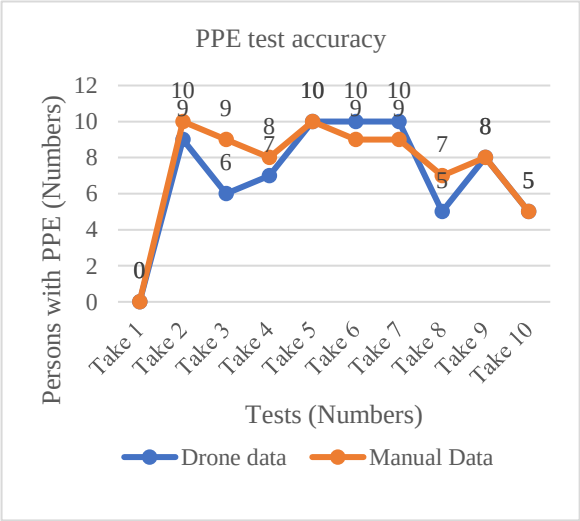

Figure 7:11 PPE test accuracy test results

Using F score; (Rahman and Devanbu, 2013)

$$\text{Precision} = \frac{True\ positive}{True\ positive + False\ positive} = \frac{68}{68+2} = 0.97$$

Equation 10: Precision equation

$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negetive} = \frac{68}{68+7} = 0.90$$

Equation 11: Recall equation

$$\text{F-score} = 2 \times \frac{Precision\ x\ Recall}{Precision + Recall} = 2 \times \frac{0.97x0.90}{0.97+0.90} = 2 \times \frac{0.89}{1.89}$$

$$= \underline{0.94}$$

Equation 12: F-score equation

(4) Overall Accuracy of hazard identification

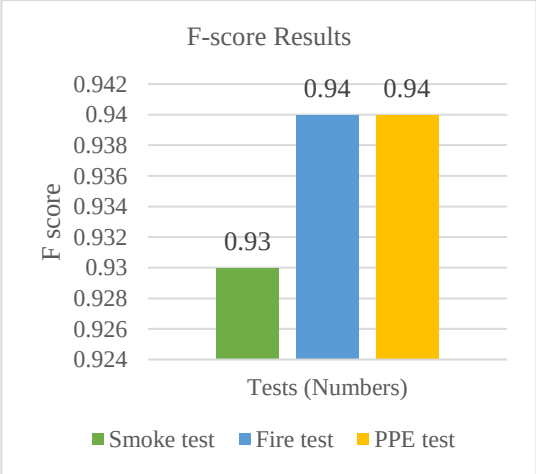

Figure 8:12 Overall accuracy of detection tests

Overall accuracy $= \frac{(0.93 + 0.94 + 0.94)}{3} \times 100\%$

$= 0.94 \times 100\%$

$= \underline{94\%}$

Overall accuracy of above three tests is higher than 90%, close to the best possible value of "1". A good data model produces high precision and high recall stated by Rahman and Devanbu (2013) and higher F-score (Sokolova, Japkowicz and Szpakowicz, 2006), the better predictive power given by the algorithm for the classification procedure. This automated system detected most of the site safety hazards including Smoke, Fire and PPE absence of labourers. Implementing this method will not be a wastage to a construction site, above real-world data are proving the capabilities of this automated safety drone is ideal to deploy to aid on safety inspections.

V.CONCLUSION

The main aim of the research is to show how to develop an algorithm to implement safety inspection drones in Sri Lankan construction sites.

A. Objective one

Develop a suitable algorithm to provide an artificial analysing capability to the program for an automated safety inspection process.

For the beginning, to make the foundation for this automated system, a suitable algorithm was developed. For this instance, YOLO v3 architecture was used and examined the accuracy of the data model and gain over 70% of accuracy **(**Redmon and Farhadi, 2018). After that, in lab test for image detection was performed prior to employing the drone in real world, in this test all the images were detected with over 80% of accuracy by achieving the first objective. The algorithm is only capable to detect smoke, fire, and PPE according to this study, it can be developed for detecting more safety related hazards by developing the code.

B. Objective two

To do an experimental analysis consisted of using the drone as a tool to inspect real time videos from a typical worksite and measure the accuracy of hazard detections.

Next step was employing the drone in real world scenario, for this instance a high-rise construction building in Colombo, Sri Lanka was selected to do an experiment by implementing the drone to assist the Safety Officers. In this assessment, three tests were performed to measure the accuracy of the drone's hazard identification capabilities. All three accuracy testes were scored above 90% of accuracy by proving that this automated inspection drone has a high accuracy of hazard detection and reliability to deal with real world situations while fulfilling the second objective of the study. All three tests were carried out under clear weather day. But to check drone's detections in the low light conditions, it is ideal to perform tests under low light weather conditions too.

C. Limitations and Further Directions of Research

This study was limited to automated inspection in above ground constructions, and only demonstrated with buildings which are high rise. For road constructions, the same waypoint method discussed in fourth chapter, can be utilized. But below ground constructions were not studied in this research. And this version of algorithm only capable to detect smoke, fire, and PPE, this can be developed to detect more safety related factors. Furthermore, other countries use drones for 3D underground infrastructure monitoring, underground mine explorations and 3D mapping, gas detection and underground atmosphere monitoring etc (Casos, 2018).
Moreover, there are some areas which can be addressed and developed.

- Develop the current algorithm to measure the construction personnel body temperature, this will be beneficial in pandemic situations such as Covid-19.

- Develop the current algorithm to measure sound level to keep the

construction site at acceptable sound pollution level.

- Develop the current algorithm to detect unusual behaviours of the constructional personnel such as disputes, suicidal behaviours, drugs usage.
- Perform a study to implement safety inspection drone for underground constructions.
- Integrate algorithm with CCTV system for inside inspections in building projects.

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ABBREVIATIONS

CPU	Central processing unit
GDP	Gross domestic product
GNP	Gross national product
GPS	Global positioning system
GPU	Graphical processing unit
GTX	Giga texel shader eXtreme
PPE	Personal protective equipment
RAM	Random access memory
UAV	Unmanned aerial vehicle
YOLO	You Only Look Once

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An Analysis of Professional Participation of Registered Licensed Surveyors in Land Partition

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Abstract- Statistics of land ownership in Sri Lanka shows that approximately 82% of land in the country is under state control while only 17.7% is privately owned, and as a tool of administration and management of private lands, Partition Act (Amended) No:17 of 1997) has been enacted especially for clearing co-ownership disputes through litigation. Out of longer-term pending cases in the court, the main cases are partition cases followed by other land disputes. This situation urges the requirement of emphasizing 'private land administration and management as they are having "doing business" potential, due to clear title and less intervention by public sector decision-makers relative to public lands. This study aims to examine the professional involvement of Registered Land Surveyors (RLS) in partition cases as Court Commissioners and its relationship with laws delays in land litigation. Two provinces; 'Sabaragamuwa' and 'Southern', were selected purposively for the study, and statistics of RLS were analyzed. A simple Random sample of RLS s was drawn from Kegalle District in the Sabaragamuwa Province. Answers were obtained for a structured questionnaire. The study reveals that a large number of private lands which have development potentials remains stuck in the adjudication process of partition due to the lack of Court Commissioners which in turn leads to prolonged litigations. It was also revealed that 50% of the RLSs are reluctant to join this volunteer position due to drawbacks in the Partition Act. More than 70% of the RLS who are engaged with partition surveys are over 70 years of age and joining of new RLS with the courts for the last ten years is below 1 %. It is anticipated that if the situation continues and if appropriate remedial measures are not taken by the authorities and professional institutes, partition litigations would adversely affect the private sector land administration and management.

Keywords: *partition, appraisal for owelty, court commissioner, Registered Licensed Surveyor (RLS)*

I. INTRODUCTION

It is revealed that the number of litigated co-ownership disputes over private lands under the Partition (Amendment) Act no. 17 of 1997 are being increased (Progress Report, 2018, Ministry of Justice, World Bank Report, 2012). There are 215,855 cases in District Courts, 6261 cases in civil appeal courts and 4051 cases in Court of Appeal. 8% accounts for land, and partition cases (World Bank Report, 2012). 45% of the Partition cases are more than five years of time pending and 54% of the cases in such courts that are more than 10 years pending. (Progress Report, 2018, Ministry of Justice).

15% of the total lands are considered private lands out of which 1% accounts for 'urban lands' with 'doing business' potentials (World Bank). As 80 % of 'urban lands' are private lands, situation highlights the requirement of emphasizing on administration of private lands by 'Partition', especially for clearing ownership disputes through litigation which is being neglected.

According to the ownership statistics, 85% of the total lands in Sri Lanka are under the control of public sector institutes under any kind of law or administration and those laws have a long history. The administration and management of public lands in Sri Lanka is governed by more than 39 operational laws (Mapa, R.B., et al, 2002). As the land related functions institutionally fragmented, and geographically deviated, existing legislative framework is complex, inconsistent and fails to address the current and future needs of society and to enhance the investment climate in Sri Lanka (World Bank).

Overall accessibility to the land is one of the eight factors that defines 'rank of potential of doing business' in a country (Doing business, 2020). It takes 129 to 144 weeks for finalizing acquisition proceedings of a public land (Land manual, Acquisition guidelines, Page 340). The Efforts on administration of private lands are fewer than public lands as they are not under the public sector hence decision makers do not need to have documents like land permits or annual permit, land grants, long term leases, or processes of vesting or acquisitions.

Private sector land partitions and subdivisions are mainly being accomplished by the Registered Licensed Surveyors (RLS) as Freelance Practitioners (other than 'Bimsawiya' declared areas) complying with the regulations and recommendations stipulated by Sri Lanka Land Survey Council (SLLSC). RLS are the commissioners usually appointed to the 'Partition', 'appraisal of shares to Owelty' and recommend to 'Partition in Kind or Sell' (Partition (Amendment) Act no. 17 of 1997).

II. BACKGROUND OF THE STUDY

In 1909, Crown Landmark Ordinance No:7 of 1909 was introduced for further improvements of boundaries separating public lands with private lands clearly. (Perera, N.S, 1958). As the British has established deed registration in Sri Lanka in 1863, most of the private land registrations were being carried out under 'deed registration system' which is one of the three registration methods still in use in Sri Lanka (Lars-Jonas Kaddik & Jona Rydberg, 2013, Divithure, H, 2008). It designates the document to transacted land with no spatial data leading to unclear location, unclear boundaries, and time-consuming ownership investigation during the transaction, mortgage, or subdivision (Lars-Jonas Kaddik & Jona Rydberg, 2013). The influence of real estates with an unclear legal status on lands is repeatedly indicated. Such a property, among others, extends the time necessary to prepare land for investment projects (Buśko & Przewięźlikowska, 2016). Most of such private lands were being transferred through generations by 'deed registration system' leaving co-ownerships. It is necessary to establish institutional frameworks minimizing complications due to co-ownerships by national, cultural, political and judicial settings (Enemark, S et al, 2005).

III. PROBLEM STATEMENT

Number of partition cases over coownership disputes on private lands is being increased. Partition cases are the longest running cases in courts followed by land cases. The contribution to the administration and management of private lands in terms of 'Partition Act' by 'Professional involvement of RLS' has not been studied so far.

IV. LITERATURE REVIEW

For the court ordered surveys, there are two identified types of disputes namely 'L' type and "P" type (DSR 2018, Partition Act no. 17 of 1997). Matters due to uncertainty between true boundary lines as defined by deeds or other instruments and the line actually established by occupation and the erection of buildings, fences, and other structures are under 'L' or 'land' (Joseph P. L, 1916).

"P" cases are formed due to co-ownership of subjective objects. "Partitioning refers to the situation where land is with co-ownership (whether as joint tenants or tenants in common) is transferred to one or more of the co-owners of the land. (Schurgott, K. et al, 2005). The legal meaning of the terms 'partition' and 'subdivision' are not same. The term 'partition' is used to describe both the action and the remedy available to any 'co-tenant' who wishes to dissolve a co-tenancy relationship (Giulietti V.G, 2021).

The Partition Act empowers the court to order a sale of the entire property instead of partition, and to divide the proceeds of sale among the co-owners in accordance with their shares in the property (Conway, H., 1997 Pepler, W.R., 1976). It is sometimes described as a 'forced sale' (Paul, P, 2005). Under the common law in Sri Lanka, any owner of property who owns an undivided concurrent interest in land can seek such a division. In some cases, the parties agree to a specific division of the land and if they are unable to do so, the court will determine an appropriate division (Partition Act No. 17 of 1997).

A subdivision is an interim step involved under partition where an identified plot of land divided into several plots. A track of land segregated from

large track in technically subdivision (Chang, Yun-Chien, and Fennell, Lee Anne, 2014). There is a 'statutory gap' in between 'partition' and 'subdivision' that should be bridged by appropriate enactment. Since the concept of partition is heavily involved with legal, social, and economic matters; ethical and moral, most of the countries used different tacit knowledge. There are discussions among academics that courts could have taken judicial notice of the Planning Act to avoid public policy denied partition to minimize the dichotomy (Chang, Yun-Chien, and Fennell, Lee Anne, 2014).

Voluntary and compulsory partition

If all the co-owners agree to the terms of the partition and none of the co-owners is a minor or an interdict or no sever property interests, the partition may be voluntary (Gates, A.L., 1982-1983). In some states of United States (US) additional rules are added depending on industries like oil drilling for voluntary subdivisions (Block, G., 1961-1962). If cotenants know each other's portions, they may reach an amicable partition (Chang, Yun-Chien, and Fennell, Lee Anne, 2014).

In some states of US, independent 'arbitrators' or 'appraisers' are involved when co-owners of a property are unable to come to an agreement on the value of the property and their rightful shares to divide the property and to allot the shares (Mitchell, Thomas W, 2001).

A tenant in common or tenants as a team has the absolute right to seek a 'compulsory partition' unless there are exceptional circumstances. If a single owner objects to right, share and/or value, interest or improvements, partition must be made (Act No: 17 of 1997, https://legal-dictionary.thefreedictionar y.com /partition). Both real (buildings, soil and plantations) and personal property (movable property) can be subjected to compulsory partition (Act No: 17 of 1997).

Partition in kind and partition by sell

The 'Partition in Kind' is provided by Act considering lifelong interests, equity, and fairness (Gates, A.L.,1982-1983, Block, G.,1961-1962, Giulietti V.G, 2004). Partition on kind is an egalitarian method and do not sever personal sentiments, does not compel person to sell land, and displace families or family members from their land (Gillian K. B., 2004, Peiris, G.L, 2013).

The 'Partition by Sale' are concerned in two occasions. First, a 'Partition by Sale' takes place if it is impossible to divide the property physically among the co-owners. The second occasion is when a 'Partition by Sale' can also take place when a 'Partition in Kind' could not be made without substantial injury to any of the interested co-owners. (Peiris, G.L, 2013).

Sales are also voluntary, forced, public or private. For instance, private sales necessarily auction sales sometimes are voluntary (Bouvier, J.,1856, Conway, H.,1997). A forced sale or judicial sale is one made without the consent of the owner of the property by some officer appointed by law (Bouvier, J., 1856).

Appraisal value of shares and their improvements

A valuation is not the same as a survey as there are difficulties in identifying the basis for valuation (Cooper S.A.A., 2010). It is important to get a property survey under partition as well as a property valuation for soil, interests, and improvements and plantations and finally equal values which is assessed by the court (Abdul, R.A., et al, 2008, Cooper S.A.A., 2010).

In United Kingdom, valuation is carried out by a RICS registered property surveyor. The Co-owners feedback pressure plays an important role in valuation behavior and judgement accuracy (Abdul, R.A., et al, 2008).

Actual appraiser behavior was found to be driven by subconscious procedures and production rules, called heuristics, learned gradually with experience. It is necessary to perform normative valuation model, which corresponds to the general information processing and human problem-solving theories (Newell and Simon, 1972, Simon (1978). It provides a standard, systematic algorithm to form a perception of the problem within a valuation task within the environment (Wolverton, 1997).

Partition acts in the world

In Poland, 'Court Commissioners' are called 'Legal Surveyors' and the documentation prepared by licensed surveyors play a crucial role in the regulation process.

In Canada, the law of partition is statutory and as a matter of right, laws of different states vary greatly. Alberta, under the common law of English, only coparceners had a legal right to demand partition. But later, right to proceed at 'law for partition' was extended to joint tenants. The partition Act discourages the sale in lieu of partition where only physical division was impracticable. The present aspect of public interest is that land should not be subdivided without regard to sound planning principles.

In the United States, partition is statutory and federal governments have enacted different Acts, generally favoring physical division. American judiciary does not encourage Partition in Kind and Owelty instead, court system uses its discretionary power to order partition by sale (Gillian K. B. 2004).

In England, there was no partition action in law or in equity for joint tenants or tenants in common until the mid-sixteenth century. The court of chancery could order 'Partition in Kind' or 'Owelty Partition' only for coparceners to seek judicial intervention through courts of chancery (highest court in UK). This situation prevailed concurrently in Alberta (Gillian K. B.2004). Partition was effectively eliminated in England when the 1925 property legislation restructured co-ownership tenure to give effect to a policy against fragmentation of holdings (Cooper, S.A.A, 2010)

In Caribbean islands, for partitions, four varieties of common law co-ownership needs have to be fulfilled with no hesitation as tenancy in common, joint tenancy, parcenery and tenancy by the entireties.

There, as has been shown, the owners of a moiety of the property are usually entitled to a sale as a matter of right. Owners of less than a moiety may obtain a sale but must show cause (Pepler, W.R.1976).

Amendments, replacements, insertions

History of the Partition Acts in the world goes back to 16th century. Between 1600 and 1830 British parliament passed more than 3500 acts altering individuals' right to real and equitable access (Dan Bogart & Gray Richardson, 2008). Most of the partition Acts in the world are influenced by traditions of England, as they were British colonies. Even in United States, up to the 20th century, partition law had some residuals of English law. With the economic boom and enterprise development, parties wanted the right of deciding Partition in Kind or Partition in Sell.

The Coparceners and/or co-owners wanted right to have decisions in their own. Legal process and concurrent activities needed to be much coherent, and amendments, replacements and insertions were made constantly for addressing equity and other issues like social, political, legal, and economic.

At the beginning, partition was a 'Right' and then it was a 'Writ' to partition. Later it was 'bill' to partition. Later Partition can be 'Owelty partition' or 'payment of Owelty'. Partition can also be made by granting each party the right to use the land for a specified duration. This remedy has fallen out of favor due to the obvious inconvenience and potential inequities created. Partition by sale is the more modern remedy, whereby a court may order that the land in question be sold for the highest price obtainable and the proceeds distributed to the parties according to their interests (Gillian K. B, 2004).

Planning control over partition

Most of the partition Acts in the world are included with reference to the sections of planning Acts and varies greatly deviating from English law (Pepler, W.R, 1976). Section 31 (scheme of partition) of the amended partition Law says, "where any F divided partition or portions that are to be allotted to any person under an interlocutory decree are less than the minimum extent required by written Law regulating the subdivision of land for development purposes, the surveyor shall, so far is practicable, divide the land in such a manner as would enable the allotment or sale of such portion as one lot (Act no 17 of 1997).

There are arguments that planning regulations derogate the absolute right to a partition and issues of pursuant with partition act and subdivision as defined by planning acts concurrently. A Partition to be a subdivision within the meaning of the Planning Act must meet three basic requirements. (1) There must be a division of the parcel. (2) The order for partition must be a tool within the meaning of the

Planning Act. (3) There must be a transfer or creation of an estate or interest in part of the parcel.

Court automation in the world

Sri Lanka reports least Land Disputes Resolution Index (LDRI) in the region as 1.0 out of 8 which is one of five measures of the quality of land administration index. This value for Maldives is 4.5 which is best in the region and Pakistan remains 3.5 (World Bank 2018). In terms of longer term cases in the system, the main cases are partition cases, followed by land and money matters. (World Bank, 2013).

Litigation on partition requires dozens of documents which are publicly unavailable and inaccessible information. In terms of management information, the data on court cases and disposal rates that is gathered by the Judicial Service Commission (JSC) is not publicly available (https://openknowledge.Worldbank.org/). Information about trends in the practice of law in Sri Lanka's courts is also not consolidated or automated. There are government run databases of acts with search capability called Lawnet, but it does not contain important implementing regulations by agencies. The 'Law net' publishes law reports with judgments, but these are not searchable beyond the alphabetical names of litigants in cases. (https:// openknowledge.worldbank.org/). Sri Lanka could learn from the court automation adoption experiences of India and Australia.

For instance, the first judicial IT-project was started in 1980 when the Austrian land registry was automated electronically. Within twenty years, summary proceedings on payment, electronic register, establishing Electronic Legal Communication (ELC) and electronic edict file for the publication of court documents were created. In year 2003, a website for a list of court experts and court interpreters was set up (Maurer, M., 2007).

Appointment of commissioners

The 'Commissioner' means 'person with a commission', a member of a commission, the representative of the governmental authority in a district, province, often having both judicial and administrative powers or the officer in charge of a department or bureau of the public service or the administrative head of a professional sport (Webster Dictionary).

The provisions applicable to Court Commissioners have not been clearly defined in statutes but have certain powers in voluntary assignment proceedings (Nohl Max W., 1917). The 'Court Commissioner' is appointed for executing interlocutory decree to partition the landed property (Loyd, William H., 1919). The RLS becomes an 'Appointed Commissioner' to a particular commission received by him or her. It is unclear whether the designation 'Court Commissioner' is terminated once the commission accomplished by the appointed commissioner to that commission or continued. Lawyers are sworn as 'Commissioner of Oaths' to attest affidavits, statutory declarations and other legal documents.

Alberta Survey Act says "Everything done in the practice of land surveying shall be done by or under the supervision, direction and control of a practitioner. No Alberta land surveyor shall sign a plan or document in the practice of surveying unless it is prepared by him or under his personal supervision, direction and control" (Allred, G. K., 2007).

V. ROLE OF A COURT COMMISSIONER

The partition statutes provide for the use of a 'panel of commissioners' to assess whether and how a parcel should be divided which panel has the power to recommend Owelty payments equally as an appraiser. If the commissioners feel that the parcel cannot be divided fairly, they could recommend partition by sale. In some states in US like North Carolina, statute sets forth a detailed process that empowers three disinterested commissioners to obtain a survey, plot tracts and streets for accessibility, and make Owelty determinations (Rivers, F, 2007-2008). In Georgia, three disinterested qualified persons are appointed for 'appraisal' and Owelty determination. Some courts in some states are allowed to appoint a commissioner of commissioners.

PROFESSIONAL BODIES AND ACADEMIC BACKGROUND

Most of the countries have regulatory bodies for registration of surveyors but only for cadaster.

Because of the cadastral surveying the term 'registration' is used to indicate government recognition of competence in cadastral surveying.

The profession is changing and the number of competencies in which surveyors are actively involved is over 200 (Hannah, J., et al, 2008). The professional membership is awarded based on the degree level academic qualification and industry training which runs not more than three years and recognized by the relevant professional institute. In Turkey, to provide a legal status the Act about Licensed Offices of Surveying and Cadaster was enacted in 2005 to accredit surveyors. According to the Act, accreditation of private surveyors requires written and oral exams, work experience and certain legal prerequisites (Yunus, K., Mehmet, C., 2015).

International Federation of Surveys (FIG) and Royal Institute of Chartered Surveyors (RICS) are global level professional institutes that offer memberships to survey community that represents their work ethics and values to employers.

Different parts of the world report a range of major problems. Some surveying skills which are recognized and valued in some countries are not considered in the same light in others. Issues of registration with regulatory bodies, barriers to membership and Professional negligence of institutes are some inherent problems with institutes.

Institute of Surveyors Sri Lanka (SISL) is the local professional body of the RLSs. During the past 10 years, 227 surveyors have been enrolled with the SISL membership.

VI. METHODOLOGY

Firstly, two provinces 'Sabaragamuwa' and 'Southern' were selected and statistics of the RLS were analyzed. Secondly, a Random sample of 25 RLS including two male and 23 female RLSs were selected from Kegalle District in Sabaragamuwa Province. Accordingly, answers were obtained for structured questionnaires forwarded to the sample through Google document.

There were twenty-two questions intended to draw direct answers to evaluate the suitability of the commissioners and level of participation for executing commissions. There were 73 questionnaires in accordance with five-point Likert Scale, intended to pronounce their opinion on selected specific matter.

Provisions of Partition Act No:17 of 1997 was examined by perusing the 83 sections and subsections which are directly related to the commissioner and practical application of each section was analyzed. The Appropriateness of the land partitions were evaluated by perusal of the quality of the final partition plan randomly selected.

As public sector RLSs are ruled out by the head of the institute not to involve in the court commission surveys, statistics of public sector RLSs are excluded from the calculations. This analysis focuses only on effect of RLSs on delays of partition cases. There are several other reasons for prolonged delays of partition and land cases in Sri Lanka.

VII. ANALYSIS AND DISCUSSION

The concept of 'Partition' and how it differs from 'Land subdivision were elaborated under the literature review. The provisions of Partition in Kind and Partition in Sell and appraisal for Owelty were discussed. Global literatures on different partition acts, provisions within them, alterations taken place and effect on planning regulations were analyzed. Requirement of court automation for avoiding long term pending was discussed. Appointment of commissioners, role of commissioner, registration of surveyors with regulatory bodies, role of the local and global bodies and their influence on commissioner, global survey community and their knowledge, skills and attitudes towards the judiciary process over partition and level of involvement with partition and their influence on public sector land administration and management were discussed.

Above mentioned facts are analyzed with reference to Sri Lanka and based on the level of contribution of RLS towards the judicial process over 'Partition' when appointed as commissioners, to what extent Partition (Amendment) Act no. 17 of 1997 is effective to

the commissioner, what are the remedial measures to be taken to improve the commissioner's role for expediting the partition process, and the institutional reforms, legal reforms and professional improvements for smoothing the partition platform in Sri Lanka.

Analysis of court cases in district court and magistrate court

Analysis has revealed 11 types of court cases in Sri Lankan judicial system. The aggregate data from individual courts shows that nearly 79% of pending cases in first instance courts in 2012 were in the Magistrate Courts, while 21% were in District Courts.

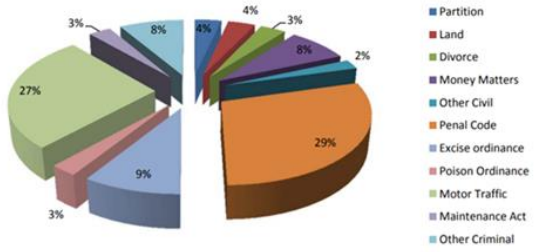

Figure 1: Breakdown of Cases in District and Magistrate Courts, 2012 Source: Sri Lanka Justice Sector Review, World Bank Report No. 77662-LK

A. Longstanding cases

In 2011, land, and partition, cases accounted for 8% of all cases in District Courts. Partition cases accounted for 45% of cases pending in District Courts for more than five years and 54% of cases were pending for more than 10 years.

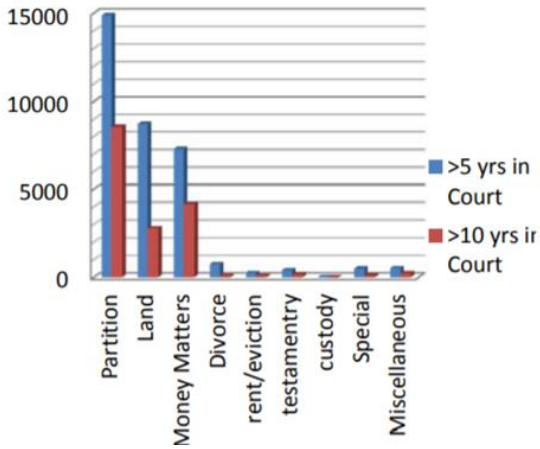

Figure 2: Longstanding civil cases by case type in 2012.
Source: Sri Lanka Justice Sector Review, World bank Report No. 77662-LK

There was a small increase of partition and other land cases in 2012 compared to 2011. Number of pending cases in Appeal Courts, Provincial Appeal Courts and Supreme Court have not been considered. It was revealed that majority longstanding cases are partition and land cases.

B. Participation of RLSS in southern province

Almost 50% of the RLSs in Southern province have decided not to involve with the court commissions surveys.

Table 1: RLS in Southern Province

District	Total RLS	Registered Licensed Surveyors			RLS (Non-Court Commissioners)	Number of Courts
		RLS (Public Sectors)	RLS (Private Sector)	RLS (Court Commissioner		
Galle	83	34	49	39	10	4
Matara	64	20	44	24	20	2
Hambantota	25	14	11	6	5	4
Total	**172**	**68***	**104**	**69**	**35**	**10**

Source: Sri Lanka Land Survey Council (2021)
* Not allowed to involve with court commissions surveys

There are eight (10) courts in the Southern province including three District courts namely Galle, Matara & Hambantota. There are only sixty-nine (69) RLSs as Court Commissioners within Southern region. 34% RLSs has declined to join with partition surveys. This amount is 45% in Matara district. From among these 69 surveyors, 73% of the surveyors are over 70 years of age (SISL, 2020).

C. Participation of RLSS in Sabaragamuwa province

Almost 51% of the RLSs in Sabaragamuwa province decided not to involve with court commissions surveys.

Table 2: RLS in Sabaragamuwa Province

District	Total RLS	Registered Licensed Surveyors			RLS (Non Court Commissioners)	Number of Courts
		RLS (Public [illegible])	RLS (Private Sector)	RLS (Court Commission		
Kegalle	40	11	29	17	12	4
Ratnapura	60	31	29	15	14	4
Total	**100**	**42***	**58**	**32**	**26**	**8**

Source: Sri Lanka Land Survey Council (2021)
* Not allowed to involve with court commissions

VIII. SURVEYS

There are eight (8) courts in the Sabaragamuwa province, including two District courts namely Kegalle and Ratnapura. There are only thirty-two (32) RLSs as Court Commissioners within Sabaragamuwa region. It means 45% of the RLS have declined to join partition surveys. This amount is 59% in Kegalle district. From among 32 surveyors, 65% of the RLSs are more than 70 years of age (SISL, 2020). During the last ten years, 6 surveyors only have joined the District court as court commissioners, while 5 surveyors have left the courts.

A. Knowledge and skill

All the RLSs in the sample have more than 30 years of experience. 92% possesses diploma or higher diploma. One is a graduate and another one possesses post graduate degree also. 88 % of the RLSs in the sample use digital data collection methods while 12% is using analog data collection methods. 64% of the RLS are working in fully digital environment while other 36% is still in transition period from analog to digital. 28% of the RLS are considering other emerging planning and environmental regulations need to be incorporated into their works.

All the surveyors are freelance practitioners other than legal surveyors. These freelance practitioners are not fully committed for court commission surveys. Average number of fieldwork days is three or less. Monthly submissions are not more than three commissions.

ATTITUDE TOWARDS COURT COMMISSIONS

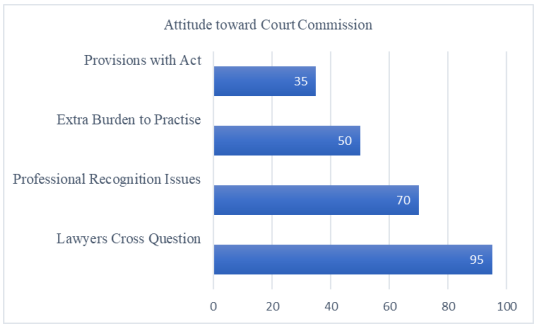

Figure 3: Measure of RLSs Attitudes

95% of the RLSs expressed their reluctance to face the nature of taking evidence and cross-questioning by the lawyers which they deem is not appropriate to a commissioner but to a suspect.

75% of the RLS surveyors were reluctant to be a court commissioner due to derogation of professional recognition at the partition process and insufficient facilities to commissioners.

80% of RLSs says that involvement with court commissions is an extra responsibility that is unnecessary burden to their professional life, and it is a disturbance to their freelance partitioning.

85% of the RLS expressed that the provisions in the Partition Act was not enough for charging survey fee timely. There are cases dismissed without charging survey fee, evading payment for small shares, mismanagement of the clients' payment by the lawyers and taking long time to final deposits.

In Southern province, only 2 surveyors have joined the courts during the last 10 years.

B. Application of technology

The survey proves that 36 % of the sample is still technologically in a transition period. 25% of the commissioners are still using very conventional instruments for partition and subsequent plan works. 40% of the sample is still reluctant to use online applications, working with Computer Aided Drawings (CAD) environment, using

digital equipment and smart applications in websites of supportive institutes.

C. Analysis of partition act no: 17 of 1997

Partition Act No:17 of 1997 in Sri Lanka mainly focuses on Partition in Kind. The Act consists of 83 sections. Twenty amendments; two replacements and three insertions have been made so far. Even though section 29 of the Act provides for some provisions for recovering survey fee, 95% of the RLSs are of the view that those provisions are not enough. Issues related to labor charges, transport cost and/or facilities, and non-payment of share of fee by plaintiffs and defendants were their major concerns.

95% of the RLS expressed that, the Act has not catered for personal security at the field when executing the commission.

30% of the RLSs said that, still they are waiting for payments owed from the plaintiff and/or defendants.

70% of the RLSs say identifying 'subjective object' is the most important.

90% of the RLSs say issuing proxy under section 16.3, of the civil court procedure to the parties appear at the preliminary survey is important.

65%of the RLS say that the calculation of valuation, compensation and Owelty to the parties is crucial at the middle of feedback pressure of the parties.

D. Appropriateness of the partition plan

According to the questionnaire, 80% of the RLS revealed that stakeholders support was not enough due to social, legal, economical and practical matters.

25 manually prepared plans and 25 computer aided plans were used for this evaluation. All the plans were prepared under Partition Act. All the plans were perused in terms of Regulatory Acceptance, Mobility and Accessibility, Physical Dimension (shape), Circulation, Neatness, and Completeness.

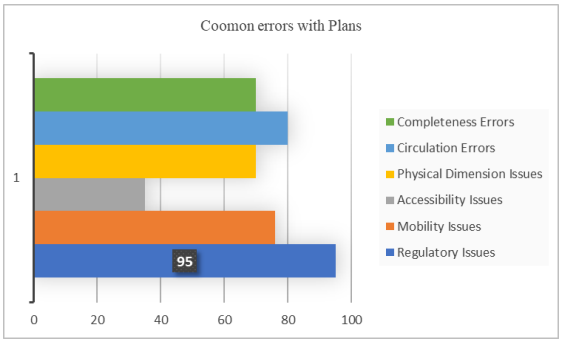

Figure 4: Percentage of Planning Regulation violation

Errors in CAD plans are largely reduced compared to manually prepared plan

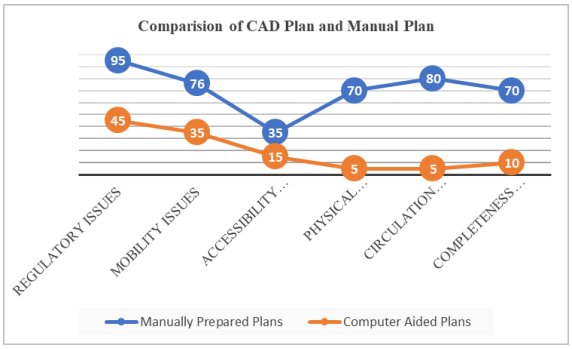

Figure 5: Manual and CAD Plan Comparison

IX. CONCLUSION

Partition and land cases are the cases longest pending in courts for a long time: Lack of RLSs, lack of information required, complexity of court proceedings and high ratio of judge: number of cases are the main reasons.

More than 50% of the RLS are reluctant to join with the court commission surveys: There were only two RLSs who have joined with the panel of court commissioners in Sabaragamuwa Province as well as Southern Province during the last 10 years.

More than 70% of the RLSs who were engaged with court commissions in Sabaragamuwa, and Southern provinces are above 70 years of age: Barriers to registration with LSC and membership with SISL are the main reasons for lack of younger RLSs. Inherent difficulties with the job, limited adaption to the new technology and limitations of physical mobility due to ageing are the reasons for quality of the final output.

There is an obvious issue of carrying out court commission surveys.

Means of recovery of payments for surveys are informal: Due to delay of payments, inadequate rates, travelling and other expenses and time cost, 100% RLSs have not been fully committed for court commissions. This is one of the main reasons for late submissions. Number of monthly average survey days is three. Average submission rate is 3 commissions per month, as surveying, drafting, documentation, correspondence and submissions are carried out by RLSs themselves.

As tendency of partition in Sri Lanka is mostly towards 'Partition in Kind', RLS involvement is high**:** Physical partition, appraisals of shares and buildings plantations there on and appraisal of values for Owelty for equity shares are crucial tasks accomplished by RLS at the middle of pressure of plaintiffs, defendants and lawyers in absence of arbitrators. There is an emerging issue of professional qualifications regarding the appraisal of valuations for such calculations in urban areas with high land values.

Almost 100% of the RLSs don't feel that they are part of the court**:** The nature of taking evidence and cross-questions by the lawyers make the commissioners feel as if they were accused rather than a commissioner assisting the court. This is another reason for lack of court commissioners. 90% of the RLSs assume that court commission surveys are an extra burden to their freelance practice.

Lack of facilities at the court, slow speed of encashment of survey fees, unnecessary noticing and wasting additional days for the summons discourages the long stay with court commission surveys: Most of the RLSs are reluctant to involve with "L" cases.

Need of remedial actions**:** If remedial actions are not taken, 75% of the commissioners would be retired from this voluntary task during the next 5-10 years. This will adversely affect the administration and management of private sector land which claims 80% of urban lands with enormous potentials of doing business.

There is an issue of professional recognition of the 'commissioner' and satisfaction with the job they perform.

ABBREVIATIONS

RLS	Registered Licensed Surveyors
SLLSC	Sri Lanka Land Survey Council
JSC	Judicial Service Commission
FIG	International Federation of Surveyors
RICS	Royal Institute of Chartered Surveyors
CAD	Computer Aided Drawings

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Addressing Barriers to Integrate Social Sustainability in Construction Industry

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Abstract— The social, ecological, and financial scopes of sustainability are all influenced considerably by construction operations. Regardless of the fact that there is significant literature on financial and ecological sustainability, diminutive was done to investigate social sustainability in the building industry. In light of this, the goal of this research is to look at the major barriers to social sustainability in the Sri Lankan construction industry. The findings of this study may fill in the information gap about the barriers to social sustainability, and improve social sustainability practices in the construction industry. Expert interviews were performed using a complete literature review and a qualitative research technique. The findings were analysed using content analysis. The findings show three major barriers, namely, thelack of awareness of the concept, deficiency of government support, and stakeholders' conflicts of interest and divergent points of view. Sub-barriers were then discussed under each main barrier. Further, the solutions to overcome these barriers were discussed briefly to improve the social sustainability in the Sri Lankan construction industry.

Keywords: *social sustainability, barriers, construction industry*

I. INTRODUCTION

The interconnectedness and balance of the economic, ecological, and social aspects are key areas in sustainable development (UNCED 1992). Sustainability approach has prompted initiatives in construction sector to address financial and ecological concerns by reducing waste and energy consumption, as well as improving end-user satisfaction and protection of the environment (Liu, 2020). Nevertheless, a successful sustainable construction project must consider social aspects as the project's impact on the broader society, as well as the safety, healthcare, and education of the workers. Implementing these elements will expand the project's continuing effectiveness and also the wellbeing for those who are impacted (Shirazi, 2017).

Social, environmental, and economic dimensions of sustainability are all influenced considerably by construction operations. As a result of the issue of the sustainable development goal, the demand for performance expected into building operations has risen. The construction industry has responded by supporting the sustainable progress goal and taking the social component into account throughout the course of a construction project's life cycle as an effect of increased awareness. The United Nations and other affiliates presented "Agenda 21 for sustainable building in developing nations," which has gotten the attention of the building sector (UNCED, 1992). The importance of social sustainability has grown throughout the project lifetime, including the design phases, building, operation, and deconstruction (Sierra & Pellicer, 2015). Numerous books and publications on sustainable construction and design have recognised the need of considering sustainability in all elements of the built environment. Interestingly, the focus of this work has always been on the environmental and economic components of sustainability, with little attention paid to the social components.

Sustainable development is the development that fulfills current requirements while not jeopardising future generations' capacity to achieve their individual requirements (Brundtland,1987). Recent years, the notion of sustainability has gained widespread acceptance in the building sector. It is multifaceted, with

many aspects bringing to light distinct perspectives (Torku, 2017). The elements of sustainability are the social, environmental, economic, and cultural. When these components are included, the explanation of sustainability becomes complete. Sustainability has acquired widespread acceptability in the last few years on social, environmental, and economic concerns as a result of its positive influence (Saab & Sadick, 2018). Social sustainability, which has now been established mostly ignored in the conventional sustainability discussion, has recently attracted a lot of interest from construction professionals.

Employees, communities, customers, and the supply chain must all work together to guarantee that the requirements of present and future people and societies are met (Herd-Smith & Fewings, 2008). End-user concerns should be prioritised in a socially sustainable construction, as well as the influence on the wider community (Valdes-Vasquez & Klotz, 2013). In construction projects, social sustainability encompasses a wide variety of characteristics, including the management in construction workforce's comfort and well-being (Gatti, et al, 2012). As an effect, the security of construction workforces and construction communities must be addressed while attempting to integrate social sustainability into the construction sector. Many studies on social sustainability have recognised the procedures and the importance of including several key professions in its implementation (Paige & Thirukkumaran, 2018).

Poor knowledge of the notion of sustainability among construction employees, is one of the challenges to sustainability implementation in construction (Dzokoto & Dadzie, 2014). As a result of the lack of sustainability literacy among construction professionals, progress toward sustainability in building has been gradual (Shen et al., 2011). Studies on long-term impediments were confined to the opinions of consultants in general (Dzokoto & Dadzie, 2014). As a result, a thorough examination of the obstacles that impede the route to social sustainability should not be overlooked. In light of this, the aim of this research is to improve the social sustainability in construction industry. To achieve that, social sustainability has been defined from the view of construction industry and identified major barriers in socially sustainable construction industry. Findings of this study may not only fill in the information gap about the barriers to social sustainability and to expand social sustainability practices in the Sri Lankan construction industry.

II. LITERATURE REVIEW

A. Social Sustainability

Having a solitary definition of social sustainability leads to more or even more complexity than achieving a common tactic, and that assign according to the idea that would lead to greater comprehension (Vallance, 2011). Further, they divide social sustainability under three categories as addressing challenges of poverty and injustice as part of development, support for strong environmental values in order to conserve the environment and conservation of social and cultural identities is referred to as maintenance.

In the study, McGuinn (2020) recommends the following definitions as appealing from the standpoint of systematic study;

•A society that is socially sustainable is one that is just, egalitarian, comprehensive, and fair, as well as one that offers a reasonable standard of living for present and future generations (Partridge, 2014)

•The term "social sustainability" refers to "society's orderly growth" (Shirazi, 2019)

•Accomplishing a reasonable level of social homogeneity, a balanced respect for tradition and innovation, employment that promotes the formation of decent livings, and equity in availability to services and financial services, as well as personal qualities, endogeneity, and self-confidence, are all significant elements of social sustainability (Adranghi, 2019)

•Social sustainability is a state that improves people's lives in communities, as well as a method that can help them attain it. (McKenzie, 2004)

Some of the essential characteristics of a socially sustainable system are justice in supply and distribution of options and chances, adequate delivery of social areas such as healthcare and educational, gender impartiality, and government responsibility and involvement (Kandachar,2014)

B. Social Sustainability and Construction Industry

Sustainability in the construction industry can be described as the goal of establishing a balance among a project's economic, environmental, and

social impacts. Specifically, a balance in terms of enhancing human lives through accomplishing economic and social objectives without causing environmental impact (Shi, Zuo, & Zillante, 2012).

Researchers define social sustainability as workforce, local community, customer, and supply chain participation in order to satisfy the requirements of present and future people and communities, a term that more accurately represents the many viewpoints of project stakeholders. (Herd-Smith & Fewings, 2008). Depending on the perception of the stakeholder as well as throughout the project, the notion of social sustainability has several implications in the sector. Because social sustainability is a multi-faceted perspective that is influenced by a variety of stakeholders, it necessitates an integrated approach from numerous stakeholders in order to achieve effective and optimal results (Almahmoud & Doloi, 2015). They go on to say that taking into account not just the impact of building projects on future users' lives, however a strategy to achieve social sustainability is to consider the effects during building, such as on workplace health and safety and job circumstances. Yet, it is important to highlight that the idea may be interpreted in a variety of ways in the construction industry, depending on the parties' points of view and wherever used within the project duration (Valdes-Vasquez & Klotz, 2013). As a result, rather than theoretical definitions, most of the research has focused on key criteria and indicators for operationalising social sustainability (Ahman, 2013).

People are at the heart of social sustainability. This term is defined differently in the construction area formed on the perspective of the stakeholders and where it is implemented within the life cycle of the project (Duxbury, 2017). Environmental impact evaluations, which are mandated by government agencies, usually include these figures. External stakeholders and governmental organisations employ community participation techniques like public hearings to influence design decisions at these early stages (Solitare 2005). While these social advantages may be elusive to contractors, they are just as important as environmental and economic ones, according to community experts (Hammer 2009). Since the idea of social sustainability is in the developing stage, now is a great moment to start adopting the social sustainability procedures that must be implemented in building projects. (Valdes-vasquez, 2011)

C. Barriers to Integrate Social Sustainability

Barriers abound on the road to long-term sustainability (Bostrom, 2012). The following sections address the primary barriers and sub-barriers found in the literature under those primary barriers.

1) Lack of awareness of the concept: In the literature, there are many diverse explanations for sustainable progress, and there is still a lot of misperception and dispute about what it implies and sustainability is a broad, cross-cutting phrase characterized by significant tensions between competing goals (Ajmal, 2018). Below Table 1 summarizes the sub-barriers discovered under the major barrier of "lack of awareness of the concept."

Table 1. Lack of awareness of the concept barrier

Primary Barrier	Sub-barriers
Lack of awareness of the concept	Ignorance or misinterpretation of the impression of social sustainability (Ametepey, 2015)
	Social Sustainability is misunderstood due to a deficiency of knowledge of the dynamics (Ametepey, 2015)
	The lack of education of stakeholders (Fujii, 2006)
	Other relevant experts are unaware of the situation (Ayarkwa et al., 2017)
	Insufficient ICT knowledge and abilities for facilitating work procedures and information searches (Ametepey, 2015)
	Inadequate technical knowledge (Ametepey, 2015)

2) Lack of government support: At the international, national, and community level, sustainable development necessitates concurrent changes in the configuration of social and political factors (Cerna, 2013). Anyway, this is a complicated procedure that necessitates cultural transformation, and numerous

intentional treaties have been grasped, notably prior to and during the Rio Summit, but governmental resolve to implement them has been sporadic. (Blair, 2005). The sub-barriers found under the primary barrier of "Lack of government support" are summarized in Table 2.

3) Stakeholders' conflicts of interest and divergent points of view: Divergent perspectives and conflicts of interest among stakeholders are the primary reasons of inadequate practices in social sustainability and this has prompted concerns about the efficiency in achieving long-term growth of social sustainability (George, 2017). Because every stakeholder does have a personal interest within the project this can lead to divergent priorities, disputes, and a substantial rise in the situation's complexity (Karlsen, 2008). Table 3 summarises the sub-barriers discovered under the major barrier of "stakeholders' conflicts of interest and divergent points of view."

Table 2. Lack of government support barrier

Primary Barrier	Sub-barriers
Lack of government support	Building codes on sustainability are lacking (Ametepey, 2015)
	Concerns about politics and policy (Emuze, 2015)
	Government policies and assistance are lacking (Ayarkwa et al., 2017)
	Design tools' complexity and limits (Crane, 2008)
	Public policy and rules clash (Ahn et al., 2013)

Table 3. Stakeholders' conflicts of interest and divergent points of view barrier

Primary Barrier	Sub-barriers
Stakeholders' conflicts of interest and divergent points of view	Apprehension over rising investment expenses (Ametepey, 2015)
	Client expectations are increasing due to the growing complication of modern construction projects (Ametepey (2015)
	Inadequate professionals (Ayarkwa et al., 2017)
	The organization's size and operations are diversified (Ayarkwa et al., 2017)
	Managing sustainability with other company goals is difficult (Ayarkwa et al., 2017)
	Competition (Häkkinen & Belloni, 2011)

III.METHODOLOGY

Through journals, conference papers, books, and dissertations, a comprehensive analysis of the literature was conducted, followed by moderately interviews, to recognise the idea of social sustainability within building construction industry and also to explore the major barriers associated with adopting social sustainable practices in construction sector. To fulfill the research's goal, the literature was evaluated using previously identified theoretical facts and practical factors relevant to the study issue from existing literature. Critical literature evaluation is an important element of any research project, since it allows for the development and refinement of study objectives.

To achieve the research's goals, semi-structured interviews with ten experts in the field were used as a data collecting strategy. On the basis of their exposure to sustainability, experienced experts from the construction sector were selected and interviewed. Defining the social sustainability in the context of construction industry, and the key barriers to implementing social sustainability procedures in Sri Lanka, were explored through this study. The data was examined using content analysis as the method of data analysis. The key impediments to implementing socially sustainable practices in the construction sector, were investigated.

A. Interviewee profile for expert interviews

A brief summary of the ten interviews is presented in Table 4 as follows;

Table 4. Interviewee's profile

Interviewee	Profession	Experience
E01	Chartered Quantity Surveyor	25 years

E02	Chartered Quantity Surveyor	15 years
E03	Quantity Surveyor	12 years
E04	Civil Engineer	10 years
E05	Quantity Surveyor	09 years
E06	Chartered Architect	16 years
E07	Civil Engineer	14 years
E08	Chartered Architect	13 years
E09	Quantity Surveyor	10 years
E10	Project Manager	20 years

IV. RESULTS AND DISCUSSION

Social barriers, unlike economic and environmental barriers, are difficult to identify, choose, and quantify, according to all experts. It's tough to figure out what improvements are needed because of the ambiguous socio-related elements and their prejudice, along with differing perspectives and objectives as indicated by E10.

As per the experts and literature findings, impediment to the embracing of social sustainability was identified as a deficiency of education and understanding about the subject. E01, E02, E03, E05 and E09 insisted that sustainability can't be accomplished without expertise or awareness of experts, given the complex, dynamic, and difficult character of building projects. Ignorance or a lack of shared knowledge of sustainability might stymie social sustainability in building. Obstacles arising from a lack of knowledge, according to all experts, are a regular occurrence for most stakeholders in the building business. Deliberate development in providing sustainable growth has been attributed to a deficiency of experts in sustainability, and results approve these issues as challenges in the practices used by stakeholders to guarantee social sustainability.

Accomplishment of sustainable building is contingent on good government procedures and assistance, which would stymie the process if not provided. Majority of experts say that the lack of sustainability-related building regulations, deficiency of government pledges, and absence of legislation are all major barriers to achieving social sustainability in construction. The government's commitment and the development of legislation are crucial to the accomplishment of social sustainability in building.

As indicated by E07, Sri Lankan construction sector has a long history of functioning in a certain manner, and it has a reputation for being tough to change. E07 further commented that the stakeholders have little desire for sustainability because of this aversion to change where all the other experts agreed. According to all experts, a key stumbling barrier is stakeholders' lack of desire for sustainability. The most critical barrier, according to all experts, is that a building project cannot be carried out sustainably without the complete backing of the client, contractor, and other stakeholders for sustainable principles.

The majority of expert interviewees (E01, E02, E03, E04, E05, E06, E08, E09 and E10) felt that organisations' lack of contribution to social sustainability practices has had a detrimental influence on implementation of social sustainability practices in real life. To that E07 added bringing stakeholders together, resulting in societal concerns that must be addressed in accordance with sustainability standards in construction industry. According to all experts, a key barrier to integrating social sustainability is a lack of organisational support. Furthermore, organisations view social sustainability practices as an add-on task that falls outside of their normal area of business. According to E01 and E02, some firms aim to pull the competitive market to promote their companies by implementing sustainable concepts, while others implement sustainable concepts through corporate social responsibility programs. As a result, those firms do not intend to be long-term viable.

In light of these considerations, all the experts emphasise the need for solutions of social sustainability improvement centered on universal co-responsibility norms and innovative deliberative techniques to satisfy opposing interests and economic and governmental regulatory mechanisms' constraints. All the experts further expressed these solutions should have a decision-making procedure focused on discussion, mediation, and transition management, rather than the existing voting and negotiation approach. The following suggestions were made by the experts in order to incorporate social sustainability into the building sector.

- Addressing all important stakeholders and linking them to various sustainability-related goals.
- System innovation provides a path to obtaining long-term advantages. To address the corporate and public sectors' long-term

sustainability objectives and short-term ambitions, "transition management" is necessary.

• Firms of the Future: As evidenced by the rising number of green consumers, the companies of the future will begin to integrate longstanding forecasting into their principal business. As a result, every organisation must establish transparent long-term goals.

• Increased public discourse throughout all levels to establish a link between the system and its subsystems – science, policies, law and the policymaking procedure in the building sector.

• Constitutional or structural political transformation is necessary to allow for new kinds of community discourse and the expansion of transcendental science and technology evaluation methods.

• Sustainability is a complicated structure characterised by logical ambiguity and inexperience. There is a case to be made for an innovative sort of tools to aid in the even integration of research. A new tool to evaluate the quality of data than the veracity inside each scientific report.

• As a starting point, design that is methodical and is based on expertise objectives will aid in the discovery of a mutual ground among scientific and policy levels. Considered methods, for instance the use of the cautionary principle, aid in the development of agreement on such goals.

V. CONCLUSION AND RECOMMENDATIONS

Social sustainability has lately garnered a lot of attention from across the world in order to adopt sustainability in the building sector. Meanwhile, in nations like Sri Lanka, the discipline of social sustainability is still in its infancy and confronts significant challenges. These barriers must be overcome in order to develop successful and widespread social sustainability practices in building industry. To that end, the goal of this research was to look at the obstacles to social sustainability. Barriers were identified by a complete literature study and expert interview to accomplish the aim. Lack of understanding in concept of social sustainability, lack of government backing and stakeholders' conflicts of interest and divergent points of view were identified as key barriers based on the findings. To attain the objective of social sustainability, experts recommended to facilitate a seamless integration of public requirements, as well as encouraging public engagement, maximising policy and scientific evidence, to guarantee a high quality decision-making process, substantial use of new techniques such as the precautionary principle, involvement of stakeholders to improve a participative approach, encourage the creation of suitable institutional frameworks and most importantly to consider the impact on the current social structure. This study paves the way for future research as developing initiatives to improve social sustainability in Sri Lanka.

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Mitigating the Effects of E-learning in Higher Education Sector in Sri Lanka during the COVID-19 Pandemic

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Abstract— This study sets out to examine the efficacy of e-learning in the Sri Lankan higher education sector that was ignited by the emergency created by the COVID-19 pandemic. Drawing a random sample of 350 undergraduates from seven major universities of Sri Lanka through the means of a questionnaire, the study was set against the key benchmarks derived out of a review of literature that affects e-learning. The study unearthed that unsatisfactory internet access, inability to correspond to the prerequisites of relevant subjects, psychological concerns enumerating due to shift in learning strategies, increased concerns about COVID-19, and lackadaisical attitude towards learning from home front, to be the noticeable factors having a larger bearing on the efficacy of online learning process. The study thus advocates proper infrastructure facilities and customization of teaching and learning process according to the subject content to elevate the standards of the e-learning process in the Sri Lankan higher education sector.

Keywords: *e-learning, pandemic, higher education, Sri Lanka*

I. INTRODUCTION

For an online learning environment, it is common to consider it as an internet-based framework that facilitates the delivery of training to students who are physically distant from one another or in distinct time zones (Dempsey and Van Eck, 2002, p. 283). In unusual circumstances, like as the COVID-19 pandemic, eLearning has emereged as a backup educational system to continue the learning process at the institutional level. The pandemic has spread practically each nook and corner of the world, albeit the first official case in China was not confirmed and hospitalized until December 2019. (Huang, cited in Roman and Plopeanu, 2021).

The coronavirus pandemic has now exacerbated to a point where the World Health Organization (WHO) has declared a Public Health Emergency of International Concern (Lai et al., 2020) Because it is impossible to foresee when the epidemic will end, there are a variety of situations that can arise as a result of the lack of predictability. This status quo creates a great deal of uncertainty and confusion, which has an impact on economic, social, and political institutions, as well as individual relationships. All of these developments have a huge impact on people and their interactions with other individuals and institutions. In terms of education, the unanticipated health crisis caused more than 1.2 billion learners, or around 70% of total registered students, from 158 nations to be severely impacted by the global lockdown on May 15, 2020. (UNESCO, 2020a). Hundreds of millions of students around the world have been and continue to be marginalised by “social distancing” or “self-isolation” policies imposed by their governments, due to the inability to attend physical classes that could damage their academic performance (UNESCO, 2020a). It is evident that their learning patterns are heavily affected, especially when those pupils lack the necessary infrastructure for online learning. According to the same earlier survey, a low level of household wealth limits the level of access to technology since it is difficult to establish an internet connection, which is a formidable barrier to eLearning and a big source of exclusion, isolation, and inequality (UNESCO, 2020b).

The context in Sri Lanka is no different by means, for the first time in history, the education through elearning platforms was given foremost prominence. Even the primary and secondary schools in Sri Lanka resorted to elearning whereas the higher education had to be overhwhelmingly dependant on the elearning concept even by conducting the graduate examinations.

It is in this context that this study sets out to examine the efficacy of elearning education as self reported by a random sample of undergraduates of the state Universities in Sri Lanka tested against some selected variables pertaining to elearning. The study thus postulates on the hypothesis that the elearning in Sri Lankan higher education sector induced by educational lockdown has triggered certain difficulties for the students concerned. The study thus strives to unearth these issues in order to provide new knowledge to enhance the effectiveness of the elearning education in Sri Lankan higher education sector.

II. LITERATURE REVIEW

E-learning has been established as an effective means of delivering instructional content for years, and face-to-face communication is still widely regarded as important to the learning. Unlike traditional classroom purported benefits of distance education include reduced college tuition, better test scores, increased task engagement, and decreased attrition. An efficient infrastructure is required for effective eLearning (Zhang, cited in Roman and Plopeanu, 2021), which entails not only solid technical connections, but also professional management of courses, apps, and excellent pedagogical soundness (Costa, cited in Roman and Plopeanu, 2021). For an instance in Korea, proactive involvement in establishing a good infrastructure has had a significant impact on the efficiency of the eLearning platform (Teo, cited in Roman and Plopeanu, 2021). Furthermore, Liaw et al. (2007) and Selim (2007) show evidence for the favorable impact of teachers' attitudes on the degree of eLearning success. Low internet connectivity at home, according to Balfanz and Byrnes (2006), is equally damaging to eLearning achievement as bad internet infrastructure at schools (Nicholas, cited in Roman and Plopeanu, 2021).

Distance education may be successful if the subject effectively and efficiently interprets potential barriers (social interaction, administrative issues, student motivation, and time/support for studies) (Muilenburg and Berge, 2005). Additionally, self-regulation has been found to be critical to the efficiency and success of such practices (Yukselturk, cited in Roman and Plopeanu, 2021), as well as proper instructional design and rigorous educational planning (Hodges et al., 2020).

The successfulness of implementing e-learning requires the understanding of end-user acceptance process. Therefore, a set of factors should be provided to be considered when an E-learning activity is planned and proposed to E-learners in universities of Sri Lanka. Through a technology acceptance model it has been proven that the students following the computing degrees tend to focus more on perceived ease of use on elearning and the students‘ attitude has more influence on intention to use elearning. So it could be stated that providing more technological facilities with infrastructure would increase the positive attitude towards using e-learning among Sri Lankan university students and their behavioral intentions (Vidanagama, 2016).

The use of the internet is just a particular ICT application, but nevertheless a cornerstone application. Moreover, the problems faced due to intenet are symptomatic of the more general ICT issues for developing countries like Sri Lanka. Thus, the knowledge and competencies of ICT and the ICT literacy is a must to be advanced and developed within the Sri Lankan community. In order to approach for a digitalized society based on the internet and the technological infrastructure where online learning and teaching become a major activity, the ICT literacy and the skills of the community should be mandatorily be developed per Gunawardhana (2005).

Additionally, research has demonstrated that policies aimed at closures of schools and universities have exacerbated inequity and frustration among these students Additionally, these constraints have impacted the foundations of cognition, specifically socialization and

interaction. Academic assistance (Cigognini et al., cited in Roman and Plopeanu, 2021) and appropriate educational platforms (Isaeva et al., 2020) are viewed as critical components of an efficient online learning social process that is password protected.

As with any conventional educational form, eLearning education is believed to be entirely dependent on effective interpersonal interaction between all of the actors involved in the process (Bernard et al., cited in Roman and Plopeanu, 2021), in order to benefit from the exchange of knowledge and ideas (Cole and Engestrom, 1993). According to previous research, students who exhibit a proclivity for depressed behavior or pessimism may face formidable obstacles that impair their ability to cope with disturbing, novel, and anxious circumstances (Miceli and Castelfranchi, 2002), resulting in a lower level of achievement (Yates, 2002).

That is why, while the COVID-19 pandemic may be viewed as a challenge on effective education, particularly for these categories of students. However, the scenario also viewed as an opportunity to abandon established customs and paradigms in traditional education system in favor of more accessible, affordable, and technology-based learning systems globally (DePietro, 2020).

Student achievement and skills are clearly linked to the adoption of learning strategies (Pressley & Associates, 1990). Research in curriculum areas ranging from physics to literature and social studies to science has frequently demonstrated this link. Given the strong link between learning method and positive outcomes, it's no surprise that students who use learning strategies have a high level of self-efficacy, or the belief that they are competent learners (Zimmerman & Pons, 1986)

Learning cognitive strategies such as reasoning, analyzing, taking notes, summarizing, synthesizing, outlining, reorganizing information in order to develop stronger schemas (knowledge structures), and practicing in naturalistic settings are all examples of cognitive strategies that assist the learner in acquiring Knowledge. Furthermore, metacognitive strategies such as pre-planning a task, acquiring and organizing materials, setting up a study space and schedule, monitoring mistakes, and evaluating task success, as well as analyzing the success of any type of learning technique, are all used to manage the learning process in general.

Memory-related methods help students connect one thing or concept to another. Various memory-based strategies enable learners to learn and recapture information in a logical sequence (e.g. acronyms), while other techniques create learning and recapture through sounds (e.g. rhyming), images (e.g. a mental image or the word meaning), a combination of sounds and images (e.g. a keyword approach) (e.g., on a page or blackboard).

Affective strategies have been demonstrated to be important in learning, such as evaluating one's mood and anxiety level, talking about feelings, praising oneself for successful performance, and adopting deep breathing or positive self talk. Social Strategies such as asking for clarification on a confusing issue, asking for assistance in completing a task) have also found to be important in learning. Thus, it is highly sceptical as to what extent elearning education in Sri Lankan higher education sector could correspond for the above stipulated learning strategies.

III. METHODOLOGY AND EXPERIMENTAL DESIGN

As per the findings of the International Association of Universities as stated in their Global Survey Report on the Impact of Covid 19 on Higher Education around the World, three basic variables have been validated to be affecting the efficacy of distance learning systems through the online platforms. The factors are namely the a) accessibility to the technological infrastructure, b) the distance learning competencies and c) the field of study. The study was set againts these benchmarks which were identified as emerging challenges to the e-learning practices (Marinoni et al., 2020).

The study employed hallmark features of a quantitative study while resorting to a random sample of 350 undegraduates studying in seven universities of Sri Lanka. A questionnaire consisting of questions under four sections was

administered among the undergrdautes to accumulate the required data for the study. The key variables tested through the questionnaire were stipulated into the sub sections as, the demographic factors of the students, accessibility to technological infrastructure, psychological concerns of the students, impact of the field of study on the effectiveness of e-learning and the overall perspective of the students on online education system. The sample of students were aggregated from multifarious fields of studies that included the Engineering & Surveying, Quantity Surveying, Architecture, Biology & Chemistry, Arts and Information Technology disciplines drawing representative sample from all the localties of the country.

The accumulated data were then analyzed in order to infer the impact of the technological infrastructure and their accessibility, the psychological concerns and the learning competencies of the undergraduates and the satisfaction of the undergrdatuates who are being engaged in elearning so far, in cognizance of their respective fields of studies to assess the efficacy of e learning within the context of Sri Lankan higher education system.

IV. RESULTS AND DISCUSSION

A. Accessibility to the Technological Infrastructure

The Covid19 pandemic situation has enforced most of the Higher Education Institutes around the world to shift to the e-learning practices confronted with many sudden and unfamiliar aspects of teaching and learning. This predicament has been a greater challenge for the educational Institutes concerned, teachers as well as for the students. It is a stark fact that the technological infrastructure and the access to the internet are essential prerequisites to participate in the e-learing process.

The International Association of Universities has evinced three different aspects pertaining to the implementation of online learning and has classified three different groups accordingly; (i) countries for which the shifting to online education is extremely unrealistic since the students do not have the necessary infrasture and the access to the internet from home. (ii) countries whose internet penetration and the technological infrasture among the academia and the students are adequate to establish a proper e-learning system. (iii) the countries having a partition between the students having the necessary infrastructure and the students who do not which makes it excessively difficult to cater equal opportunities to all the students. Sri Lanka comes under the third mentioned category which is the most frequent category in this group of classification. Hence, it is postulated the unavailability of the necessary infrastructure and the internet access for a set of students have to be overcome which was further testified by the findings of the study as follows;

The following chart exemplifies the nature of the technological devices used by the sample in study for elearning tasks . 46.8% of the students construed that they are capable of using a laptop/computer for their academic activities while 43.1% states that they resort to mobile phone devices for the online learning. 9% of the students states that they are selecting the device depending upon the situation. A marginal proportion of 0.3% states that they do not have the necessary infrastructure.

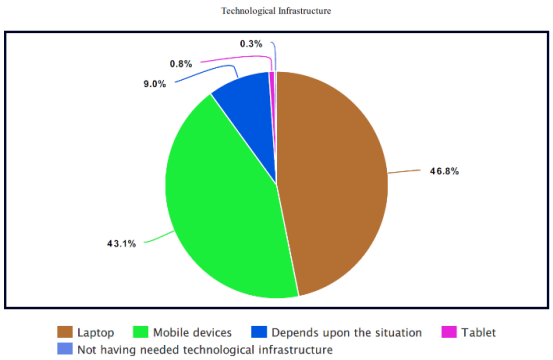

Figure 13: The accessibility of Technological infrastructure by the respondents

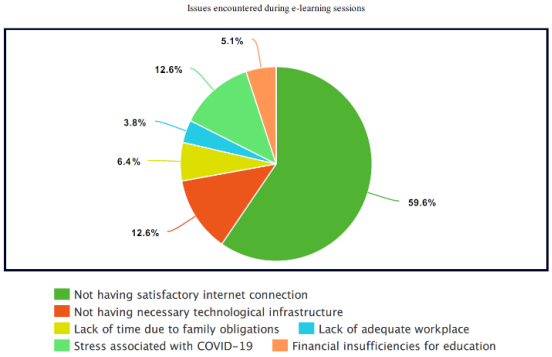

Figure 14: Issues encountered during e-learning sessions

From the undergraduates who state that they select the device, depening upon the situation, 37.8% states that the device is selected upon the type of activities/modules/subjects that they learn while a percentgage of 62.2% accounts to the fact that that the device is selected based on the network coverage, the access to the internet and the localities of the learner group concerned.

A frequency of 195 students which accounts to 59.8% of the sample underscores that the perennial problem that they confront during online learning is not having a satisfactory internet access whereas a frequency of 41 students amounting to 12.6% declares that not having the needed infrastructure devices is the main problem that they have faced. This result has proven the statement provided by Gunawardhana (2020), which is that, for a developing country like Sri Lanka, the imprudent internet connection and its associated facilities are the major drawbacks for the institutions to shift to e learning approaches.

In cognizance of online examinations, 48.3% conveys that not having a satisfactory internet access which was the major reason for them to underperform during online examinations and 18.1% states that they do not possess the necessary technological infrastructure needed for online examinations. This situation hence, has happened to be a critical scenario where a motivated and hard working students' performance during an exam can be hindered due to the unsatisfactory internet connection that the student possess or due to the fact that the student is incapable of acquiring the needed technological devices and infrastructure. Concurrently, a student with less ICT literacy as explained by Gunawardena, (2005), may underperform than expected at the examinations even though the student may occupy the relevant subject knowledge and the needed competencies.

The figure 3 and figure 4 exemplify the summary of the responses pertaining to the key issues that the students have encountered within online lectures and online examinations.

B. Distance Learning Competencies and Psychological Concerns

The findings of the review of the literarure of this study, highlighted that the impact of learner strategies and learner styles have an important bearing on the learner's capability to grasp what is being taught. Opting for the online education system has deterred these individual learner styles and strategies which cannot be corresponded in this elearning process unlike in a traditional classroom context(Luaran, Samsuri, Nadzri and Rom, 2014). In view of above, the

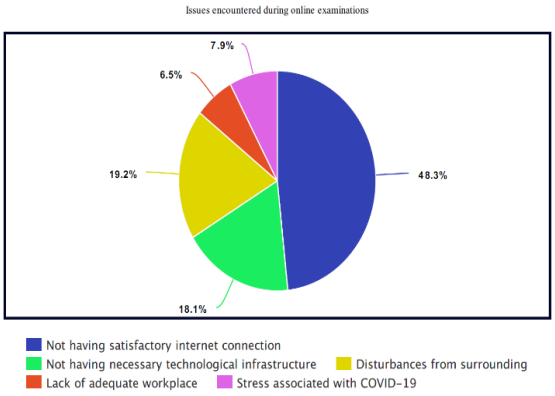

Figure 3: Issues encountered during online examinations

study encapsulates the cognitive aspect of elearning in this study and it was unearthed that the sample of the learners undergo certain psychological distress ignited by the pandemic condition which has an impact on their capacity to engage in online education effectively.

In cognizance with above, it was ascertained the undergraduates level of worriness and stress associated with the pandemic situation of the country. The 350 undergraduates were querried to scale their distress associated with Covid19 on a scale of 1-5 where 1 indicated that the distress is very low and 5 indicated that the respondents are highly concerned. The findings show the

following frequencies and the descriptive statistics

Table 1: Descriptive Statistics of Psychological Distress

Descriptive Statistics					
	N	Min	Max	Mean	Std. Dvn.
Psychol o--gical Distres s	350	1	5	4.42	0.869

Table 2: Psychological Distress Associated with COVID-19

Psychological Distress		Frequency	Valid Percent	Cumulative Percent
Valid	1	2	.6	.6
	2	10	2.9	3.4
	3	47	13.4	16.9
	4	70	20.0	36.9
	5	221	63.1	100.0
	Total	350	100.0	

Thus, the students have expressed an average of 4.42 has their level of concern towards the covid19 situation. Concurrently, a frequency of 40 undergraduates amounting to 12.3% indicates that due to the stress associated with the Covid19 pandemic was the main reason for them to not attentively enagage in the online lectures and 7.9% of them claim that it was the main reason which affected their low performance during the online examinations. When examined further, the sideline remarks made by the students, revealed that this physchological quagmire entails factors such as the lackadaisical attitude of learning from home, familial commitments due to pandemic, not being able to resort to their usual learning styles & strategies unlike in the traditional classroom setup etc.

Hence, it was understood that the psychological concern of the undergraduates is a mandatory fact to be considered when the effectiveness of elearning is considered. This predicament essentially underscores the vital requirement to conduct further research pertaining to the teaching and learning styles in the domain of elearning.

C. Field of Study

The potency of elearning is profoundly dependent on the respective field of studies. The learning process of various
disciplines varies according to the reliance on content of the subject matters concerned such as use of specific technical equipment, use of laboratories, field work , design work and so on.

Given the above essential preequisties that entail multifarious fields of study, it is conspicuously evident that the efficacy of elearning largely depends on the extent to which such learning process could accommodate the requirements of the subjects matters concerned.
The sample of the undergrdauates to this study were gathered from several fields of study concerning this issue. The undergraduates were hence from Engineering & Surveying, Quantity Surveying, Architecture, Biology & Chemistry, Arts and Information Technology desciplines.

These respondents have expressed their satisfaction towards the effectiveness of elearning process on a scale of 1 to 5, based on their partuclar area of study and the descriptives of the responses can be summarized as follows:

Table 3: Descriptive Statistics of effectivess of e-learning pertaining to the field of study

Descriptive Statistics					
	N	Min	Max	Mean	Std. Dvn.
Biology/ Chemistry	55	1	5	2.5455	1.13559
Engineering/ Surveying	52	1	4	2.1346	0.97073
QS	65	1	5	3.2308	1.12873
Architecture	42	1	4	1.7143	0.74197
Arts	75	1	5	3.4133	1.05386
IT	60	2	5	3.9667	0.71228

As testified by the above data, the Information technology undergraduates for whom the lectures and activities are largely computer aided, records a higher level of satisfaction towards elearning which is averaged around 4; the highest mean value obtained. In terms of the Architecture undergraduates whose studies are mainly based on design based works, records a satisfaction level with a marginal mean value of 1.7 which was the least that could be noted. Moreover, the Biology and Chemistry undergrdauates records a satisfaction level of 2.5 owing to the fact that most of their modules are laboratory based whereas the Engineering/Surveying undegraduates express their unsatisfaction to the online lectures with a mean satisfactory level of just 2.1. Gunawardhana (2005), has stated that the insuffiencent knowledge and competencies on ICT and technological devices can also become a challenge when the elearning systems are approached. This statement has also been verified through this study, where the undergrdauates of Computing and Information Technology desciplines whose studies are basically associated with technology, has shown a higher degree of satisfaction towards elearning practices implemented in Sri Lanka.

Thus in an ascending order, the satisfaction of the respondents varied from Architecture, Engineering/Surveying, Biology/Chemistry, Quantity Surveying, Arts and Information Technology.

V. CONCLUSION AND RECOMMENDATIONS

With the viral outbreak of the novel coronavirus:SARS-Cov2 and the associated infectious respiratory disease named COVID-19, the World Health Organization (WHO) officially announced a situation of a global pandemic on 11th March 2020. Ever since more than 3.4 billion people, representing a total of 43% of the world population were locked down within 80 countries and territories across the world (Marinoni et al., 2020).

The distruption caused by COVID-19 on school and higher education was immense as all schools and higher education institutes of 185 countries had to be closed affecting a total of 1,542,412,000 learners worldwide (Marinoni et al., 2020). In concern with the above situation, most of the higher education institutes of the affected countries had to shift to the distance learning methods which was essentially involved with elearning practices. The feasibility of this transition from the physical in class education system to online distance learning system can be compartmentalized into several interconnected dimensions which can be named as i. Technologocal Infrastructure, ii. Distance Learning Competencies and Psychological Concerns, and iii. The Field of Study.

Through this study, efforts were taken to examine, the impact of the above mentioned variables on the elearning practices of the undergraduates within the Sri Lankan Higher Education System. Thus, a questionnaire survey was conducted with a sample of 350 undergradtuates from diversified fields of study, through which data were gathered from the students perspective and were analysed to generate conclusions. The ultimate objective of this study was to ascertain the perspectives of the students regarding their elearning experience and related issues which can be eventually employed to develop an advanced, efficient and effective education system.

The findings of this study exemplified that the biggest problem faced by the undergratuates in Sri Lanka is the access to the internet where the respondants claimed that most of the parts of the country does not contain a viable network connection. This situation is a key challenge that should be addressed by the decision makers of the country with the intent of providing learners across the country with a satisfying network coverage and related infrastructure facilitices. Apart from that, the field of study was understood to be a key problem faced by the undergraduates. More specifically, as stated by the respondents and as proven and validated through statistics, the elearning system of Sri Lanka is only seen to be favorable to few disciplines of study which are most computer aided and theory based. The Practical and lab based dsciplines are still struggling with finding an optimum elearning approach which is a challenging matter to be concerned. Thereby, further studies should be encouranged on subject/module specific pedagogies and

assessing related delivery modalities in online learning platforms.

Concurrently, the undergraduates themselves have suggested the factors such as conducting the lecture sessions with a small group of students and a smaller lesson content which can be delivered with a satisfying student-teacher interaction. Thereby, it can be observed that the distance teaching and learning necessitates a distinct pedagogy, rather a systematic transition from face-to-face to distance teaching and learning. It is difficult for higher education to make this abrupt and unprepared shift, thus there should be a determined action plan in the higher education sector to develop the teaching capacities of the academic staff concerned in order to assimilliate them towards online teaching & learning platforms.

Hence, this unplanned situation can be adopted as an oppotunuity to inculcate the critical thinking capacities of the humankind in creating and innovating flexible teaching and learning pedagogies applicable for distance learning situations which will subsequently lead the teaching-learning process to a new horizon in the sphere of education. The study thus eventually recommends government initiatives to upgrade the required infrastructure facilities and related resource development for elearning in Sri Lanka, and implementation of investment projects for the capacity building of all stakeholders involved in this process including staff and the learnerns. This will eventually improve the options for learners to access lifelong learning opportunities as well as the ability to work from a distance which will inavirably make an positive impact on the development of the country and its economy in the time to come.

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ABBREVIATIONS AND SPECIFIC SYMBOLS

COVID	:Coronavirus Disease
ICT	:Information & Communication Technology
WHO	:World Health Organization
UNESCO	:United Nations Educational, Scientific and Cultural Organization

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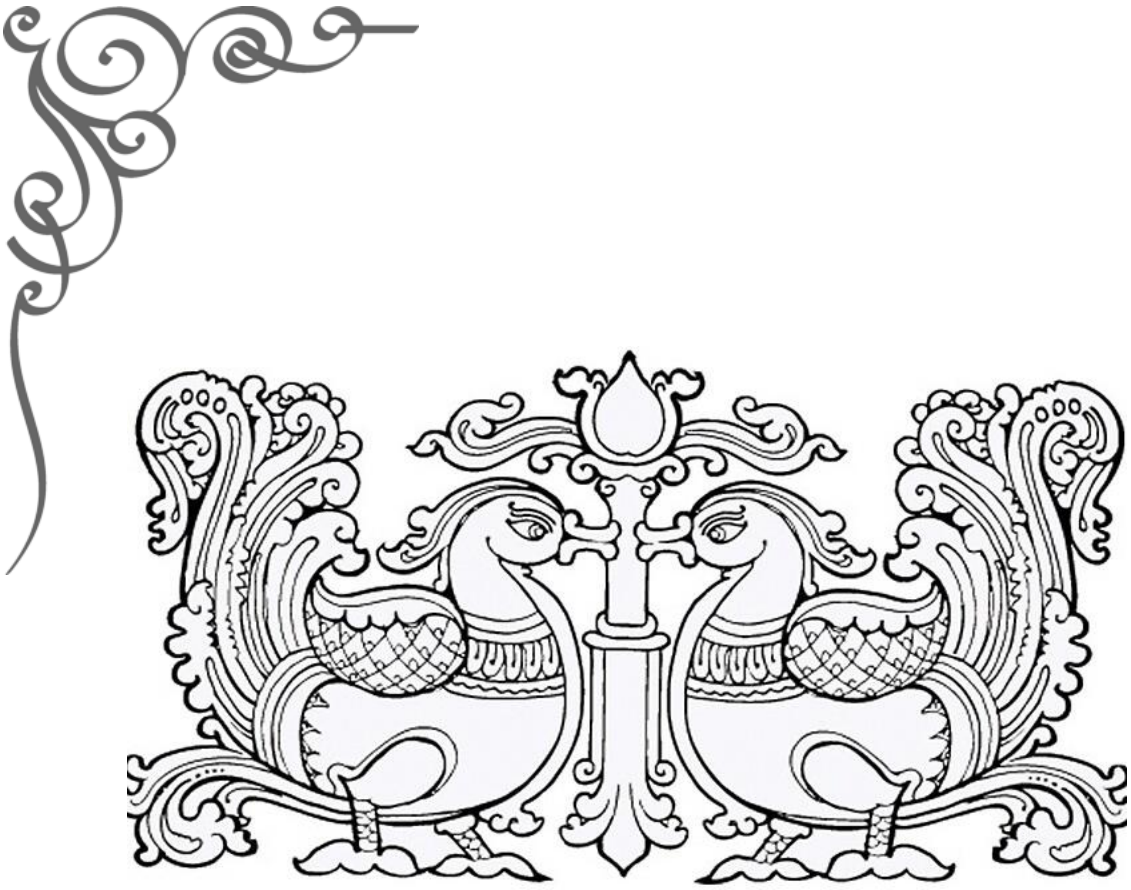

Poster Sessions

Accuracy Assessment of UAV Mapping Based on Pattern and Density of Ground Control Points

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Abstract- Unmanned aerial vehicles (UAVs) are very important for surveying purposes of the modern-day construction industry when considering the time and cost allocated for the surveys. The surveyors could use the images taken from high altitudes to obtain orthoimages, digital surface models, and digital terrain models in high temporal and spatial resolutions using the photogrammetric processing software. This study aims to analyze the effect of ground control points that govern the accuracy of the 3D surface model. Thus, the study focused on observing the effective distribution of ground control points. Hence, six different GCP combinations laid in four different laying patterns were examined. Data used for the study were collected using both field surveys and photogrammetric surveys. In the field survey, the X, Y coordinates of the ground control points were examined using a total station and Z coordinates with the automatic level instrument which is considered as the most prominent surveying technique in Sri Lanka. The edge layout and star layout illustrate the maximum accuracy among the four laying patterns in both planimetry and altimetry perspectives. Root Mean Square Error is the method used for error calculation. Based on the study conducted, it is concluded that commercial drones could be used to determine the terrain features with reasonable accuracy.

Keywords: *Unmanned Aerial Vehicles (UAV), Ground Control Points (GCP), Root Mean Square Error (RMSE), Digital Terrain Models (DTM), orthoimages*

I. INTRODUCTION

Land Surveying has combined three dimensions (3D): plane and elevation. When considering construction platforms, the task of a surveyor has been important since ancient times. Therefore, technology has developed over time. Generally, land surveying has been intervened in several fields like cadastral surveys, engineering surveys, disaster management, map preparation, 3D reconstruction, etc. In the conventional surveying techniques, the land surveys, engineering works, and topographic map preparations have been done with the aid of Automatic Level instrument, Total Station (TS), and Global Navigation Satellite System (GNSS) based Static/Real-Time Kinematics (RTK) methods. (Kršák *et al.*, 2016) Although these conventional surveying techniques have fulfilled the accuracy of the outcome, surveyors are not satisfied with the time efficiency, labor efficiency, and cost allotted to the survey works within the project proposal. Although satellite images could cover a large area at once, they cannot be used for surveying activities due to the limitation available that these images have a poor resolution configuration when conducting surveys below the areas of 1-hectare. (Mesas-Carrascosa *et al.*, 2016) however, conventional GNSS-based data collection combined with Total Station was accurate enough to reach the architectural and civil engineering planning level.

With the development of technology, a new platform for surveying has been created. Unmanned Aerial Vehicle, known as UAV technology, was an important technique when considering aerial photogrammetry. The UAV had its unique technological advantages like flexibility to every situation, low cost, low labor force, and low time consumption. (Kršák *et al.*, 2016) It has provided the ability to capture multi-temporal images of the ground surface with different angles having multi-image resolutions. These photos are known as orthoimages and lead to building a digital surface model. (Chi, Lee, and Tsai, 2016)

Although technology evolves, these instruments have a high initial cost when compared to conventional survey instruments. When purchasing a Survey Grade Drone, the initial expense would be comparatively higher than the investment to be spread over a Total Station and Level instrument. However, the other supportive factors like the consumption of human force and the time cost are considered over traditional land survey methods, new technology has greater productivity. (Wingtra, 2020).

When considering the aerial surveying technique with UAVs, it is stated that only X, Y parameters to be accurate but Z (height value) parameter is not at a good level. (Benassi *et al.*, 2017) Therefore, this study has gone through several techniques to increase the accuracy of the Z parameter directly through orthoimages taken via a remotely sensed quadcopter drone. For this research, it has been applied both GNSS technology together with UAV technology to increase the accuracy of the survey. The outcome of the study aims to discover a pattern to lay an optimum number of GCPs.

II. METHODOLOGY AND EXPERIMENTAL DESIGN

The data collection was based on both field surveys and photogrammetric surveys. The field survey was conducted with conventional land survey techniques consisting of the Total Station and the Automatic Level Instruments, which support the comparison of the study.

A. Study site

The field survey was conducted over a 9800m^2 of the water-free area attached to 'Muruthawela Reservoir' in Hambanthota District, Southern Province of Sri Lanka as shown in Figure 1. The study area is an undulated ground with approximately a 5m elevation difference between most elevated and least elevated points. The undulated ground surface, less population disturbance, and less interference from man-made constructions were the main reasons for selecting this land portion for the study.

Figure 15: The Area of Study

B. Instrument Specifications

The data collection process was conducted with highly accurate survey equipment and the total station, automatic level instrument, and drone were calibrated and checked with the initial configurations mentioned in Table 1 before the field data collection to improve the accuracy of the survey.

Table 7: The Specification of the Instruments used

Instrument	Specifications			
Total Station	Sokkia CX 101	Accuracy	Angular	1"
			Prism	4000m
Automatic Level	Sokkia B20	Accuracy	Level	+/- 0.7mm
Commercial Drone	DJI Phantom 4 Pro	Camera Quality		20 MP
		Flying Height		50m
		Overlap	Linear	80%
			Side	80%
		Camera Tilt		80^0

C. Data Acquisition and Processing

The field survey of this study was conducted using conventional land surveying techniques, which consisted of Total Station and the Automatic Level Instruments. As the initial step, a grid was designed to overlay the ground control points in an equal gap between each other. It marked the grid points on the ground surface using a Total Station. Since the coordinates wanted to tally with the coordinate system of drone images, two traverse control points were established on the ground using GNSS static

observations. Next, the topographic survey of the area was conducted, and calculated 3D coordinates of the GCPs very precisely, using both total station and automatic level instruments as supportive data for future processing of photogrammetric data. The next step of the survey was to conduct the UAV-based data collection on the same area of concern. For this purpose, we have established 120 GCPs and obtained their 3D coordinates according to the SLD99 coordinate system.

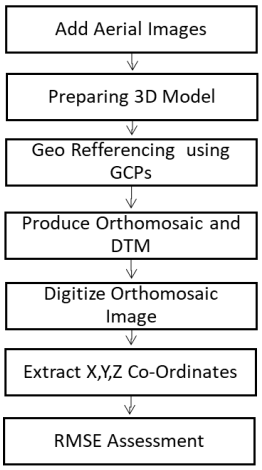

Figure 17: Image Processing Methodolc

After field and drone data collection, it was required to process the data using Pix4dmapper aerial image processing software. For georeferencing of image data, the total station readings and level instrument readings were merged to extract highly accurate XYZ coordinates of the GCPs concerned.

The input of precise data is important for the exterior orientation of the 3D model. This study has considered four different layout patterns to overlay GCPs, namely Edge layout, Corner layout, Centre layout, and Star layout. The Edge layout consider the GCPs over the Edge of the block, while the Centre and Corner layouts concerns laying GCPs in the centre and one corner of the block, respectively.

The Star layout is proposed to merge Edge and Centre layouts by considering the same edge distribution with one GCP at the centre. The processing was conducted at six combinations of GCP which were selected randomly (i.e., *4, 8, 12, 16, 20, and 25)* for every layout and was tested for at most three different selections to obtain a mean value.

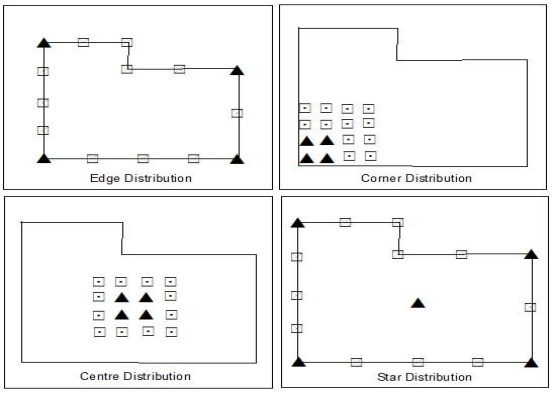

Figure 16: Four GCP laying patterns with four GCPS | black solid triangles denote the GCPs and blank squares denote few control points

For the construction of a highly accurate 3D model, the spatial reference of 12 orthoimages was performed manually for each control point. The final result of each GCP contained orthoimages ranging from 40 to 60 per control point based on automatic marking. The final outputs from Pix4dmapper were orthomosaic, digital surface model, and digital terrain model based on the “Structure From Motion” (SFM) Technique.

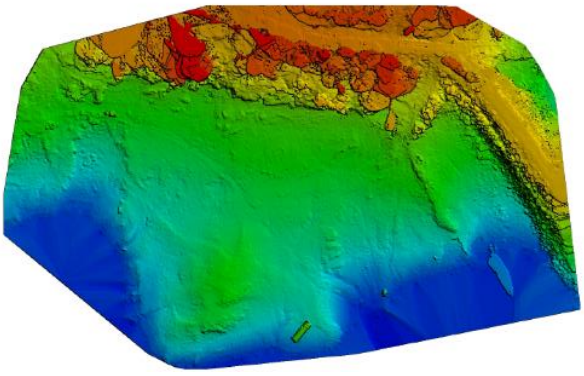

Figure 4: Digital Terrain Model generated from Pix4dmapper

The resolution of the orthomosaic image generated was 2.2cm/pixel based on the flying height and angular field of view (F.O.V.). Then the ground control points were digitized manually as visible on orthomosaic image using Esri ArcMap 10.5 software. Then relative XY coordinates of the GCP were extracted while relevant Z coordinates were extracted from the digital terrain model.

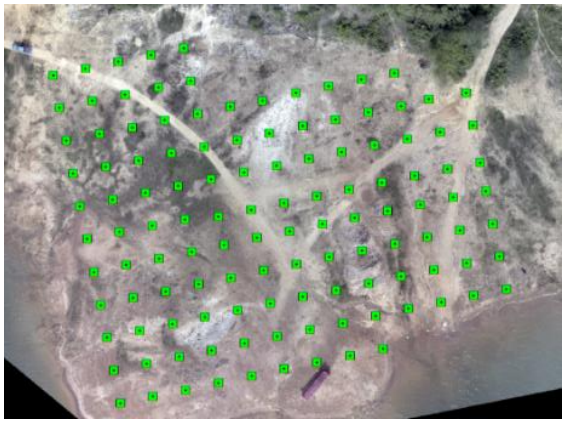

Figure 5: Digitized Orthomosaic Image | Green dots represent the locations of GCP

III. RESULTS AND DISCUSSION

This analysis used the Root Mean Square Error (RMSE) of the control points with respect to the conventional reading from the total station. Here two parameters; the planimetry and altimetry error have been checked. The $RMSE^{XY}$ was used as a parameter to measure the radial dispersion with respect to X and Y coordinates. Altimetry error ($RMSE^{Z}$) was calculated considering the observed DTM data.

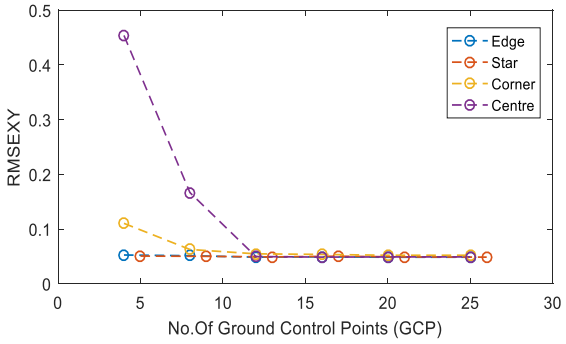

Figure 6: Graph of $RMSE^{Z}$ vs No. of GCPs

Figure 6 indicates that the $RMSE^{Z}$ will decrease with the number of ground control points in all laying patterns. Considerably low altimetry error is displayed in Edge and Star layouts. The lowest range of $RMSE^{Z}$ (0.02-0.035 m) is visible when 10 -15 GCPs are utilized in both layouts. In a construction survey, not only the altimetry error but also radial error is prominent. Similar to the altimetry error, Edge and Star layouts indicate a minimal radial error as illustrated in Figure 7. According to Figure 7 $RMSE^{XY}$ <0.05 m when more than 10 GCPs are used in Edge and Star layouts.

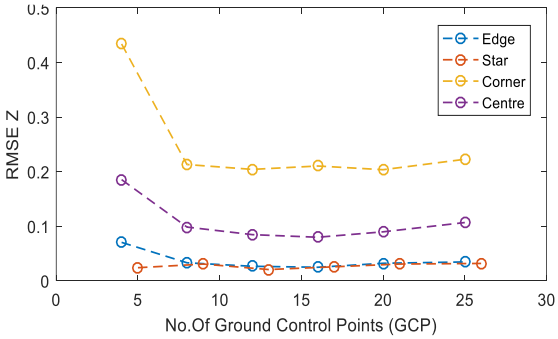

Figure7: Graph of $RMSE^{XY}$ vs No. of GCPs

IV. CONCLUSION AND RECOMMENDATION

It has been found that there is a variation of mapping accuracy based on GCP available for an aerial survey. The availability of more quantity of control points never increases the accuracy of the survey. So, it is concluded that it must be more convenient when laying GCP and selecting the best pattern to lay GCPs. According to the parameters used for the study, the findings denote that the quantity of GCP required for the maximum accuracy lie between 12-16 GCP. When considering the patterns, it is clear that GCP should be placed based on the edges and centre of the survey area.

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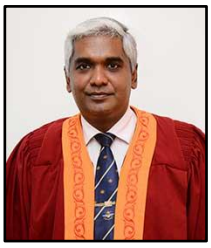

AH Lakmal is the current Dean of the Faculty of Built Environment and Spatial Sciences (FBESS) of General Sir John Kotelawala Defence University. He holds a Doctor of Philosophy from the School of Geomatics, Liaoning Technical University, People's Republic of China, Master of Science from Postgraduate Institute of Science, University of Peradeniya, Sri Lanka, and Bachelor of the Science (Surveying Science) from the Institute of Surveying & Mapping, Sri Lanka. His research interests include Spatio-Temporal Process Modelling, Location Based Services (LBS), Microwave Remote Sensing, Light Detection And Ranging (LIDAR) Remote Sensing, Generalization in Military Mapping, and UAV utilizations for Aerial Mapping.

ID 145

An Analysis of Suitable Location for Establishing Telecommunication Tower at General Sir John Kotelawala Defence University, Southern Campus

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Abstract— Wireless telecommunication is broadly utilized around the world and Sri Lanka, particularly due to increased use of mobile users, and the conversion of mobile phone into a primary essentiality of a person. High population density of the urban or suburban areas requires the establishment of telecommunication towers because the service providers consider low manufacturing cost and give maximum benefit. The telecommunication tower is the key device for supplying mobile users with a telecommunication network. The requirements of telecommunications towers are growing parallel to the growth of mobile users every year. This project aims to explore the coverage of the existing towers and to propose a new suitable location to establish a telecommunication tower that supplies the best coverage and capacity by optimizing the resources and cost-effectiveness. The study investigated Sooriyawewa area distressed with insufficient coverage from the existing towers for daily necessity, which causes the necessity to establish a new telecommunication tower. Data were collected from open-source platforms and the Survey Department of Sri Lanka, processed with ArcMap 10.5 licensed software. Population, Existing tower locations, Roads, Land use, Reservations, Elevation, Schools, and waterbodies were used as the data layers, and data was analysed using both vector-based and raster-based approaches in Geographical Information Science (GIS) environment. Conclusively, factor maps were prepared and the optimal locations were identified for establishing telecommunication towers, and validated with the existing locations.

Keywords: *coverage, telecommunication towers, service providers, Geographical Information Science (GIS)*

I. INTRODUCTION

The current situation in Sri Lanka highlights the rapid increment of telecommunication systems in the past decade. During the covid-19 pandemic period, the world changed their living patterns as new normal with referring technologies. Mobile phones have become the primary need of a person (Mauludiyanto, Prakoso, and Faricha, 2018). Students learn with e-learning methods, workers do their jobs online, etc. So, telecommunication fulfills huge service for developing the existence. According to the statistical overview 2020, Mobile Broadband Subscriptions (for 3G, 4G) is 11,484,649, and the Number of Cellular Mobile Telephone Subscriptions is 27,678,977 (Communications and Providers, 2020). The telecommunication tower is the key device for supplying mobile users with a telecommunication network. The requirements of telecommunications towers are also growing with the growth of mobile users every year.

The telecommunication service providers are highly concerned about the cost of the tower establishment and the population density of the required area. And, they consider accessibility for the towers, elevation, and weather conditions of the area. SLT (Sri Lanka Telecom), Mobitel, Dialog Axiata, Hutchison Lanka, Etisalat Sri Lanka, Bharti Airtel Lanka, Lanka Bell, Suntel are the service proving companies in Sri Lanka ('Sri Lanka - Telecoms, Mobile and Broadband - Statistics and Analyses', 2017). In the urban

areas, they use high-rise buildings for implementing telecommunication towers because it is a low-cost method.

Establish and maintain the telecommunication network is not an easy task and selecting a suitable location for establishing a telecommunication tower is a challenge. Because needs to cover the most demanded areas including the highest signal quality with low cost. Cost, technology, rules and regulations, spatial data are the considering factors for selecting a site (Janah A, Asassfeh, 2017). If unable to decide the suitable site, it may affect financial and economic problems, environmental damages, health issues, and customer satisfaction.

The purpose of this project is to evaluate the optimal site for establishing a telecommunication tower, near the Sooriyawewa area and validate the existing tower locations of the study area. Normally, the maximum high-quality coverage from a tower is 10km and there is no existing tower location in that range from the southern campus. So, that was the problem for our case study, and a 25km radius area from the southern campus was selected as our study area. The study area is covered with portions of Southern, Uva, and Sabaragamuwa provinces. There are special features in this area for the analysis. First, this area is flat, not consistent with higher geological barriers for disturbing the analysis, this is a dry zone (Senanayake, 2015) and not affected by environmental hazards such as floods, landslides. Second, normally the area is called a rural area, but nowadays it is changing.

Geographical Information Science (GIS) is used for examining the data and it is an efficient software that can do several analyses. It efficiently stores, retrieves, analyses, and displays information according to our purpose. The software can manage a large amount of spatial data from various sources and its saves time.

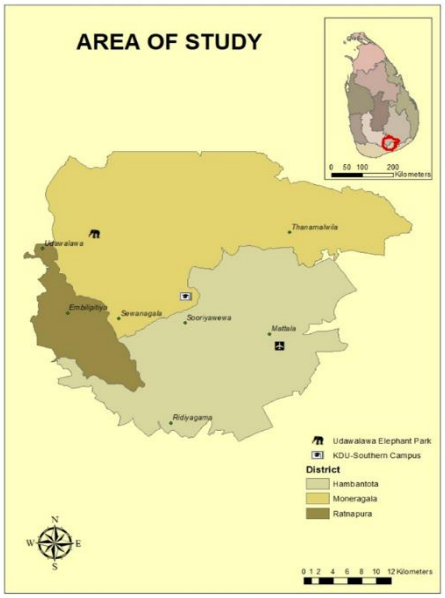

Figure 1: The Study Area

A. Significance of the Research

Lack of signal coverage and poor signal strength is caused to face a lot of difficulties for mobile users/ internet users who live around the Sooriyawewa area.

Sir John Kotelawala Defence University, Southern Campus is situated in Sooriyawewa, Sri Lanka, and the lecturers, Undergraduate students, and the other parties face some issues for their academic studies caused by the signal problems. This was the main problem what we observed. Due to the covid-19 pandemic period, lectures and school lessons are conducting through online education systems. So, the schools and the students around this area face the same problem, unfortunately. There are lots of important places around this area like Mattala airport, Mahinda Rajapaksa international cricket stadium, Sevanagala sugar factory, schools, public library, and hospitals. And there are some tourist attraction locations like Madunagala hot water springs, Ridiyagama safari park. Normally, the population density of an area is caused for establishing telecommunication towers. Service providers highly concern highest population density and the huge network users for implementing telecommunication towers. Furthermore, we are unable to consider Sooriyawewa as a rural area due to people

frequent in this area daily and need a strong network connection for their issues. The project aims to select suitable locations for establishing telecommunication towers and provide proper mobile signal coverage for the users. In this case, 5km range is applied for existing towers, because towers have 5km range good broadcasting facility.

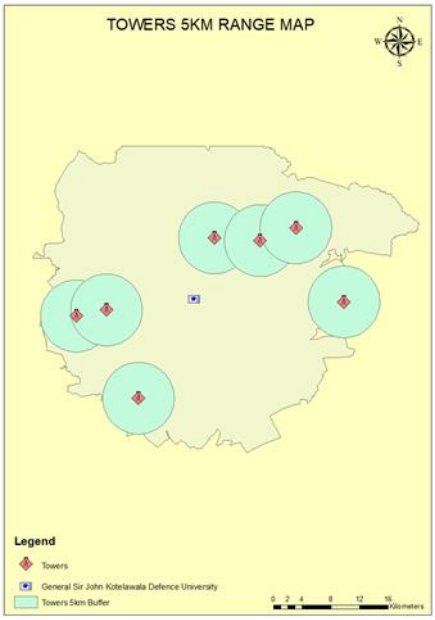

Figure 2: Existing Towers in 5km radius in study area

B. Research Objectives

To propose a suitable location for establishing a telecommunication tower with strong network coverage for General sir john Kotelawala defence university.

To examine the suitability of the existing telecommunication towers, in the study area

To evaluate the suitability of each land parcel for establishing telecommunication towers

II. METHODOLOGY

First, it was required to orient the data layers we are going to use for this research. However, for this research, we had to use buildings, hydrological features, land use, reservation areas, roads, GND map, existing tower locations, Digital Elevation Model (DEM), and finally the exact location of Kotelawala Defence University (Southern Campus). Initially, forming a 50m buffer for every building was important. Then we have erased the building buffer, hydrological features, and reservation areas from the area of concern layer and made a separate map for each layer. The next step was to extract suitable land area from the land use map. Also, a 500m buffer was created for the roads which consist of primary, secondary, and tertiary roads within the area. After obtaining the above-mentioned outputs, it was important to convert the vector data into raster data to conduct a weighted sum analysis.

Since we have obtained a result for the weighted sum, it was important to consider the 5km buffer from university premises. Thereafter, considering the ground elevation of this area to establish the telecommunication tower. Therefore, we had to obtain a result with the DEM values and the previous results obtained from weighted sum analysis.

Table 1: Efficient criteria and considering factors

Criteria	References
Transportation	(McGregor, 2016)
Population	(Tayal, Garg and Vijay, 2017)
Waterbodies	(Tayal, Garg and Vijay, 2017)
Land Use	(Tayal, Garg and Vijay, 2017)
Reservation	(Tayal, Garg and Vijay, 2017)
Elevation	(Tayal, Garg and Vijay, 2017)
Schools	(Katiyar, 2015)
Existing tower locations	(Sangeetha M, B. M. Purushothaman, 2014)

Getting reliable and timely information is one of the main criteria for rural development. Information on geospatial forms that allow different maps, GIS data and applications to be generated and used and details about Rural area that characterize the social and economic background, the physical environment and rural services and facilities are vital to rural area planning and development. The researcher (Singh, Bhatt, and Maheshwari, 2015) used Geographical information science to do the research and concerned about some factors.

- Availability of barren lands - telecommunication tower requires a certain area for the establishment
- Cost of construction - service providers highly concern about the expenses. Construction expenses, maintenance expenses, labour fees are the most common costs.
- Accessibility – the tower near to the roads is very important because of easiness of the repairs.
- Topography – before the establishment, one must concern about the topography whether it is suitable or not for the construction.

ArcGIS software has been used for this research work and the processing part. Used the DEM to obtain the elevation of the area and used digitizing and geo-referencing google earth data to obtain the data and convert it as shapefiles.

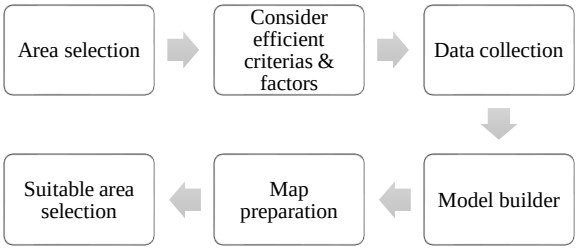

Figure 3: Methodology adopted over the Study

After getting all things done and bringing into the GIS platform, then data was analysed using weighted overlay analysis and the map of suitable locations were generated for tower establishment.

III. RESULTS AND DISCUSSION

Mainly open-source data that available freely used for the analysis integrate with the data provided by the survey department of Sri Lanka.

To collect the presently available towers and the range of them used google earth platform as a data collection source. Then by digitizing relevant tower locations data were obtained. There were several towers located throughout the area of study. However, there were not any telecommunication towers located within the 5km range to receive strong signal coverage. But for the reliability of our project, we had considered the towers situated nearby.

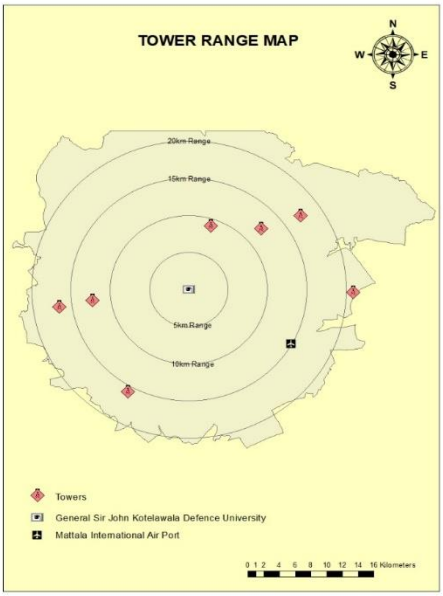

Figure 4: Existing Tower Range Map around Study Area

The Digital Elevation Model was a key factor when considering the elevation of the ground of the area concerned. We have used the Shuttle Radar Topography Mission (SRTM) DEM open-source data for the analysis as the elevation source of the study.

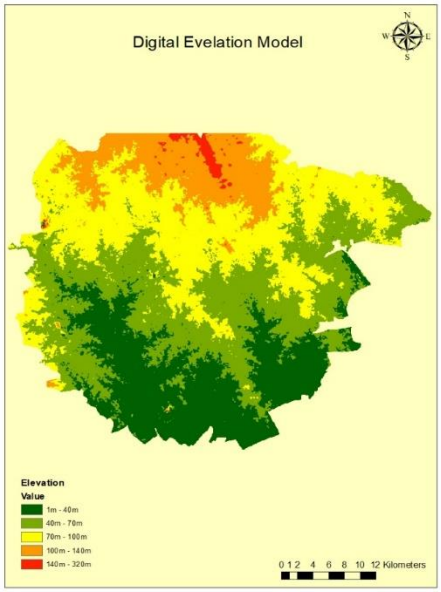

Figure 5: DEM of the study Area

The study area consisting of 104 GN divisions when considering an area of a 15 km circular path away from the General Sir John Kotelawala Defence University (Southern Campus). However, we had to consider the population increasing of every GN division as the mobile network providers are highly considering this factor when establishing a new telecommunication tower. We have found the census data related to these areas and found that the population has increased in every GN division over the years.

Figure 6: GN divisions over the Study Area

Then consider the water feature situated within the area. Since the telecommunication towers are built avoiding these areas as it is hard to reach the places and maintenance is highly costly.

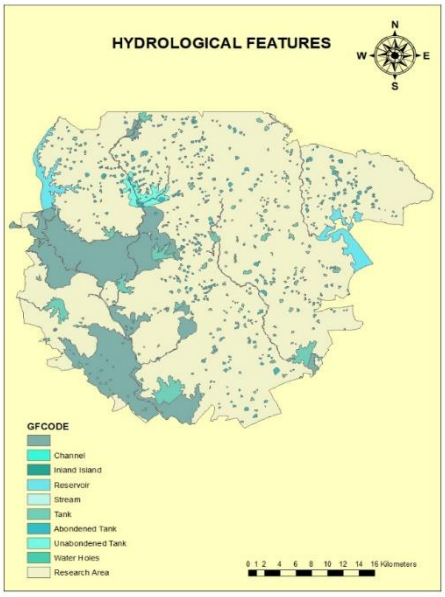

Figure 7: Hydrological Features associated in the Study Area

The study area consisting of different types of land use and while conducting our project, we had to eliminate several lands uses features to obtain better output. So, we had to restrict only to coconut cultivated area, chena, grassland, home garden, scrublands.

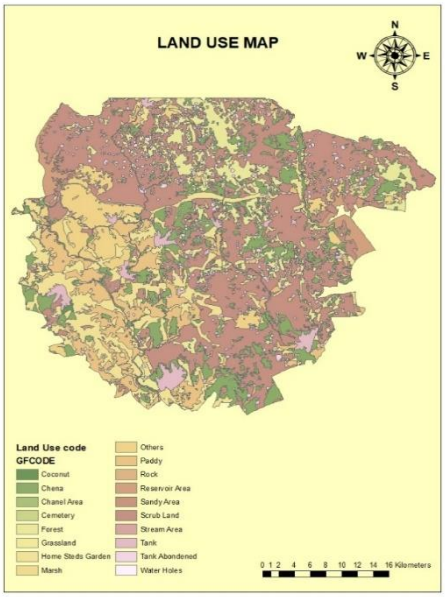

Figure 8: Land use Landcover types associated in the Study Area

The project area has mainly consisted of forest reserves. Therefore, as we were highly considered on environmentally friendly construction, we had to refrain from using forest reserved lands.

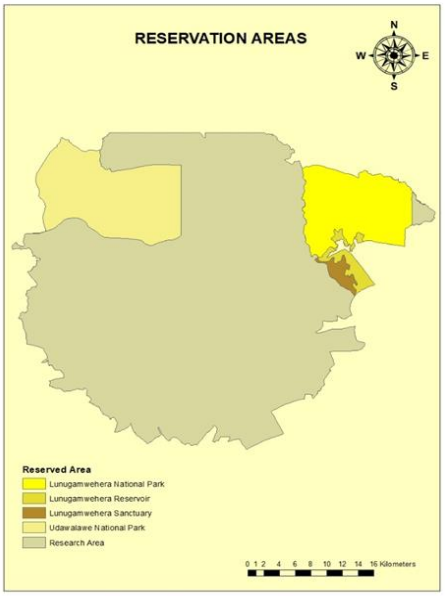

Figure 9: Conservation areas of the Study Area

Due to the pandemic situation arrived in the country, the education sector of the country has been shifting to a different level. Therefore, it is really important to have a better mobile 4G connection around the school premises. Since this quite deviates from the urban area, we have assumed that the students reside nearby the school and conducted the research.

Figure 10: The available Schools at the Study Area

The area of study has mainly consisted of a 20 km buffer zone around the headquarters building of General Sir John Kotelawala Defence University, Southern Campus. By using the weighted overlay analysis in the ArcGIS environment obtained a suitable location for establishing a telecommunication tower in the study area.

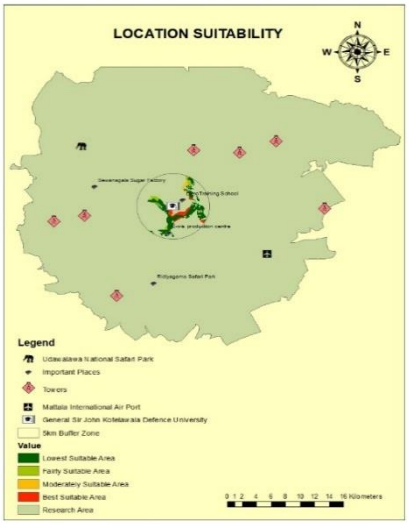

Figure11: The Location Suitability Map

After the analysis done with the respected data layers, it had given the idea that six out of seven of the previously located telecommunication towers were within the suitable locations. Therefore, it was an as important factor to prove that the procedure we had followed when conducting this research was reliable.

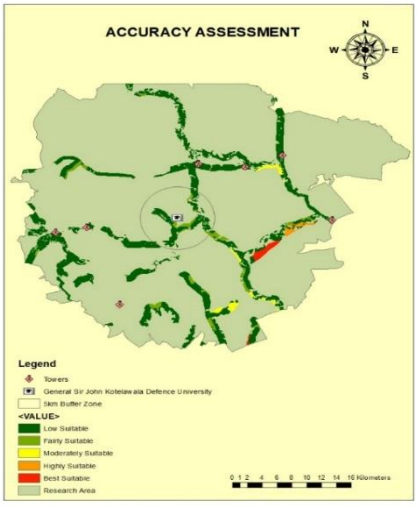

Figure 12: Check the accuracy of the resulted suitable location with the available tower locations around the Study Area

Further, it was crucial to consider the elevation factor when finding the best suitable location to establish the telecommunication tower. Therefore, it was obtained four areas with different suitability to establish the new tower.

IV. CONCLUSION AND RECOMMENDATIONS

This project includes how to select a suitable area for establishing a telecommunication tower around General Sir John Kotelawala Defence University, Southern Campus by using different criteria. The ArcGIS software is very useful for conducting this study. ArcGIS software is very convenient for students to use for their project works.

These areas generally satisfy the minimum requirements for site selection. If select the suitable areas for establishing a telecommunication tower, it will enhance and make easier the studies of the students who are engaged in their higher educations and also it will develop the study facilities of the schooling aged people who were disturbed due to COVID-19 pandemic. In this base of analysis, the suitable area was selected by giving a priority to the university students. But the best opportunity could be obtained up to 5km from the campus premises and others can also obtain the opportunity, but the quality may be varied with time and the number of users. Our idea was to establish a tower within the area owned by the University but, it was obtained outside of the university premises. But this analysis considers eight characteristics for selecting a suitable location for a telecommunication tower.

The progress of the development control needs to be monitored and evaluated annually and to take remedial actions to rectify incompatible development activities. For monitoring the application of the regulation within the zones need to analyse properly by the GIS tool. GIS is very helpful for analysing and make predictions. Zoning and their regulations and promoting or discouraging the activities need to do then and there with the evaluation of GIS.

In this study, there are some limitations. First thing, there is not highly different variants of height and there are not high-rise buildings. Therefore, not much consider about the elevation.

ABBREVIATIONS AND SPECIFIC SYMBOLS

GIS - Geographical Information Science

SLT - Sri Lanka Telecom

QC - Quality Control

QA - Quality Assurance

BTS - Base Transceiver Station

NDVI – Normalized Differential Vegetation Indices

3D – Three Dimension

RS – Remote Sensing

GPS – Global Positioning System

DEM – Digital Elevation Model

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A GIS Based Approach for Identifying a Suitable Location for Residence in the Ratnapura Municipal Council Area

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Abstract- When considering Sri Lanka, with the developments in the country, the infrastructure of the urban city areas is being developed year by year. As a result of these conditions, people in rural villages are moving to cities for a better future. With the increasing demand for urban areas, countries are facing the problem of finding the best place to live in urban areas. Available lands in urban areas are limited. Accordingly, the government of Sri Lanka has faced some problems in finding enough spaces for all citizens for establishing their residential places. . This study focuses to develop a method from GIS (Geographical Information Science) providing some facilities for finding suitable locations for the new residential areas with respect to the criteria people desire. The integrating with the GIS data layers of the real world and the criteria of the people, the GIS can be defined as better solutions for finding suitable locations for new residential areas. In this research, the Ratnapura Municipal Council (MC) area was selected as the study area and distance from the roads, water features, religious places, service buildings, new town, and the police station have been selected as criteria for integrating with GIS. To identify the new residential locations, the reclassify and weighted overlay functions of Arc GIS software were used. 0.25% area has been established as new residential places in the Ratnapura MC Area. The digital data layers used in this study were 1:10000. If it was scaled up to 1:1000 data layers, the accuracy of the result may be high. Further, the results accuracy too would be satisfiable as suitable areas were inside the existing high residential zone.

***Keywords**: GIS, spatial data, reclassify*

I. INTRODUCTION

The world is developing rapidly with technology and accordingly the living needs of the people on the earth are increasing. Not only for the developing countries as well as the developed countries have been facing the problem of population increasing. Because of increasing the population of any country they have to develop their cities as parts for the human accommodations. In Sri Lanka, most of situations the population are gathered to the main cities of every district. With the increase in infrastructure in urban areas, people are trying to move to urban areas. Figure 1 illustrates the increasing in the urban population of Sri Lanka from 2006 to 2017.

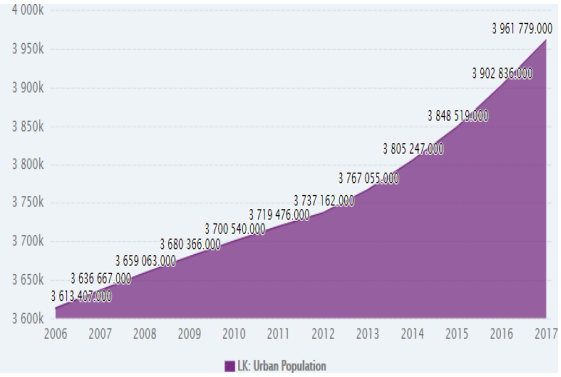

Figure 1.Increasing Urban Population

Source: Statistical Department of Sri Lanka

When increasing the urban infrastructures in the city area the people who are in rural areas are moving to the urban cities for getting better future. Therefore, the government is facing some difficulties in finding residential housing for the growing urban population. Due to limited amount of land in city area there are not enough spaces for finding the residential for every people in separate lands. So the solution to this problem is to find the most optimal locations for residential areas within the city limits and build

new high-rise residential buildings. It will be a best solution for the finding the newly residential places for the people who are coming from rural villages to urban cities. People are searching some factors for establishing their residential such as transportation, education, electricity, and distance to facilities as supermarkets, ground variance and land use.

GIS (Geographical Information Science) acts important role for finding best suitable location by using geospatial data analyzing. One of the most useful application of GIS for planning and management is the land use suitability mapping and analysis (McHarg, 1969; Hopkins, 1977; Brail and Klosterman, 2001; Collins et al., 2001).GIS provides some visual interface with coordinate systems for overlaying different geographical features such as road network, land use, water features, distance with infrastructure facilities as spatial data layers. Figure 2 describes GIS Suitability Map.

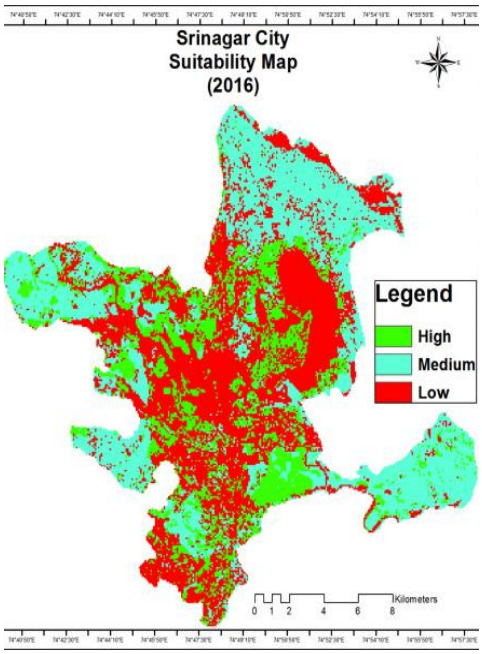

Figure 2.GIS Suitability Map

Source: Internet

GIS provides some most flexible functions for creating and decision making process to urban planning. When considering the decision making process for finding the suitable location approaches. GIS has some capabilities, such as buffer zone generation, criterion classification, and weighted cover functions. Ratnapura MC Area was selected as study area for this research. The selected area is located in the Ratnapura District of the Sabaragamuwa Province. Figure 3 describes area of Ratnapura MC Area.

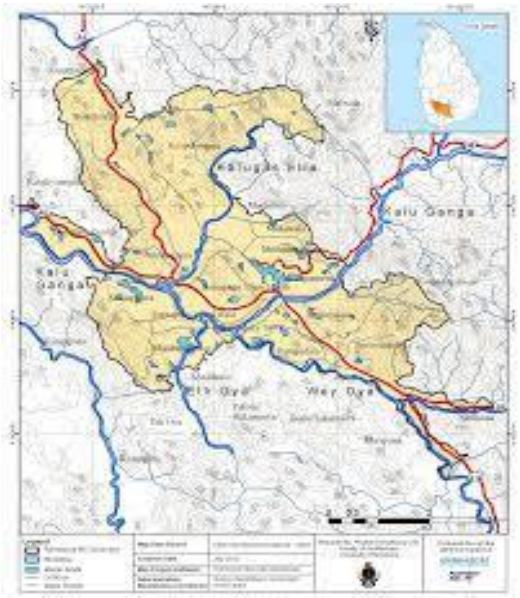

Figure 3.Ratnapura MC Area

Source: Urban Development Authority

The urban population of the Ratnapura urban area is increasing year by year and the city is merging with buildings and people are looking for new places for residential areas. Figure 4 describes the population in Ratnapura.

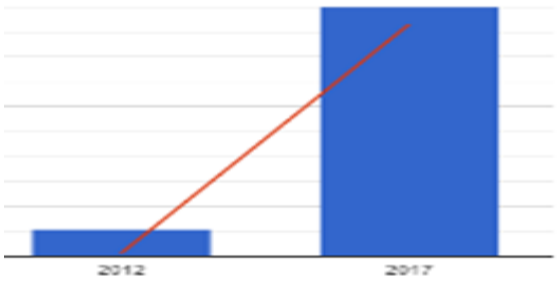

Figure 4.Population of Ratnapura

Source: Statistical Department of Sri Lanka

There is a project which regenerating the Ratnapura town area in another place and it is called Ratnapura new town Project. With this Situation finding the suitable location for newly residential place in Ratnapura MC Area is very important factor to reducing urban population compactness in future. Because of increasing

infrastructure facilities like schools, Transportations and other facilities people who are in rural villages in Ratnapura district but have middle income try to find the residential places in Ratanpura MC Area. So such kind of research is very important for the urban planners for developing the urban cities which not being compactness of urban population in future. The main Objective of this research is finding the newly residential location for urban planning and sub objective of this research is creating GIS models for decision making process for finding the suitable locations.

II. METHODOLOGY

The digital spatial data layers from Survey Department of Sri Lanka was used for creating the real situation in Ratnapura MC Area details. Several criteria in GIS were used for finding the suitable locations for establishing newly residential place in Ratnapura area and they were distance form road, distance from water features, distance from religious places, distance form schools, supermarkets and hospitals, distance from government service buildings and as well as the distance from police station. Euclidean distance zones and buffer zones were created for all the data layers and the reclassify them under the statically data of the criteria. For finding the criteria, questionnaire survey was conducted for the city people. According to the willingness of the people the criteria were scaled. Weighted overlay was used for finding the best locations for establishing newly residential areas. The flow chart in figure 5 describes the steps taken to perform to finding the best suitable location for establishing the newly residential area in the Ratnapuara MC area.

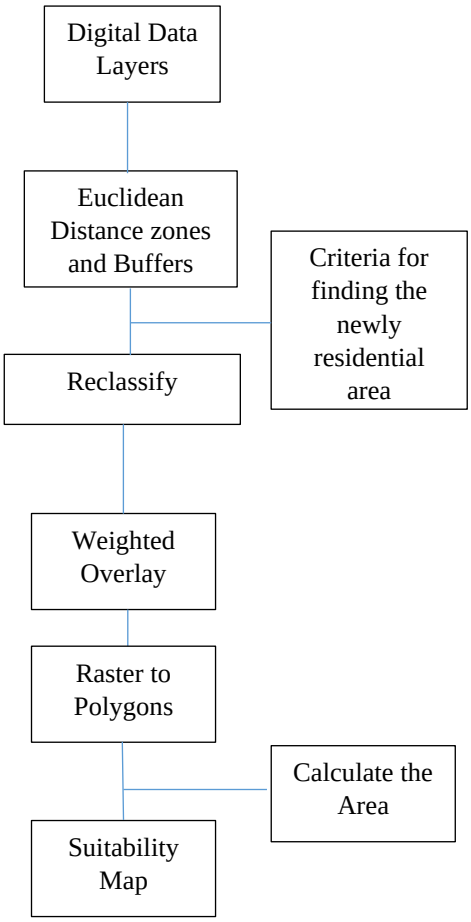

Figure 5. Flow Chart

A. Digital Data Layers

Vector format of road layer, water feature layer, school hospital and supermarket layer, religious places layer, new town layer, government service building layer and police station layer were overlapped for finding the place for newly residential area. Figure 6 of result and discussion is described the digital data layers as a map.

B. Criteria for finding the newly residential area

Comments of sample of thirty people who are coming to Ratnapura city from the villages for doing their jobs were selected for identifying which factors about people need to fulfill for selecting the residential location in Ratnapura MC Area. Those people were working in government and non-government agencies and they were 30-45 years old. Distance from roads, water features, government service buildings, religious places, schools, hospitals and

supermarkets, police station and new town area were selected as their criteria for finding the residential location. Ten people have selected distance from the road as the first choice and as well as the eight people have selected distance from water features as their first choices. The criteria which would be needed to selecting the newly residential location was scaled with respect to the choices of people. Table 1 describes the scales of the criteria.

C. Reclassify and Weighted Overlay

Analytic Hierarchy Process (AHP) method has been used for finding the weights of each criteria for the research. Basically scale of the criteria was used for calculating the weights values. The number of classes was defined according to the condition of each criteria. Four classes were defined as reclassify classes. Table 2 describes the weights.

III. RESULTS AND DISCUSSION

Table 1. Scales of the Criteria

Criteria	Conditions	Scales
Distance from Roads	<10m 10m-100m 100m-1000m >1km	1 4 3 2
Distance from Rivers	<100m 100m-500m 500m-1000m >1km	1 2 3 4
Distance from Schools-Hospital-Supermarkets	<50m 50m-500m 500m-1000m >1km	1 4 3 2
Distance from Religious	<100m 100m-500m 500m-1000m >1km	1 2 3 4
Public Buildings	<100m 100m-500m 500m-1000m >1km	2 4 3 1
New Town	>100m 100m-1000m 1000m-2000m >2km	3 4 2 1
Police Station	<500m 500m-1000m 1000m-2000m >2km	1 2 3 4

Table 2.Weights of Criteria

Criteria	Weight (%)
Road	29
Rivers	23
Schools-Hospitals-Supermarkets	18
Public Buildings	13
New Town	11
Religious Places	03
Police Station	03

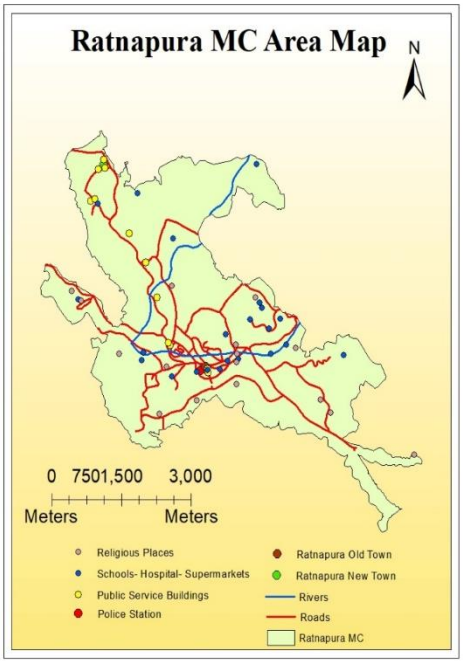

Figure 6. Ratnapura MC Map

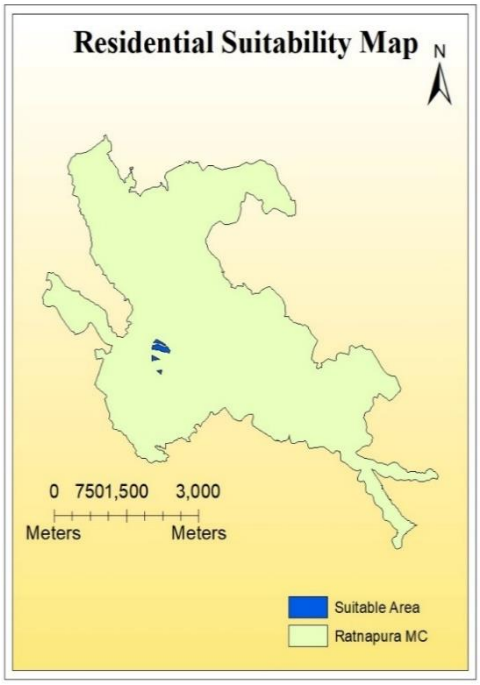

Figure 7 Residential Suitability Map

Figure 8. Area Validation

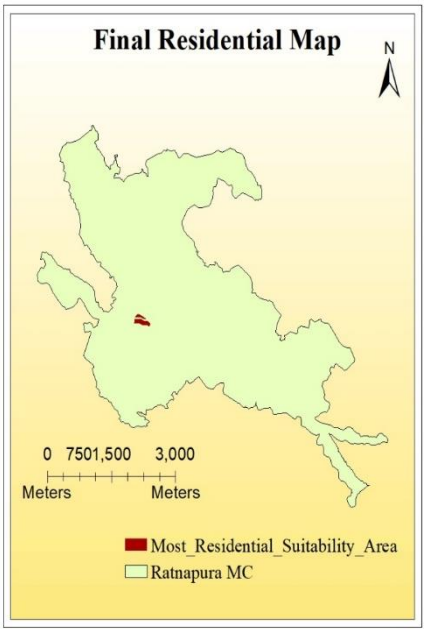

Figure 9. Final Residential Map

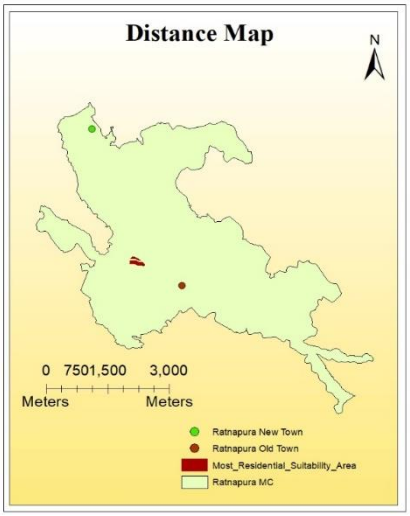

Figure 10. Distance Map

When considering the suitable locations, it describes in figure 7 for establishing the newly residential area. When considering the sizes of the area, it was eliminated the area which is less than 500m^2 according to the choices of the people. The total area of Ratnapura MC Area is 22453678m^2 and suitable area for residential location was calculated as 56220m^2. The percentage of the suitable area with respect to the total area of Ratnapura MC Area is about 0.25%. After checking the accuracy of four isolated parts of the suitable residential areas with ground truth data from field verifications, the number 1 and number 2 parts were confirmed as more accurate locations. The final residential map is described in figure 9 the more accurate locations for newly residential locations and it is about 44531m^2. The distance to suitable residential location from Ratnapura old town is less than from new town.

IV. CONCULSION

The accuracy of output result of this study was increased due to consideration of more number of criteria. In testing the accuracy of selecting suitable locations in the Arc GIS with respect to the ground observation data, it was most satisfactory. The elevation of the area was not selected as a criteria by the target group. The reason for that may be, people are living in hilly areas in current situations. When examining from the Google map, some houses are about 200 feet with respect to the main road. The scales of all digital data layers were 1:10000 further if there was 1:1000 data the final output would be more accurate. Although most of features which were considered as criteria for finding the suitable location, the best locations were shifted here to closer to the Ratnapura old town area than the new town area. It is described in figure 10. When considering number 1, 2, 3 and 4 in figure 8 Area Validation, number 3 area is not applicable for residential because of it is situated close to the reservation of the Kalu Ganga and number 4 area is situated in existing building area. The distance from water features has been considered as main criteria by people for finding the suitable locations for their residential places. The suitable location is mostly away from the water features. The best suitable location is situated closer to the public service buildings and very famous schools like as Aloysius' college, Seevali college and Ferguson college. As future recommendation, if it was considered about the flood levels and areas of crimes, sometimes the final result may be changed to good accurate point of view than this.

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I have Studied BSc Surveying Sciences (GIS and Cartography). I have an interest for visualizing environmental problems by using GIS and cartography. Arc GIS provides very important mapping environment with cartographic visualization for spatial mapping. Here I have prepared a Residential Suitability Map for urban planning.

ID 622

Implementation of Collaborative Procurement Method to Sri Lankan Construction Industry

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Abstract— Construction procurement methods have developed for decades under four main categories to address different financial arrangements, different relationships between parties, different project delivery methods and to suit the client's requirements. The joint venture, partnering, alliancing and voluntary agreement were developed as sub-categories of Collaborative Procurement Methods (CPM). Currently, these methods are being practised all over the world considering the benefits it provides whereas less practice in Sri Lanka (SL) due to plenty of barriers. This study explored the current procurement practices in SL, implementation possibilities and barriers for successful practising of CPMs in the country. Further, proposals for mitigating the identified barriers are also recognized through this study. To achieve this aim, a comprehensive literature review, a questionnaire survey and a semi-structured interview survey were conducted. Less awareness of the concept and associated benefits, the government's promotion of traditional procurement method, and issues in trust-building among parties were identified as the foremost barriers for the successful implementation of CPMs. Moreover, the findings implied the requirement of cultural changes in Sri Lankans to experience these new procurement practices, challenges and to develop trust between parties within the construction industry.

Keywords: *Collaborative Procurement Methods (CPMs), construction industry, joint ventures*

I. INTRODUCTION

Construction industry counts as a cornerstone of any country's economy (Rameezdeen and De Silva, 2002). Solomon and Byung-Soo (2018) stated that the complexity of the construction industry gradually increases due to its extensive nature, involvement of high number of stakeholders and multifaceted newer projects, contractual relationships, distribution of responsibilities and authorities between parties, scope of allocated duties, and uniqueness of the construction products.

According to Naoum and Egbu (2016), construction procurement methods have been developed regularly to manage growing challenges in the industry and thus it can be identified as a systematic mechanism of linking parties together in means of functionally and contractually, to deliver a successful construction project. Additionally, Solomon and Byung-Soo, (2018) argued that the selection of a suitable procurement method helps to avoid problems and leads to a successful project through the achievement of project specific goals.

Rameezdeen and De Silva (2002), Solomon and Byung-Soo, (2018), Wijewardena et al. (2013), recognized traditional, design and built, management-oriented and collaborative methods as four main types of construction procurement methods. According to the studies, the worldwide construction industry has shifted its focus away from traditional methods and toward alternative procurement methods, which take into account changes and challenges in the economy, time constraints, project complexity, and fund-raising issues, among other factors (Naoum and Egbu, 2016; Rameezdeen and De Silva, 2002; Ratnasabapathi et al., 2005; Wijewardena et al., 2013). Morledge and Smith (2013) explained that requirement to change supplier and customer relationship between

employer and contractor under traditional process in terms of avoiding confrontation and disputes lead to developing Collaborative Procurement Methods such as Partnering, Joint Ventures and Alliancing. Naoum and Egbu (2016) described the major advantage of collaborative method as technical and human resources, provision for parties to share their finance, which they cannot afford as a single party. Accordingly, it is evident that the use of collaborative procedures ensures that both parties involved in a contract benefit.

Despite the fact that the separated procurement method has a monopoly in the Sri Lankan (SL) construction industry due to government regulations, socio-cultural background, economic growth, and diverted clients' requirements, several other procurement methods such as design and build and joint venture arrangements have been partially established between 1977 and 2003. (Ratnasabapathi et al., 2005). According to Wijewardena et al. (2013), it is emphasised that practice of CPM is rare in Sri Lankan construction industry. the main reason for the unpopularity of CPM in SL has been identified as lack of awareness in construction industry and lack of standard contract conditions (Ratnasabapathi et al., 2005; Wijewardena et al., 2013).

Thus, this paper aims to investigate the basic requirements needed to implement CPM in SL. This paper is accordingly formulated as follows. First, a thorough literature review on types of CPM, its practice and barriers to implementing CPM is presented. Next, the research process containing the methodology of research and data analysis is elaborated. This is followed by the findings and conclusions.

II. LITERATURE REVIEW

A. Collaborative Procurement

Ratnasabapathi et al. (2005) pointed out that sharing assets and investments, optimizing design and commitments of all parties towards the success of the project as the principle of collaborative procurement. CPM further has been categorized as Partnering, Joint Ventures, Alliancing and Voluntary Arrangements (Solomon and Byung-Soo, (2018), Wijewardena et al. (2013). Moreover, National building specification (2019) added that collaborative working fulfils client's requirements by proportionately sharing responsibility, risk, reward and helps to eliminate possible disputes and possible cost and time overruns.

1) Joint Ventures (JV): Tetteh and Chan (2019) explained that construction joint ventures (CJV) are short-term and focus on resource collaboration to undertake procurement works, engineering, consulting, construction and construction management services. Badger et al. (1993, cited in Hong and Chan, 2014) stressed that the CJV differs from the alliance concept since it is a temporary, project-based agreement. With the support of the findings of Grab (1988); Sornarajah (1992); and Mohamed (2003), Hong and Chan (2014) stated that CJV can be classified either as (i) Integrated CJV (Parties agree to perform as a single entity having several stakeholders), and (ii) Non-integrated CJV (Parties manage separately and take-over their respective portions of the work distinctly) or (i) International CJV (JV agreements forming with multinational partners) and (ii) Domestic CJV (JV agreements forming with parties from a single country).

2) Partnering: Eriksson (2010) stated partnering as a method which incorporates multiple parties towards the success of a project through cooperative decision-making which focuses on admitting feedbacks for the development of the project. Challender et al. (2019) described partnering as business relationships formed among contract organizations aiming at acheiving common objectives and benefits. There are two types of partnering namely project partnering and strategic partnering, which have been differentiated considering the depth of partnering applicability (Ashworth and Perera, 2018).

3) Alliance: Ingirige and Martin (2006) stated that alliances provide opportunities for individuals, teams and firms to gain mutual benefit from sharing skills and resources, combining insights and understanding to reduce uncertainties and accelerate learning. an Alliance is a willingly initiated cooperative agreement between two or more firms who perform business activities. The Alliance is referred to

strategic partnering in the United Kingdom (UK) (Ingirige and Martin, 2006).

B. Global Practice of CPM

According to MohammadHasanzadeh et al. (2014) practicing partnering over a decade has significantly affected on performances of Iranian construction industry. Partnering practice in Iran is continuously increasing as construction clients implement CPM considering the conformity and benefits. Chan et al. (2004) showed that cultural and economic needs have paved the way to the adoption of partnering in the Chinese construction industry of Mainland China. Adding to that, Samantha and Singla (2019) stated that Indian government assists in implementing collaborative systems especially the CJV aiming at operational efficiencies and solutions to construction related problems.

Currently, contractors of the UK tend to engage with the CPM with the hope of high financial savings through reduction of risks and development costs. Clients also preferred to enter in to CPM considering the high response to customer needs, enhanced market opportunities and reduced construction development risks (Akintoye and Main, 2007). Accordingly, literature elaborates that the CMP has become a trend in the global construction industry considering its easy adoptability and highly benefited nature.

C. CPM Practice in Sri Lankan

Rameezdeen and De Silva (2002) had researched and concluded majority of public works procured under traditional method due to the barriers created through financial regulations and administration regulations, accountability aspects and transparency aspects. Due to the promotion, private sector had also practiced the same over that period, which made a barrier towards development of alternative procurement practices.

However, the SL construction industry abled to experiment with alternative procurement due to the economic growth of the country. Design and build became popular along with industrial growth, while CPM emerged with the involvement of international contractors in SL. Recent studies show an increasing tendency of local practitioners to enter joint venture/ partnering agreements with foreign contractors. (Ratnasabapathi et al., 2009; Wijewardana et al., 2013)Rameezdeen and De Silva (2002) had researched and concluded that alternative methods had been practiced in low profile while traditional method maintained a monopoly for years in local context. Further they added that majority of public works procured in measure and pay system due to the barriers created through financial regulations and administration regulations. Traditional procurement had widely applied for public projects by government up-to 2013, highlighting accountability and transparency aspects. Due to the promotion, private sector had also practiced same over that period, which made a barrier towards development of alternative procurement practices.

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D. Advantages Collaborative Procurement

Challender et al. (2019) highlighted that consultants and contractors tends to practice partnering considering the workflow security and trust, when client continues different construction projects. Probable benefits of collaborative methods may contain an increase in profits brought by shared expertise, efficiencies and improvements in decision-making through shared knowledge, cost reduction through sharing best practice, and increased levels of innovation (Hansen and Nohria, 2004). In addition, Wu and Udeaja (2008) showed lower transaction costs can be achieved through repeat tendering, earlier appointments, and general familiarity between partnering organizations. Furthermore, they explained that external forces may encourage greater collaboration between organizations where uncertainty, competition, program, and budgetary pressures are prevalent on projects.

Table 1. barriers to implement CPM

	Identified Barrier	Akintoye and Main (2007)	Angliger and Jenk (2004)	Bresnen and Marshall (2000)	Eriksson et al. (2008)	Kadefors et al. (2007)	Hasanzadeh et al. (2014)	Naoum (2003)	Wijewardana et al. (2013)	Zuo et al. (2013)
01	Lack of trust	x								x
02	Lack of commitment									x
03	Lack of training and experienced staff		x				x			x
04	Poor communication practice among team/ Poor consultation between parties	x								
05	Traditional construction process and procurement procedures				x			x		x
06	Laws and regulations				x				x	x
07	No specific guidelines and policies implemented by authorities					x			x	
08	Undefined roles and responsibilities	x								
09	Adversarial attitudes/ failure of individual relationships	x		x	x					
10	Focus on projects instead of processes				x					
11	Short-termism				x					
12	Delay in decision making							x		
13	Differences in partner's organization direction/ aim and goals		x							
14	Differences in partner's cultures	x					x			
15	Stakeholders not developing win-win attitude				x		x			x
16	Risk or rewards were not shared directly						x			
17	Integrity, ethics and cultural aspects				x					x
18	Lack of planning/ poor management	x								x
19	Lack of belief in the system	x								x
20	Lack of uniform implementation procedure									x
21	Integrity, ethics and cultural aspects				x					x
22	New competence requirements				x					

It could possibly explain why in challenging environments, companies may be more inclined to share information and achieve higher performance levels through partnering. Risk management under traditional procurement is problematic, especially when complex projects create greater risks for project teams, delays, cost overruns, and disputes. (Chan et al., 2004 and Challender et al., 2019). CPM could be applied to comfort such situations. Moreover, it enables

parties to improve their efficiencies by sharing knowledge, enhancing trust, reduce cost via best practice and sharing risk.

E. Barriers to Implement CPM Practice

Even though there are plenty of advantages, owing to barriers of implementing CPM, this procurement mode is not become more popular in some countries (Zuo et al., 2013). Lack of experience, lack of trust, lack of commitment by parties, lack of awareness in industry, consolation, cultural issue, higher risk, restrictions imposed by existing regulatory frame and lack of standard contract conditions were identified as obstacles for the development of CPM (Akintoye and Main, 2007). Table 1 summarised the identified barriers to implement CPM.

III. METHODOLOGY

A. Research Approach

There are three main types of research approaches as qualitative, quantitative and mixed methods. Saunders et al., 2016 stated that the quantitative approach employs to find solutions for a social/ human problem based on theory/ hypothesis, measured and analysed with numerical values. while Naoum (2007) stated qualitative approach emphasized on meanings, experiences and descriptions. Case study research, ethnography, action research and grounded theory approach are coming under qualitative approaches. the mixed approach is a combination of quantitative and qualitative data collection techniques and analytical procedures. This utilizes the strengths of both qualitative and quantitative studies and this combination provides a wider understanding of the research questions. Therefore, this study used the mixed approach as research method.

B. Data Collection

This research had gathered pertinent primary data initially through a questionnaire survey and secondarily conducted semi-structured interviews based on questionnaire survey results. A sample always represent and express the population. Hence it has to ensure thet the research sample contains characteristics similar to its population (Naoum, 2007). To get a worthwhile response, the questionnaire had been circulated among 45 people. Subsequently, five persons were interviewed. The target population was professionals working under contractors, consultants and clients who have experience of more than 03 years in the field.

C. Data Analysis

There are two methods to analyse the findings of research quantitatively; the descriptive statistics method provides a general overview of results, and the inferential method which focuses on the nature of relationship between two variables. Data collected through the questionnaire survey has been analysed using the frequency distribution method and presents through graphs, tables and figures. Data collected through interviews were recorded and analysed by content analysis and cross case analysis.

IV. DISCUSSION

A. Data Analysis of Questionnaire Survey

The questionnaire was circulated among forty-five (45) numbers of selected professionals and received thirty-five (35) responses. Table 2 displays respondents' experience in the construction industry. Out of the responses, fifty-seven percent (57%) was quantity surveyors, twenty percent(20%) was engineers, twelve percent (12%) was project managers and eleven percent (11%) was architects.

Table 2. Respondents' demographic profile

Category	Type	Responses	Percentage
Years of experiences	3-5 years	13	37%
	5-10 years	16	46%
	10-20 years	5	14%
	over 20 years	1	3%

Gathered data was analysed through the frequency distribution method under descriptive statistics. Two professionals among the thirty five (35) respondents were not aware about procurement practices in construction industry.

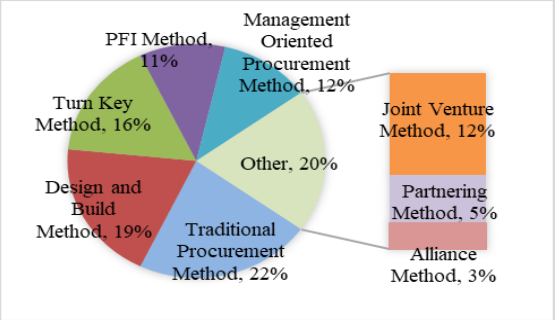

Figure 1. Current procurement practice in SL

Survey result for procurement methods which respondent experienced are illustrated in figure 1. Findings proved that integrated procurement methods including design and build method, turn key method and PFI methods are practiced in SL than the traditional procurement method. Moreover, it confirmed CPM methods are practiced in a low profile in the local context.

However, survey results showed only fifty one percent (51%) of the respondents had experience in CPM.

Table 3. Awareness about benefits of CPM

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Traditional procurement systems are timely effective than CPM systems.	-	21%	33%	42%	3%
CPM allow to share assets and investments only.	3%	18%	39%	39%	-
CPM could apply for projects where integration of modern technology requires.	15%	55%	27%	3%	-
Integrated Procument systems allows to share knowledge and experiences of professionals than CPM does.	39%	42%	18%	-	-

Requirement for an alternative procurement method in SL has been highlighted through the findings. Majority of the respondents deliberated building projects procured under traditional method do not fulfil financial, functional, and technical requirements of the client when completed. Further, they added that contractors do not have enough own resources to do the construction work in required quality within allocated time period.

Awareness of the benefits of CPM identified through literature survey was surveyed and illustrated in table 3. The table shows that the majority believe CPM methods are timely more effective than traditional methods. Further, they confirmed the necessity of trust among parties, commitment for work and communication within the parties towards successful CPM.

Furthermore, thirty-nine percent (39%) of respondents feel that CPM simply provides for the sharing of assets and investments, whereas eighty-one percent (81%) believe that integrated approaches allow for the sharing of professional knowledge and experiences. CPM helps parties to enhance decision-making, reduce production costs, boost creativity, and many other advantages by sharing corporate objectives, best practices, risks, resources, technologies, costs, information, and ideas, according to Akintoye and Main (2007) and Challender et al. (2019). CPM, according to Munns et al. (2000, quoted in Hong and Chan, 2014), provides for information communication, social interaction, effective knowledge sharing, and uncertainty sharing. The disparity between survey findings and literature reveals SL professionals' lack of grasp of the CPM concept.

A survey was undertaken to determine the most significant hurdles to CPM implementation in Sri Lanka. According to the findings displayed in Figure 2, lack of awareness was recognized as the primary obstacle to CPM implementation in SL, accounting for twenty-one percent (21%) of the total, while a lack of trust and prior experiences was cited as the secondary cause. Barriers included legal history, existing rules and regulations, a lack of communication and lack of commitment..

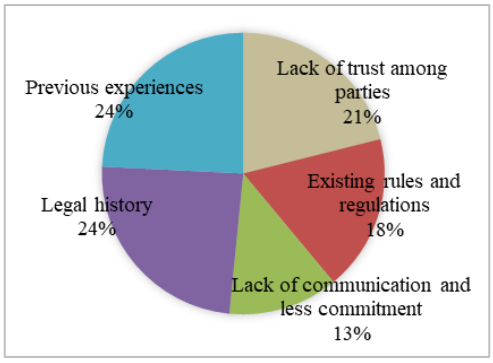

Figure 2. Barriers for implementation of CPM in SL

B. Data Analysis of Interviews

Subsequently, five semi-structured expertise interviews had been conducted on barriers of CPM identified through literature survey and questionnaire survey analysis. Data collected through interviews were analysed using cording method. Table 4 displays respondents' demographic profile. Forty percent (40%) had 10-20 years experiences in construction industry while sixty percent (60%) had over 20 years. Eighty percent(80%) of them had engaged with local CPM projects whereas the rest had foreign experience.

Table 4. Respondents' demographic profile

Category	Type	Responses	Percentage
Years of experiences	10-20 years	02	40%
	over 20 years	03	60%

All interviewees had recognized CPM as a suitable practice for an upper middle-income country like SL assuming that CPM will allow opportunities to bring in much-needed investments and financing. Further, they proposed that CPM would be ideal for building projects which exceed LKR 100Mn cost.

Further, they confirmed all barriers identified through the questionnaire survey are highly influencing factors. They added that lack of standard contract conditions, lack of experience, lack of awareness with in clients/investors, cultural issues, limitations in sharing internal data with partners, transparency and clarity in public sector projects and promotion of traditional procurement by public sector were recognized as barriers towards implementation of CPM in SL. The utmost significant factor is cooperating partners' failure to contribute to the partnership needs, goals and objectives as predictable. This is tracked by deficiency of trust among the cooperating partners and lack of frequent consultation between them.

It has been suggested barrier overcoming strategies to implement CPM in SL, such as improving public awareness through promotion campaigns/ workshops, reinforcing client resources, framework agreements, establishing clear legal procedure/ form of contract to CPM, promotion among subcontractors and suppliers and adopt necessary changes to legal arrangements and preparing framework to encourage alternative procurement methods in public sector projects. Additionally, they have recognized several barrier overcoming techniques practicing worldwide which could be applied to SL context, such as conducting frequent training sessions for involved parties, clearly defining responsibilities of both parties, and enhancing trust through high relevant competence. Collaboration amid construction project contributors necessitates mutual trust, involvement, common targets, commitment, joint problem and solving good communication. The attainment of long-term collaboration is highly reliant on cultural and attitudinal factors displayed by the participants.

V. CONCLUSION

The concept of CPM, its subcategories, advantages and disadvantages, worldwide implementation of CPM, barriers to implementing successful CPM and barrier overcoming techniques practicing in the world had been discussed through the literature review. Further, current procurement practices in the SL were also tried to identify using available literature. While modern procurement trends are developing in SL, alternative procurement methods have been developed for years. CPM has been introduced to infrastructure development projects, but so far, a minor percentage in practice.

It is imperative that alliances are sensibly deliberated to confirm that they fit interested in the commercial plans of the organisations which are allowing for arriving into partnerships. The barriers that the construction industry would contemplate cautiously and discourse already arriving into collaboration are opportunities to absence of trust; communication collapse; deficiency of confidence in the structure; clash of organisational principles; rigid approaches; deficiency of scheduling; fluctuating commercial goals; shortage of gratitude for contractual threats; client intervention; crash of characters; disputes not being determined; and absence of senior supervision provision. Certain aspects which are recognized to add to the attainment of partnerships in construction are a great level of commitment and reliance, capacity and enthusiasm to share possibilities among associates; reacting to clients requirements; worthy communication; appropriate properties; enhanced competence; and considerate singular characters of the companions.

CPM allows different parties/organizations to invest in a single development by sharing their resources, funds, technology, as well as risks while providing lots of benefits. Lack of awareness among public/ investors and industry practitioners about CPM concept has been identified as the key reason for less implementation of CPM. Lack of standard contract consitions, lack of trust among parties, cultural issues, lack of experiences and few other barriers are few other barriers identified. Professionals introduced industrywide promotional campaigns, framework agreements, establishing clear legal procedure to support implement successful CPM practice in SL.

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ID 638

Career Development of Young Construction Professionals in New Millennium: Application of Sun Tzu's *Art of War* Principles

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Abstract— The construction industry in the new millennium has shown a variety of challenges for young professionals. It is recognized that early career experience can play a significant part in lifelong professional capability, and the support and knowledge gained during the early years of post-graduate employment can influence future career direction and success. This study was conducted to identify the relevance of military strategies that are mapped with the career development of young construction professionals (Architects, Civil Engineers, Quantity Surveyors and Surveyors) while suggesting strategies to fill the barriers to career advancement. This study is based on the construction industry of Sri Lanka where a substantial number of young graduates enter the field not knowing the proper mechanism to build their future. The data collection was done through questionnaires and semi-structured interviews which were developed based on the Art of War. Data analysis was done by using both qualitative and quantitative techniques. It was identified that young professionals should have the inspiration to acquire the knowledge, skills and abilities of their peers by engaging deep job experience, adopting team member stance through professionalism and connectivity; handling office politics and conflicts effectively; maintaining flexibility and manoeuvrability; networking and soft skills. The outcome of the study elicits that there is a relationship between the tertiary education system and military strategies to the career development of young professionals. Therefore, it is strongly recommended to prepare a strategic agenda for the career development of young professionals by collaboratively working with the academia, industry and professional bodies, which is an important aspect to the individual, as well as to the organisational sustainability.

Keywords: *career development, young construction professional, military strategies*

I. INTRODUCTION

There are wide range of activities and professionals which constitute the construction industry, these include architectural designing and consultancy, quantity surveyor activities, engineering, surveyor activities, manufacturing materials etc…These different ranges of activities require variety of skills and cognitive abilities within the workspace of different professionals (Blokker et al., 2019).

Thus, this proves that the construction industry is a homogeneous field of work and is interlinked to one another. According to Charted Institute of Building (CIOB, 2006), during the recent decade's the forum of the construction industry has significantly diverse unless otherwise specified that the new forms of contract, methods of measurements, used of new technical tools such as Building Information Modelling, trends to deal with design and build contract, new trends for health and safety and much additional specialization and skills has emerged.

There is a problem in the construction industry as in order to meet the new demand, the current workforce has been changed, but still there has a skill gap of young people whom would be best fitted for the shortage of skill in the industry, thus it would be a threat for the future of the industry (Akintayo & Olubola , 2012). This proves there is a deficit in terms of skill and talent which should be developed by the young professionals joining the construction industry.

Silva, Rajakumara & Bandara (2007) identified that the Sri Lankan construction industry lacks in changing construction workload, unfair competition by overseas contractors, skills scarcities, and higher cost of developing skills.

Contribution of the construction industry for Sri Lankan economic takes the fourth place (Central Bank Report, 2005) so it is important to find the solution for each lapse behind the construction industry.

To mitigate the gaps and flaws courses to hinder the career advancement of young professionals in the construction industry, and to strategically face the specific challenges, application of Art of War strategies are being mapped into the context of career development of young professionals in the Sri Lankan construction industry.

A. Research Questions

Are there any gaps in construction industry for career development of young professionals?

How does the tertiary education learning process relate to the degree of developing careers amongst young professionals?

How can these gaps be filled by implementing the principles of Art of War for career development of young professionals in construction industry?

B. Research Objectives

The primary objective of the study is to identify strategies that could enhance the career development of young construction professionals in Sri Lanka. This integrates and foster significant additions that will help mitigate the problems faced by fresh graduates entering the construction industry through experimental learner cycle and Art of War principals.

C. Specific Objective

To identify the barriers that hinder the career development of young professionals in construction industry.

To identify the relationship between the learning process of the tertiary education system and career development to have stability within the construction industry.

To identify the means by which the art of war principles be used to fulfil the gaps in the development of careers of young professionals.

D. Significance of this Study

The graduate students, whose knowledge base is defined by the system of the tertiary education provided at universities. Thus, it is paramount importance to understand the learning styles of these students within the university curriculum. Thus, developing their careers based on the learning process provided at the university is significant.

II. LITERATURE REVIEW

Construction Industry in Sri Lankan Context

The human component plays the major role from inception to the end of the projects in Sri Lankan construction industry where it was found to be labour intensive (Widanagamachchi, 2013). The industry contributes significantly in economy of Sri Lanka. The new urbanization patterns and town concepts are being identified and mega projects are being pre planned (Wedikkara and Devapriya, 2000).

Modern Conceptions of Career

Career has significant change during the last decades due to several industrial impacts and demand. The word career has evolved through the traditional terms with 'vocation' or 'occupation'. The modern concepts of career have widely discussed through two forms 'boundaryless career' and subjective career'.(Adekola, 2011).

The modern demands it reveal that careers as the process by which a person's work experiences over time (Low and

Martin, 1995), and "the individually perceived sequence of attitudes and behaviours associated with work-related experiences and activities over the span of the person's life (Dainty, Bagilhole and Neale, 1998).

Career Development

Career development is a process which includes psychological, sociological, educational, economic, and physical and chance factors that connects to outlines the individuals career progression over the work life period (Ling and Lee, 2012).

Garavan (1990) defines career development as a way of accomplishing long-term match between individuals and the organisational goals. Garavan stated that an organisation should pay attention and should make preferable steps to analyse the individual abilities, interest, and plan activities to uplift the employer's career. Actual career development activities differ from firm to firm.

Young Professionals in the Construction Industry

Management of young professional's success within the labour market features a dual effect, which consists of mutual employee benefits, on the one hand, and companies on the opposite(Vanin, 2015). The young specialist receives because of a stable job, worthy material compensation, and thus the likelihood of fulfilment as knowledgeable and personal. The company additionally receives an employee with a high degree of loyalty to the interests of the organization, increasing the productivity of labour specialists, reducing employee revenue, and a full revelation of human talents (Bingham, 2013).

Barriers for Young Professionals in Construction Industry

Bozionelos (2001) determines there are two types of career barriers for construction professional as internal and external barriers. He describes the internal barriers as internal conflicts which hinder the career advancement. (e.g., motivation, self-concepts, skills and career goals, family issues, limited support, and time) and external barriers as "unfair attitudes, sex-role casts and intolerant practices in the workplace that hinders the career development of young construction professionals".

Experimental Learning Theory

Learning from past experiences is one of the greatest skills. Many scholars have shown that the base of each and everything we learn lies in experiences. (Lewin, 1951). The Experiential learning cycle reflects on four modes to grasp and capture and transform the experience (Weinberg and Weinberg, 1990). These four stages include-

Concrete Experience (CE)

Abstract Conceptualization (AC)

Reflective Observation (RO)

Active Experimentation (AE)

In the processes of stage development and individuality is manifested. According to Kolb (1998) he says that development is a multi linear process and it drastically differs from Perry (1996). In Kolb's theory he uses a spiral analogy to show individual change.

Experiential learning is a widely used model in the field of education, it defines experiential learning as "the process whereby knowledge is created through the transformation of experience. Knowledge is acquired by the experiences the learner is exposed to and translating the experience into meaningful learner friendly attributes.

By using the experience, learners are urged and encouraged on a reflection of the things they experienced, and this reflection is used to generate news patterns of thinking, skills, and positive behaviours.(Tener, Winstead and Smaglik, 2001). Chapman et al. (1995) put forward nine features that experiential learning procedures must contain:

A combination mix of theory and practice.

The learning environment should promote individuals to bring out their self-identity through a protected environment

The experiences the learners engage in is meaningful for their progress.

There should be a link between the process of learning and on what they are doing within the context.

Opportunities for reflection.

The students should be embedded with their experience on an emotional level and not proceed with the task for the sake of doing it.

The values and standards of their needs to be re-examined.

The relationship between the students and teachers should be healthy and meaningful and in turn the relationship these two groups have with the learning environment it is set need needs to be fulfilling as well.

The students learning procedures and abilities need to be exposed beyond their comfort zones.

Application of Experimental Learning for Career Development of Young Construction Professionals. Construction industry will seek for professionals with capabilities of managing the resources, achieving the set objectives, heading the projects to success (Jan, 2010). Identifies that traditional curriculums of construction professionals consist with certain gaps in

engineering methods, scheduling, and planning, analysing, and estimating, concepts and theories (Naismith, Robertson and Tookey, 2017).

The tertiary education requires to provide the necessary professional practice for the construction undergraduates in education, experience, and personal attributes (Ayres, 2006). Institutes must draw the attention to prepare the undergraduates the reality of the industry hence identify the new trends and paths to success. Undergoing the current construction educational programmes shows that there are several inclusions as per the new content of the industry (Sturges, 2013).

Sun Tzu's Art of War

The art of war is a book written by a Chinese military general Sun tzu in 400 B.C. This book is categorized into 13 chapters and has been translated and simplified by many scholars for readers to understand it properly (SF Lee, P Roberts, WS Lau, 1996).

These same strategies used can be used for business operating activities as well up to some extent. For this reason, only Sun Tzu's art of war has been more popular with the business entrepreneurs in the modern-day society

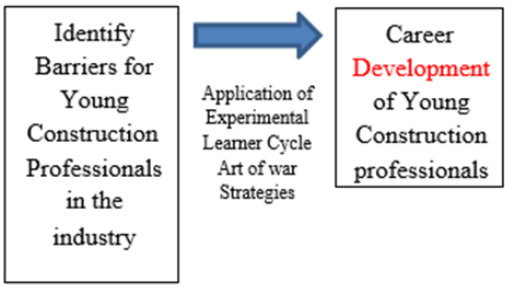
(Ling and Lee, 2012). No matter what the era Suz Tzu's principles has always been revolving around his doctrine which focuses on psychological barriers, environmental disharmony, personal agreement, and organizational contention (Michaelson and Michaelson, 2003).

Application of Military Strategies to Civil Society

Ling and Lee (2012) has identified the fact military strategies can be used for construction operations since it bears a common objective. Just like these most of the scholars have been using Sun Tzu's war strategies for construction activities (Tan, Lee and Lim, 1998). He has also told that practicing these strategies help you in negations which is fruitful for construction professionals. Further from that Lee (2012) have compared military personnel for construction professionals and accordingly commander to manger/management, warfare for competition, army troops for employees and the enemy as competitors.

Sculli (1998) stared the market as the battlefield where firms are fighting to seize consumers by pushing construction professionals to use these military strategies for construction firms. Many literatures have been written according to the strategies of Sun Tzu's Art of War, but a few have focused on marketing strategies (Hee and Gurd, 2010).

Research Gap



The study contributes to identify the barriers of young construction professionals in the industry whom with 1 to 3 year of experience. In addition, to full the barriers above military strategies are used. This also provides a framework to implement an experimental learner program for the tertiary education. It has identified that tertiary education will be the basis for the knowledge of young construction professionals.

III. METHODOLOGY

A. Conceptual Framework

Variables of the study for this research was identified as;

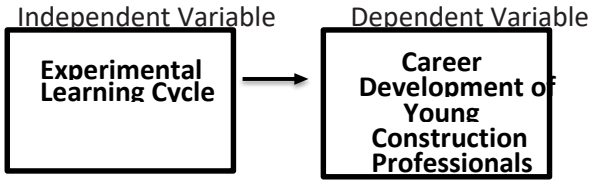


Figure 1- The Conceptual Framework

Source: (Literature review)

Population

Table 1: Stratified Sampling Size

Groups	Age	Percentage	Architects	Civil Engineers	Quantity Surveyors	Surveyors
A	23	6.25%	12	22	16	14
B	24	11.03 %	14	46	42	19
C	25	17.95 %	8	98	48	43
D	26	18.86 %	31	84	54	38
E	27	21.78 %	42	103	52	42
F	28	24.52 %	41	148	39	41
%		**100%**	**148**	**501**	**251**	**197**
Final Sample		**60**	**7**	**28**	**14**	**11**

Table 2: Population and Sampling

Objective	Population	Sampling	Sampling Technique	Reference
1	All Expertise in the construction Industry (Architect, Civil Engineers, Quantity Surveyors, Surveyors, and Project Managers)	12	Purposive Sampling	Kolb (1984) Stokes (2007)
2	1097	60	Stratified Sampling	Jayawardane and Gunawardena (1998)
3	All Expertise in the construction Industry	12	Purposive Sampling	Ling and Lee (2012)

Source: (Author, 2021)

This research is based on the construction industry professionals and the data were gathered through target population as the young construction professionals who have just stepped into the construction industry of Sri Lanka. These young professionals are working as Architects, Civil Engineers, Quantity Surveyors and Surveyors within the construction industry. The target population for this study included the young professionals who have just stepped into the industry with an experience of 1 to 2 years within the construction industry

Table 3: Data collection Method

Objectives	Data Collection Method	References	Analysis Method
01	Semi-Structured Interviews	(Wedikkara and Devapriya, 2000)	Frequency Analysis
02	Questionnaire	(Kolb, 1984)	Pearson's Correlation Co-efficient
03	Questionnaire	(Ling and Lee, 2012)	Relative Important Index

Source: (Author, 2021)

IV. RESULTS AND DISCUSSION

The questionnaire, which was finalized through the inventory, elaborates the experimental learning cycle was then distributed and gathered the data from young construction professionals in the industry. Questionnaire was sent to 86 young professionals in the above-mentioned professionals and out of that 60 responses has received.

A. Analysis the Data for Research Objectives

Table 3: Career Development Barriers

	No	Barriers	Frequency
Career Development of Young Construction Professionals	A	Insufficient career preparation	10
	B	Conflict among peers and career demands	8
	C	Not enough work experience	3
	D	Lack of appropriate education	7
	E	Disapproval by significant others	6
	F	Decision-making difficulties	8
	G	Dissatisfaction with career choice	9
	H	Job market constraints	6
	I	Inadequate relationship and networking	8

Source: (Author, 2021)

Objective 01 - To identify the barriers that hinder the career development of young professionals in construction industry.

Objective 02 - To identify the relationship between the learning process of the tertiary education system and career development to have stability within the construction industry.

B. Pearson Correlation analysis

This analysis was best suites hence it is based in covariance and gives the facts on the magnitude of the correlation, as well as direction of the relationship. The below mention table mentioned the displays a correlation between career development of young professional and experience learner cycle with the facts of concrete experience, reflective observation, abstract conceptualization and active experimentation (Tener, Winstead and Smaglik, 2001) .

Table 4: Pearson Correlation Analysis

Correlations			
		AIV	ADV
AIV	Pearson Correlation	1	.997**
	Sig. (2-tailed)		.000
	N	60	60
ADV	Pearson Correlation	.997**	1
	Sig. (2-tailed)	.000	
	N	60	60
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 5: Strategies for career development

No	Strategy	% of Frequency					Relative Index	Rank
		Very Unimportant	Unimportant	Neutral	Important	Very Important		
1	Career Planning	0	0	5	16	19	0.870	1
2	Strategies to advance in career	1	3	7	13	16	0.800	3
3	Leadership	0	0	7	15	18	0.855	2
4	Flexibility	0	3	9	13	15	0.800	3
5	Relationship and Networking	0	0	12	22	6	0.770	7
6	Information	1	2	4	25	8	0.785	5
7	Office Politics	0	3	12	20	5	0.735	8
8	Handling Conflicts	1	1	9	19	10	0.780	6
9	Leverage	3	4	11	10	12	0.720	9

Source: (Author, 2021)

Objective 3 - To identify the means by which the art of war principles be used for filling the gaps in

the development of careers of young professionals.

V.CONCLUSION AND RECOMMENDATIONS

Determination of barriers which revolves around the young professionals in the construction industry were identified. Semi-structured interviews were conducted with12 experts who has sound knowledge in field of construction industry. In detailed analysis was carried out and analysis method used was frequently analysis which caters to identify the significant barriers among the table. Significant and a positive corelation between the dependent and independent variables are tested using the descriptive statistics analysing tools. It was determined that the Experimental learning cycle has a positive impact on the career development of young construction professionals. So, the hypothesis was test and alternative hypothesis was taken hence it was revealed from the results that there is a relationship between the variables. The relationship only be prevailed if the value for the significant is less than 0.05 where the table show that vale is (0.000). To examine the final objective of the study, semi structured interviews were conducted from 12 expertise in the construction industry who has sound knowledge on *Art of War* and its application to the industry. Through the literature it was identified the art of war principles in the context of career development. And from the expertise it was revealed that 9 most important strategies which can be useful to enhance the young professionals career development in the context of Sri Lanka. Frequency analysing method was used to analysis the most important strategies and further the context analysis was used to present the data gathered from semi structures interviews. In overview of the study is that, the research objectives are being covered and the strategies to enhance the career development of young construction professionals in the industry are being identified which will help to resolve the research problem clearly.

A. Recommendations for Short Term

Application of the proposed Art of War strategies to career development.

Maintaining respectable interpersonal relationships and networking in the industry.

Being flexible in working

Participating to continuous professional development programs

Effectively analysis of construction personnel and organization.

Handling Conflicts

Career advancement through developing soft skills

Taking feedback from expertise on career development.

B. Recommendations for Long Term

Implement the experience learner cycle for tertiary education.

Young professionals must cater with leadership qualities

Improvement of Work life balance

Professionals must plan for their goals to achieve.

C. Limitations and Recommendations for Further Studies

The study was qualitative in nature where it was focused on the young construction professionals in the industry. Effective career strategies were identified; hence, the fresh graduates can adopt these military strategies to enhance their career development. It was elaborated in the earlier chapters that career advancement is similar to dealing in a war scenario, where winning is a significant factor via strategy to win is required. There also may find some strategies were missing since the interviews were avoid sharing some personals views and strategies which might affect to their competitiveness in the industry. I have identified some further research areas which will increase the pool of knowledge in construction industry. Role of career counselling in tertiary education of Sri Lanka

Application of art of war strategies to construction risk management.

Career advancement of military engineers.

Application of experimental learner cycle to all the constructional studies.

Correlation in career advancement and job satisfaction.

Role of career counselling in tertiary education of Sri Lanka.

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Study of Quantity Surveying Roles and Skills Requirement under Green Building Development in Sri Lanka

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Abstract—With the development of the construction industry, modern Quantity Surveyors diversify their roles as cost managers and perform multidisciplinary job practices at present. Green building is one of the recent trends in the construction industry. There is a tendency to adopt green concepts to building construction in Sri Lanka. When adopting green technologies to the buildings, a significant reformation to design, procurement, construction, and management processes is required. Therefore, the skills and activity requirements of construction industry professionals need to evolve with this recent development. Accordingly, this research attempted to identify principal quantity surveying duties and skills that continually evolve with the green building construction practices. At the outset, a detailed literature review and three preliminary interviews were carried out, and seven core skills and twenty-five roles of a quantity surveyor were identified that possibly to be influenced by green building development. Then, a questionnaire was formed and tested the same among fifty cost experts who work closely with the Green Building Council of Sri Lanka (GBCSL). At the time of the questionnaire survey, 76% of the experts responded, and later, the Relative Important Index (RII) formula was used to analyze the research findings.The ultimate results revealed that the ability of a quantity surveyor to appraise is the topmost skill requirement under green building development. Moreover, the results further denoted cost planning/controlling and bills of quantity preparation of green building as the prime quantity surveying activities to be performed as a cost specialist of green construction projects.

Keywords: *green buildings, quantity surveyor, skills*

I. INTRODUCTION

Construction is a mammoth industry all around the world that has a significant impact on the environment, economic and social development (Chan et al., 2009). The necessity for higher environmental consideration in the context of sustainable development has been confirmed by many governments, businesses, organizations and individuals (Cole, 2000). Consequently, sustainable development enhances quality of life and allows people to live in a healthy environment and improve social, economic and environmental conditions for present and future generations. (Chan et al., 2009). Hence, there is a consideration on how to acclimatize construction practices, in order to mitigate their negative impacts on the natural environment Holmes and Hudson (2000), Cole (2005), Pahwa(2007). The green building concepts develop and run simultaneously with sustainable development concept. Sustainable development means the development that meets the needs of the present without compromising the ability of future generations to meet their own needs and green building is a part of the concept of promoting sustainability (GBCSL, 2010)

According to Kats et al. (2003), major resources like energy, material, water and land use to construct green buildings more efficiently than conventional buildings and it will contribute to the improvement in employee health, comfort and productivity. Kats et al. (2003) further denote that green buildings help to achieve financial benefits during life cycle of the building in long-run.

Eventually, Sri Lanka as a country also adopt sustainable practices. To achieve the sustainable development goals in the country, the government of Sri Lanka developed a national programme named "Haritha Lanka" (GBCSL, 2015). As Abidin (2010) states, global interest on sustainability has increased steadily and therefore, the concept of green construction has emerged in to Sri Lankan construction industry as well. The term 'green buildings' generally refers to the buildings which are certified by green building assessment schemes such as BREEAM (UK); LEED (US); Green Star (Australia); Green Mark (Singapore) and GREENSL (Sri Lanka). Recently, a growing number of Sri Lankan green buildings obtain green certifications from the Green Building Council of Sri Lanka according to the Environmental Classification Systems for green buildings (GBCSL, 2009). One of the remarkable certified green building constructions in Sri Lanka is MAS Thurulie factory at Thulhiriya which became the winner of Globe Award for Sustainability Innovation 2010 (MAS Holdings Ltd, 2010).

However, according to Construction Holcim Foundation of sustainable (2009), the initial cost of construction of green factory building in Thulhiriya, Sri Lanka was 30% higher than the construction of a conventional factory building in Sri Lanka. Then a client may ask a question whether is it worthwhile to spend more money for the construction of green buildings than conventional buildings and that has to be answered by a quantity surveyor. Consequently, green building development is much more worthy and have future benefits in terms of economic, environmental and social dimensions (Waidyasekara, 2016).

According to the definition provided by the New Zealand Institute of Quantity Surveyors (2014), Quantity Surveyors are the construction cost professionals who measure and estimate the cost of resources for construction projects, and whose role have been laid among others to keep the projects within the budget, compromising the required quality and time. However, in 21st Century QS role has expanded to work with wider responsibilities in all stages of the building life cycle from project initiation, through design, procurement, construction, commissioning of the finished building, and to upgrade, convert, modify or alter of the building in the consuming phase (Ma & Luu, 2010).

The role of the quantity surveyor has therefore widened beyond measuring and estimating of the quantities and costs of the building project to include maturing roles such as project management, contract administration, dispute resolution, insurance and valuation. Ashworth (2011) depicts that modern day QSs play complex roles such as loss adjustment, auditing, dispute resolution and expert witnessing, advising for whole life costing, cost benefit analysis, advising for sustainable construction and green building approach etc., in addition to overseeing the financial commitments relate to construction projects. These wider roles bring questions to QSs, whether it is still required to maintain the traditional designations of the profession since it limits the capabilities of modern day QS practice or there is a necessity of bringing traditional quantity surveying profession into a diversifying profession (NZIQS, 2014). Quantity Surveyors should be able to meet changing needs of the clients and to grow the market for quantity surveying services depending on the knowledge, skills and competencies based on the profession (Nkado, 2020). Therefore, Skill based assessment of Quantity Surveying Profession is relevant in the changing built environment.

According to Green Building Council of Sri Lanka (2015), there is a growing demand for sustainable construction in Sri Lanka and therefore, the number of green buildings certified per year is rapidly increased as illustrated in figure 1 graph. Moreover, there are 29 buildings in Sri Lanka awarded the green awards until the year 2015.

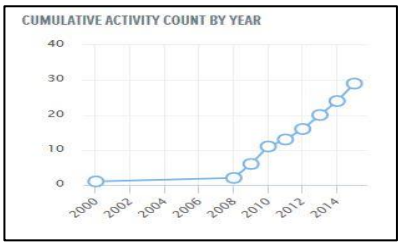

Figure 18: Rapid growth of green building development in Sri Lanka (GBCSL, 2015)

When adopting the sustainability principles into building construction projects, more changes to

be made to the design, procurement, construction and management processes (Chau et al, 2010). Concequently, construction industry professionals have often been experiencing challenges in moving from the traditional design and construction processes to a new method of delivery suitable for the green building development. Professional quantity surveyors are of no escape; they also have to keep up with the new trends in green building development. However, there's a gap in identifying the relavent quantity surveying practices that are to be evolved with green building construction.

Therefore, the objective of this research is to identify key quantity surveying duties and competencies that continue to be evolved with the green building construction practices.

Worldwide green building councils are trying to transform the construction industry towards green concept. According to Letchmiah (2015) modern quantity surveyors need to consider the driving forces of the green environment in which they operate (GBCSA, 2015). Green building council of South Africa (2015) have introduced modern roles to quantity surveyors in South Africa and that includes analyzing and advising on green capital costs, promoting the benefits of life cycle management, green financing, green leases, and cost-effective sustainable strategies. Quantity Surveyors involve the process of identifying and documenting all the costs involved over the life of an asset, which is known as Life Cycle Costing (Matai, 2021). The publication which investigating the financial benefits of green buildings (Smit, 2021) has been recommended that skilled construction industry experts such as Quantity Surveyors must consult and implement a general model pertaining to the various costing elements in green buildings. Moreover, online e-procurement which is practiced by Korean cost experts can be shown as a main tool for green procurement (Ali Hasanbeigi, 2020). Additionally, Quantity surveyors involve for comparing cost benchmarks such as $/m^2$ GFA against carbon benchmarks such as kg/m^2 of CO2 with carbon offset factors for green cover and carbon credits. (Min, 2021)

Therefore, Quantity Surveyor is one of the key stakeholders who contributes directly to the green building development (Ma and Luu, 2013). Role of quantity surveyor is diversifying with a greater tendency towards sustainable construction and green building construction (Maarouf & Hbib, 2011). Commercial management (of construction works) or Design economics and cost planning, Construction technology and environmental services, Contract practice, Procurement and tendering, Project finance (control and reporting), Quantification and costing (of construction works) Capital allowances, Commercial management (of construction works) or Design economics and cost planning (whichever is not selected as core competency), Conflict avoidance, management and dispute resolution procedures or Sustainability, Contract administration, Corporate recovery and insolvency, Due diligence, Insurance, Programming and planning, Project feasibility analysis and Risk management are the key areas of property and green building development which a Quantity Surveyor should be competent (RICS, 2018). By considering the above mentioned particulars, literature review and preliminary interviews outcomes, roles of a quantity surveyor having green construction influences can be listed out as in Table 1.

Table 1. Possible Quantity suryeyor roles required for green building development

Cost planning
Document preparation (Bills of Quantities)
Tender Documentation
Sub contract administration
Cost Engineering Services
Cost Control during construction
Preparation of financial statement
Risk analysis
Final Account preparation & agreement
Settlement of contractual claims
Advice on contractual disputes
Insolvency services
Procurement advice

Measurement and quantification
Working on green lease & green finance
Measuring of carbon footprint
Interim Valuation and payments
Investment Appraisal
Project management
Facilities management
Whole life costing
Value management
Environmental Services
Technical Auditing
Valuation of insurance purposes

In modern QS practice, roles and responsibilities of a Quantity Surveyor is diversifying with the development of sustainable construction practices. Accordingly, modern quantity surveyors have to improve the capabilities of managing maintenance costs, operational costs and life cycle costs, procuring green products and services, leases, Integrating information and green management systems (Letchmiah, 2015). Consequently, the skills requirement of a quantity surveyor cannot be limited and therefore ever improving.

As defined by Royal Institution of Chartered Surveyors UK (1992) core skills based of Quantity Surveying Profession can be identified as in the following Table 2.

Table 2. Core Skills of a Quantity Surveyor

Analysis
Appraisal / Evaluation
Communication
Documentation
Management
Quantification
Synthesis

II. METHODOLOGY

As the research topic is apparent, this research relies on primary data sources by collecting data from related professionals. The secondary data sources support for documentary evidences by responding to the research questions through published research articles, books, journals, conference papers and internet information sources…etc. (Chau, C. K.; Tse, M. S.; Chung, K. Y., 2010). As an initiation to this research, a detailed literature review was conducted. Here, available information from overseas sources is also reviewed in order to gain an adequate comparative perspective to achieve the objective.

Generally, a research methodology consists with research design and data collection methods. There are two types of data namely, Quantitative data and Qualitative data. Unlike qualitative research, quantitative research may be more familiar with and uses for numerical data collection processes, research designs and statistical procedures (Johnston, 2010). Moreover, quantitative method is used to gather data and opinions from a large group of people.

Here, a mixed method has been utilized. At the outset, key quantity surveing duties and competencies which are primarily influenced by green building applications were identified by conducting three priliminary interviews among senior quantity surveyors who had green construction experience. Further, a questionnaire was formulated and tested among 50 quatity surveyors & cost experts who closely work with Green Building Council of Sri Lanka. Among them, 37 experts responded and considered valid for further analysis. The rate of response is as cited in Table 3.

Table 3. Response Rate

Questionnaires delivered	50
Received Responses	38
Response Rate	76%

All the data obtained through primary and secondary data sources are inter-linked, summarized, analyzed and interpret the final outcome of the research for achieving the research objective and for making conclusions.

Though the responses in the questionnaire of this research are qualitative in nature, answers collected from closed-ended questions brought the same to a quantitative form by using a Likert scale as stated in Table 4.

Table 4. Likert Scale

Level of Importance	Scale
Extremely important	5
Very important	4
Important	3
Less important	2
Not important	1

Moreover, Relative Importance Index formula (RII) used to rank the duties and competencies. The same tool has been used by the Nkado (2001), Jhonson (2000), and Jayamathan (2005) for their researches and made significant results.

RII calculations are based on the following formula.

$$RII = \sum \frac{W}{A \times N}$$

Where:

RII – Relative Important Index

W – Weight assigned by the respondent

A – The highest weight

N – Total number of sample

Finally, Microsoft Excel and SPSS software were used as the data analysis tools in this research.

III. RESULTS AND DISCUSSION

As introduced by the New Zeland Institute of Quantity Surveying (2017) and (RICS, 2018) competencies are created with the amalgamation of Skills. Core skill base for Quantity Surveying profession with the development of green building concepts in Sri Lanka can be identified as in Table 5 and the results obtained through the analysis of questionnaire responses made by the experts.

Table 5: Skills required by the Quantity Surveyors working on Green construction projects in Sri Lanka.

Skills required by Sri Lankan Quantity Surveyors working on Green building projects in Sri Lanka.	RII	Rank
Appraisal / Evaluation	0.962	1
Quantification	0.962	1
Documentation	0.919	2
Management	0.908	3
Communication	0.892	4
Analysis	0.886	5
Synthesis	0.849	6

Moreover, quantity surveyor's duties identified through the literature review and preliminary interviews also tested with the use of expert's responses and the analysis results can be summarized as in Table 6.

Table 6: Quantity Surveying roles mainly influenced by green building costruction in Sri Lanka

Quantity Surveying roles mainly influenced by green building costruction in Sri Lanka	RII	Rank
Cost planning	1.000	1
Document preparation (Bills of Quantities)	0.983	2
Measurement and quantification	0.940	3
Tender Documentation	0.929	4
Sub contract administration	0.929	4
Procurement advice	0.913	5
Settlement of contractual claims	0.913	5
Cost Engineering Services	0.908	6
Preparation of financial statement	0.897	7
Risk analysis	0.897	7
Interim Valuation and payments	0.891	8
Value management	0.881	9
Cost Control during construction	0.875	10
Whole life costing	0.875	10
Final Account preparation & agreement	0.854	11

Valuation of insurance purposes	0.848	12
Working on green lease & green finance	0.848	12
Advice on contractual disputes	0.837	13
Investment Appraisal	0.827	14
Project management	0.794	15
Insolvency services	0.789	16
Measuring of carbon footprint	0.773	17
Facilities management	0.745	18
Technical Auditing	0.745	18
Environmental Services	0.664	19

After evaluating and ranking the received responses, 12 activities out of 25 provided in the questionnaire have been identified as the most essential roles of Quantity Surveyors under green building development in Sri Lanka as follows.

According to New Zeland Institute of Quantity Surveying (2017) and (RICS, 2018), Cost planning, Document Preparation (Bill of Quantities), and Tender Documentation are the key activities to be performed by a quantity surveyor under sustainable construction. Similar results can be observed in this research except the third rank. According to the results, Measurement and Quantification is the 3rd important activity to be performed under green building development in Sri Lanka. According to Matai (Matai, 2021), quantifications in life cycle costing is also important. Further, tender documentation is the fourth prominent role to be performed by a quantity surveyor in Sri Lankan green constructions.

According to New Zeland Institute of Quantity Surveying (2017) and (RICS, 2018), Cost Engineering services, Financial statement preparation, Risk Analysis, Agreement & Final Account preparation consecutively holds 6th to 9th places of the roles hierarchy. However in this research, Procurement advice, settlement of contractual claims, cost engineering services and preparation of financial statements are the other quantity surveying responsibilities claims 6th to 9th places in the order of ranking. However, green procurement advice is among the key duties of a modern quantity surveyor (Berry, 2011).

Settlement of contractual claims, advice on contractual disputes, insolvency services consequently ranked 10th to 12th position in New Zeeland Institute of Quantity Surveying (2017) hierarchy. According to the research findings, 10th to 12th positions of the activity hierarchy are held by Risk Analysis, Interim Valuation and Payments and Value Management.

IV. CONCLUSIONS

Though Sri Lanka is still a developing country, number of multi scale construction projects are carrying out at present. However, a considerable proportion of environmental pollution is evident with the works related to construction industry and building operation. Therefore, green adoption is very much essential to the present construction industry and professionals like quantity surveyors have to evolve their existing roles and competencies.

The Quantity Surveying is one of the leading professions which is evolving and diversifying its scope into new dimensions with the development of sustainablity and green building concepts. Professional and multidisciplinary job practices of Quantity Surveyors are generating from their core skills and activity base.

Difficulties behind green building adoption such as high initial cost, isuues in pricing of green materials, etc. may be the possible reason behind the selection of quantification and appraisal as the prominent skill requirements, and cost planning, controlling, and bills of quantity preparation as the key activity requirements of a quantity surveyor under green building development. The prominency of quantity surveying duties to be performed under the green building development is in the following order.

Cost Planning & controlling
Document preparation (Bill of Quantities)
Measurement and Quantification
Tender Documentation
Sub contract Administration
Procurement Advice
Settlement of contractual claims
Cost Engineering Services
Preparation of Financial Statements
Risk Analysis
Interim Valuation and Payments
Value management

However, key green concepts behind each of the mentioned Quntity surveying duties are required to analyse further in future research works. More researches have to be carried out to identify the possible reasons behind the skill & competency requirement under green building development by improving the number of responses and to generalize the findings.

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ID 410

Adequacy of the Advance Payment to the Contractor: A Study in Sri Lanka

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Abstract- Payments are essential for the contractors to maintain their constructions. The accelerations and the decelerations of the constructions will depend on the way that the contractor receivs the payments. Advance Payment (AP) is crucial for a contractor as it is the first payment received by the contractor to commence the construction, and it is an interest-free loan received by the contractor from the employer to start the construction. Even though there are research that discuss the payment procedures, recovery methods, and the benefits of the AP, there is a research gap on the adequacy of the AP to the contractor to complete initial procurements and preliminaries for the mobilisation. Therefore, the aim of this paper is to investigate the adequacy of AP made for the mobilisation activities of construction projects in Sri Lanka. Following a mixed-method research approach, a questionnaire survey including both open ended and close ended questions was conducted to collect data in the Sri Lankan context. The qualitative data were analysed through manual content analysis, whereas SPSS, and Relative Important Index (RII) techniques were used to analyse quantitative data. Many respondents claimed that the AP is not adequate, and the allocation of AP percentage should be done according to the project value and further, it was recommended to have a range of 20-30% from project value. Moreover, the study revealed that the adequacy of AP is entirely dependant on the way that the AP is utilised by the contractor. The study can be continued with the perspective of employers and the consultants as further research.

Keywords- *advance payment, adequacy, contractor, employer, utilise, construction, Sri Lanka*

I. INTRODUCTION

Advance Payment (AP) is a specific monetary payment (Cao and Zang, 2012). Furthermore, the authors stated that AP is made for the contractor's initial expenditure in accordance with materials, plants, labour, and a fair proportion of job overheads. However, this is an effective method to solve many financial issues of the contractors in developing countries (Rameezdeen et al., 2006).

In Sri Lankan construction industry, most contractors operate with a low equity base (Takhtaei and Karimi, 2017). According to Eyiah and Cook (2003), several limitations have affected the successful involvement of contractors in the industry. The absence of access to funding has become a significant constraint (Cao and Zhang, 2012). Eyiah (2001) found that contractors may not have an adequate collateral to obtain financial support from a commercial bank. Therefore, it is safer to have an AP for the contractors to stabilise and strengthen their financial health (Hussin and Omran, 2009).

There are many research conducted locally and internationally on the topic of AP by describing its benefits, and the problems incurred, when issuing the AP (Wijekoon, 2009; Rameezdeen et al., 2006; Hussin and Omran, 2009). Many contractors in Sri Lanka intend to utilise the AP for mobilisations and initial procurement as well. However, the AP should be adequate for the contractors to achieve its benefits. Even though the previous reserach discussed the payment procedures, recovery methods, and the benefits of the AP, only a limited number of research discussed about the adequacy of the AP to the contractor (Aje and Adedokun, 2018; Aje, Olatunji, and Olalusi, 2017; Cao and Zhang, 2012; Hussin and Omran, 2009). Nonetheless, there is

no consensus on the adequacy of AP in the Sri Lankan construction industry. Therefore, the aim of the study was to investigate the adequacy of the AP for the mobilisation activities of construction projects in the Sri Lankan construction industry.

II. LITERATURE SYNTHESIS

This section included definitions, importance and purpose of AP, process of issuing AP to the contractor, way of recovering the AP, benefits to the contractor from the AP, challenges faced by the contractor due to AP and the factors affect for the utilisation of AP.

A. Definitions for AP

AP is described as an interest-free loan issued for the contractor to complete the mobilisation (International Federation of Consulting Engineers [FIDIC], 2017). Moreover, AP acts as the monetary value that is given by the employer to the contractor with respect to the Works to be done in the construction (Abubakar, 2004). CIDB (2008), identifies AP as a simple advance that is given for the contractor as a part of the Contract Sum while the remaining is paid after the completion of the works. Rameezdeen et al. (2006), described AP as the monetary value issued to the contractor by the employer for the initial expenditures in terms of mobilisation activities and preliminaries. Hussin and Omran (2009), described that the AP is a payment given for the main contractor by the employer for participation in the construction activities and complete the performance under the Contract.

B.Importance and Purpose of AP

According to Akanbiemu (as cited in Aje and Adedokun, 2018), AP is a policy that is introduced by the Federal government of Nigeria in 1979 to make relief for the local contractors from the financial burden. Hussin and Omran (2009), identified AP as a great support for the contractors to reduce the financial problems that can occur during the commencement of the construction. Further, the author explained that one purpose of the AP given for the main contractors as of giving advances to the subcontractors. The AP which is given by the employer to the contractor will be able to release the contractor from the financial incapability and assist the contractor to mitigate the difficulties that occurred during the period of mobilisation as expressed by Coggins (2011). Elazouni and Gab-Allah (2004) and Hussin and Omran (2009), have stated that i) reducing the financial burden of the contractors, ii) assisting the contractor in taking the challenges of project mobilisation, and iii) helping the smaller or newer contractor company to compare with the mature contractor company as the main three purposes of issuing AP by the employer to the project contractor.

C. Process of issuing AP to the Contractor

AP will be issued by the Employer within 14 days after submitting an unconditional guarantee by the contractor in which value is similar to the value of the AP and valid until the AP is repaid as stated in the contract document (Rameezdeen et al., 2006). Further, the authors have stated that the value of the guarantee is progressively reduced while the amount is repaid by the contractor. Employers calculated the AP as a percentage of Contract Sum by reducing the provisional sums and the contingencies upon the submission of AP guarantee by the contractor (Construction Industry Development Authority [CIDA]/ Standard Bidding Document [SBD] 2, 2007). The total value of the AP and the details about the installments are included in the Contract Data (CIDA/ SBD 2, 2017) and Appendix to Tender (FIDIC, 2017). According to CIDA/SBD 2 (2007) and FIDIC (2017), AP Certificate is issued after submitting the Performance Security (PS) and the AP guarantee by the contractor and the guarantee has to be issued by an institute which is approved by the Employer.

D. Way of recovering the AP

AP is recovered or repaid from the Interim Payment Certificates (IPCs) as percentage deductions (CIDA/ SBD 2, 2007). According to FIDIC (2017) and CIDA/ SBD 2 (2007) deductions would be started from the first IPC issued after releasing the AP. Deductions are made from the IPC to recover the total value while the total payments have been reached for 90% of the Initial Contract Price (ICP) without the value of provisional sums (CIDA/ SBD 2, 2007). However, when the AP has not been recovered until the issue of Taking Over Certificate (TOC) or before the Termination of the Contract by the Employer, Suspension and Termination by the contractor or Force Majeure

in accordance with the situation in the construction project the remaining value has to be paid immediately for the Employer by the contractor (FIDIC, 2017; CIDA/SBD 2, 2007).

E. Benefits to the Contractor from AP

AP provides a huge support for the contractors in the construction industry to stabilise them in the construction projects. Accordingly, AP provides access for the small and medium scaled contractors who have awaited effective participation due to the lack of financial capabilities (Eyiah and Cook, 2003). Greater support has been given by the AP to manage the cash flow by utilising the capital at the commencement of the projects (Maravas and Pantouvakis, 2012). However, informal security for the payments of the contractor is given through the AP by the Employer (Aje and Adedokun, 2018). Moreover, AP provides benefits for the contractors such as solving the problems related to the delay payments, speeding the process of construction, managing the risks, ensuring the quality of works, and motivating the contractors for their performances (Hussin and Omran, 2009).

F.Challenges faced by the Contractor due to AP

Contractor has to face various challenges while receiving and utilising the AP as described in this section.

G. Misuse of AP

Contractors can handle more than one construction project at the same time and as a result, the need for money is higher with the contractors to balance their construction activities (Hansen et al., 2017). Accordingly, the contractor would allure to use the AP for the needs of other construction projects and sometimes for non-construction activities as well (Choi and Kim, 2014).

H. Difficult to obtain the AP guarantee

Employers issued the AP after submitting the unconditional on-demand guarantee by the contractor from a commercial bank which has been approved by the employer (Akinseinde and Awolesi, 2015). The bank will issue a guarantee for the contractor by investigating the assets of the contractor to certify that the value of the assets is similar to the value of AP provided by the contractor (Schulz et al., 2015). Sometimes, the small and medium scaled contractors have difficulties while seeking the AP guarantee as they have not enough assets to value (Abubakar, 2004).

I. Additional cost

Even though, AP issued as an interest-free loan it would cause an additional cost for the contractor in terms of money and time (Sherif and Kaka, 2003). The contractor has to prepare and maintain bank documents to obtain the AP guarantee with the aim of acquiring the AP (Akinseinde and Awolesi, 2015). Accordingly, the contractor would have spent additional costs in relation to maintaining those documentations and they have to spend a considerable time in this regard (Aje and Adedokun, 2018). This challenge is highly affected by the small and medium-scaled contractors as they have less financial capacities to compete with other contractors in the industry (Rasak, 2012).

J. Factors affect to the utilisation of AP

Effective utilisation of the AP can be identified as a common problem that can be met in the construction industry. Some of the researchers believe that inadequacy of AP is occurred due to the impacts of the project environment (Memon et al., 2014; Ezeldin and Abdel-Ghany, 2013). Although, some other thought that inadequacy is caused due to the factors within and outside of the project which is irrespective with the building environment such as less assistance of the employer and extra control from the project outside entities (Love et al., 2015).

K. Internal factors

Aje et al. (2017) described that the culture of AP would cause overruns due to the inadequacy. Mainly, this would cause for the construction projects in which the design is incomplete or incorrect and while having reworks, delays, and extra costs (Love et al., 2015). Furthermore, the authors have stated that construction projects with complete designs also can cause overruns due to errors in documentation and often for delays, disputes, and extra works. When the different parties have been involved to manage their finance effectively, that can lead to a successful construction without overruns in the construction (Aje et al., 2017). According to

Olatunji (2010), there is both symmetrical and asymmetrical relationships between the employer and the contractor in the overruns due to the cost for the contractor can be the price for the employer. Accordingly, AP can influence several factors while utilising the payment with the construction (Aje and Adedokun, 2018).

Human resource management can be identified as another factor that can affect for the utilisation of the AP in case of having less motivated and dissatisfied staff (Love and Li, 2000). According to Olatunji (2010), when there are appropriate protocols with the staff to manage the performances with the resources, there would not be inadequacy in the payment. However, AP has been issued at the commencement to reduce the issues caused due to the price escalation of the materials and when AP would not be used properly which can be affected for overruns (Aje et al., 2017).

L. External factors

Apart from the internal factors of the construction projects, external factors can be affected for the overruns in the AP (Aje et al., 2017). Accordingly, the political environment related to the construction project, exchange rates, inflations, national income, and the monetary policies can affect the construction projects as external factors for the utilisation of AP (Baloi & Price, 2003; Olatunji, 2010).

III. RESEARCH METHODOLOGY

This research intends to answer the problem of "how does the adequacy of AP affect the contractors in the construction industry in Sri Lanka?" through a mixed method approach, as qualitative methods subsidies to implement systematic analysis on evolving beliefs and is more suitable, when the study has a trifling base of literature background and quantitative method useful to analyse the close-ended questions of a questionnaire survey. Fifty questionnaires were distributed among the staff members of the contractor organisations and 38 of them have been responded to the questionnaire to evaluate the adequacy of AP to the contractor. So that, the findings from the open-ended questions were analysed with the use of the manual content analysis method. The closed-ended questions were analysed using SPSS software and the RII ranking technique. The RII values were calculated by using the following equation.

$$RII = \frac{\sum PiUi}{n(N)}$$

Where,

n- Number of participants

Pi -Participant's rank

Ui- Number of participants ranking project factor

N- Highest rank

IV. RESEARCH FINDINGS

The findings gathered in the literature survey were included in the questionnaire survey and the respondents were asked to rank them according to 5 point likert scale. Further, they were encouraged to provide more factors relating to the Sri Lankan context as well.

A. Benefits of AP to the Contractor

Majority of the respondents stated that AP is the financial support for the contractor, which creates relief on them from the financial burden at the initial stage of construction projects. On the other hand AP gives an opportunity for experienced contractors as well as newer contractors to mobilise in the construction industry. More than 68% of respondents satisfied with the current recovery method. Table 1 presents ranking of benefits of AP to the contractor.

Table 1: Ranking of benefits of AP

Benefits of AP	Mean	SD	RII	Rank
Speed up the construction process	4.55	0.86	0.91	1
Solve the financial problem	4.37	0.75	0.87	2
Provide an interest free loan	4.37	0.75	0.87	2
Motivate the contractor	4.21	0.78	0.84	4
Manage the financial risk	3.74	0.69	0.75	5

Solved the problems related to delayed payments	3.39	0.89	0.68	6
Ensure the quality of the work	3.21	1.21	0.64	7

According to Table 1, 'speed up the construction process', 'solve the financial problem', 'provide an interest-free loan', and 'motivate the contractor' were identified as the top four benefits of AP by the respondents and RII value of each greater than 0.8.

B. Factors affect for the contractor on the utilisation of AP

Factors affect for the contractor on utilisation of AP according to the RII value are presented in Table 2.

Table 1: Ranking of Factors affect on utilisation of AP

Factors affect on utilisation of AP	Mean	SD	RII	Rank
Internal Factors				
Incorrect and incomplete design	3.76	0.79	0.75	1
Culture of AP	3.68	0.96	0.74	2
Documentation errors	3.37	0.94	0.67	3
Management of human resources	3.30	1.18	0.66	4
External Factors				
Monetary policies	3.92	0.75	0.78	1
Inflations	3.84	0.92	0.77	2
Exchange rate	3.53	0.89	0.71	3
National income	3.34	0.71	0.67	4
Political environment	3.18	1.04	0.64	5

According to Table 2, respondents believed that 'incorrect and incomplete design' and 'Monetary policies' as the main direct and indirect factors that negatively affect on utilisation of AP respectively.

The reworks and the extra works due to the incompleteness of the design will negatively affect the utilisation of AP. As a result of design errors, the purchases from AP will not suit to the design. Then, the AP will overrun and be inadequate to complete the initial works. Further, monetary policies are always affected by the financial works within the country. Similarly, it will affect the AP.

C. Application of advance payment in construction projects in Sri Lanka

All the contractors have applied AP as an interest-free loan for the commencement of the construction. The contractors in Sri Lanka are also using the AP to complete the activities of mobilisation by doing the initial procurements and basic preliminaries for the commencement of the construction projects as highlighted by many researchers. Accordingly, AP is used to maintain the balanced cash flow from the beginning of the construction. Moreover, the study reveals that in Sri Lankan construction industry, AP has been used for any work item that has to be fulfilled to commence the construction. However, the contractor has to repay the AP as agreed in the conditions of the contract. Misuse of AP, and utilisation of AP were identified as main challenges for contractors while using AP.

D. Adequacy of the AP

The responses received for the mobilisation activities of AP accepted as "sufficient" by 29% (11) of the respondents. Whereas 24% (9) of the respondents believed that the amount of AP was "not sufficient" and 47% (18) of respondents said that the adequacy of the AP will depend on the nature and the size of the project. Accordingly, 82% of the respondents are unwilling to change it. Moreover, the opinion of the contractors about the current allocation and the level of adequacy have been considered through the process of data collection according to the standard forms of contracts such as SBD1, SBD2, SBD3, and FIDIC red book. Accordingly, respondents view on the allocation of the AP based on the standard forms of contracts are summarised in Figure 1.

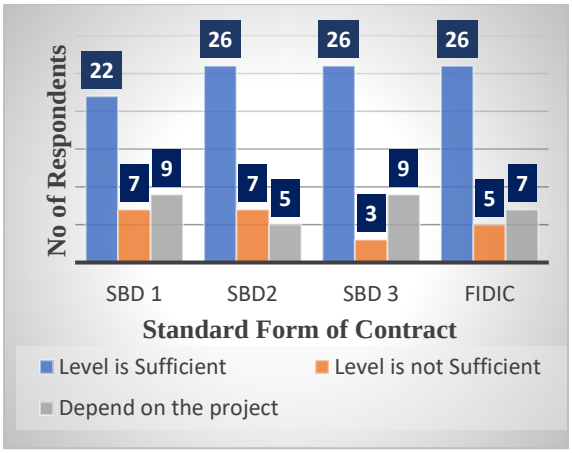

Figure 19: Level of satisfaction of AP as per form of contracts

According to Figure 1, around 60% of respondnets believes that existing AP amount is sufficient, where as some respondnets opined that it is not sufficient and the value of AP depends on the project value.

When considering the adequacy of AP, respondents have mentioned that it is the first payment for the contractor to mobilise, it should be at an adequate level. So, according to their views contractor and the Employer should negotiate and agree on a value that depends on the nature and the size of the project. Since the contractor has to maintain a better cash flow throughout the project, better consideration has to be given for the adequacy of AP. Majority of them believed that the value of the AP should be laid between 20%-30% of the contract sum. Further, respondents hope to have an amount of money that covers the initial cashflow of the project through the AP.

E. Recommendations to strengthen the AP procedures in Sri Lankan construction projects

According to the respondents, the AP has to be completely utilised by the contractor to get its maximum benefit in construction projects. It should be done in a planned manner by carefully monitoring the cashflow to reduce cost overruns.

The analysis included the respondents' reviews on the provisions given for AP in Standard Forms of Contracts as well. Accordingly, the industry practitioners were satisfied, dissatisfied, and stay as neutral by mentioning that it would depend on the nature of project and the mutual agreement between the parties about the procedures to be followed in AP. However, it has been suggested to use the formal methods mentioned in the Standard Forms of Contracts as the procedure of the AP without making adjustments for the procedure. Accordingly, responses were dissatisfied with the procedures that are followed besides the provisions in Standard Forms of Contracts.

Moreover, the respondents expressed that the AP should issue in an adequate percentage (which is not too low or too high) of the contract sum by considering the nature of the project as it is the initial financial support for the contractors to start up their workings by maintaining a better cash flow. So, before issuing the AP, it is better to consider the nature of the construction with the other environmental effects like social and political concerns. Further, the contractors should be able to utilise the amount received as the AP to achieve its maximum benefits and maintain a better cash flow.

V. CONCLUSION

AP is a significant payment received by the contractor from the employer to commence the construction works. There are standard procedures to be followed while issuing the AP for the contractors. However, the study has found that this would benefit in construction projects to speed up the construction process and solve the financial problems with some direct and indirect factors tht affect for the utilisation of AP. According to the findings, incorrect and incomplete designs and monetary policies are the major direct and indirect factors, respectively that negatively affect for the utilisation of AP. However, this study is limited only for the building construction projects, which used SBD and FIDIC as the form of contracts. This study will motivate the contractors to manage the amount received as the AP to maintain a proper cashflow and will provide knowledge on the benefits and the possible challenges laid with the AP. The study was conducted based on the perspective of contractors and it can be concluded that AP is adequate for the contractor for the mobilisation of his works at site. The research can be extended further to investigate the perspectives of employers and the consultants on the AP in construction projects.

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Developing a Cost-Effective Web-Based Communication and Information Management System for Construction Projects

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Abstract— Construction projects face several problems due to the lack of well-organized communication and information management within construction sites. The traditional communication and information management system in the site is almost run on traditional processes which makes the project delayed, misled and inefficient. Certain IT solutions have been introduced from time to time for the construction industry, and they are costly as well as do not exactly suit Sri Lankan construction conditions. Being a third world developing country, cost-effective solutions that suit the Sri Lankan construction conditions are essential. Therefore, this study aimed to develop a low-cost web-based application to communicate, make decisions, and handle information within a construction site matching the Sri Lankan construction conditions. A web-based application was developed (prototype) according to the collected expert ideas by considering their experience related to the construction sites in Sri Lanka. Semi-structured interviews were adopted to collect the relevant data, and content analysis was used to analyse them. Eventually, considering all of the above, a web-based prototype was developed to manage communication and information within the construction site. Minimizing contradictions within the worksite by providing a virtual platform to communicate with relevant parties, managing information by providing virtual document store in relevant locations, notifying tasks, etc. are provided as functions by the system.

Keywords: *web-based, communication, construction site, information management*

I. INTRODUCTION

The organizational communication simply refers to the exchanging information, ideas, particular knowledge, skill and the technology within the team members and organization in high accuracy (Sherif & Rodney, 2003). The client, designer and the builder are the main three formal communication parties that involve in a construction project (Andrew W. O., 2013). Construction sector is one of the largest industries, consisting of a low innovative rate and its projects have significant challenges as it runs on competitive and complex environment with management difficulties and it should not be ignored or underestimated while providing solutions to overcome these problems (Vasista & Abraham, 2018). One of most important factors of a successful project is the communication among the participants as there are numerous parties that involve in a project (Nipa, Kermanshachi, & Kamalirad, 2019). While many organizations work towards a single construction project (though they are located in different areas), there should be an inter-organizational communication method which is maintained under the guidance of the project manager and it helps all the stakeholders to work towards the same project (Ahuja, Yang, & Shankar, 2006; Sherif & Rodney, 2003).

Information and Communication Technology (ICT) involvement in construction projects plays a major role to improve productivity and quality in different aspects of the industry while providing some useful factors that associated internally with a project such as team management, technology and organization, strategic benefits, employee satisfaction, adapting niche requirements, moving online and

empowering semantics while reducing the issues regarding the project (Ednah & Michael, 2011). Most common problems happen in construction sites related to communication are misused or an open lines communication (protocols) is not used, inappropriate communication channels (inefficient and/or ineffective), and unexpected communication breakdown (Eddie, Heng, Peter, & Zahir, 2001). Therefore, it is essential to use the right source, through the right medium(s) in forms or formats as the receiver can easily comprehend and deliver to the right person (Nathan, Stanley, Fidelis, & Uchenna, 2018). There, the price, importance, quality, location(s) and characteristics of the information are considered when selecting the proper communication media or channels to a certain project (Nuria, Carles, Sonia, & Rafael, 2017).

Although there are some virtual models have been developed to manage the information in construction industry, most of them are very high in cost as well as do not exactly suit for Sri Lankan construction conditions. Therefore,being a third world developing country, still there is a need of a proper, cost effective platform to communicate and manage information within the construction sites in Sri Lanka. Therefore, this research was aimed to design a low cost, efficient and effective web based platform to manage and communicate information within the construction sites in Sri Lanka. Further, this research paper presents the operational aspects of the system as well.

II. LITERATURE REVIEW

A. Communication in Construction Site

In considering the documents which circulate within a construction site, the drawings receive a significant place and they transfer as CAD or any other digital form with DWG, DWF, or PDF extensions (MAGDY, ROBERT, & GEORGE, 2004). Further, the researchers reveal that the main reasons for failures related to traditional drawings and other documentation are high time consumption, misplacing information easily, difficulties in handling, etc. (Nathan, Stanley, Fidelis, &Uchenna, 2018). Electronic documentation (e-documentation) is being used as a solution for the issues that arose with traditional paper-based documentation and it has a significant impact on construction project management within the last few years (Changxin & Jim, 2012). Information and communication technologies (ICT) in modern day helps to circulate communication within construction sites while changing people interactions and overcome relational problems by reducing the face-to-face contact (Andrew, David, & Michael, 2006).

B. Web Based Management Systems

Websites have become crucial information transferring media for companies and organizations as they manage economic transactions as well as highly important information through websites (Cornelia & Paolo, 2004). Moreover, websites have been developed for the highly secured information transactions for the past few years with some methods to encrypt the messages that do not decode until it reaches its original client (Nighat & Sayed, 2011).

The web based project management is one approach with the ability to strategize, organize and manage streams of resources including resource approximations, structures of resource breakdowns, availability of the resources and resource optimizing in accordance with the complexity of the software (Management, 2008).

There are some strengths that can be seen in the current web based management systems as these projects can minimize the problems due to distance while developing strong and easy collaboration and communication, and minimize the time consumption for the re-working activities (Karatzas, 2010). Nevertheless, there are some weaknesses in web based systems such as technological issues that can provide access to the data with managing issues and make harm to the project management and planning, increase risk in data security, make changes in progress monitoring and quality control (Martinez, Marín, & Vila, 2015).

III. METHODOLOGY AND DESIGN IMPLEMENTATION

Research Appraoch can basically be categorized into three as Quantitative, Qualitative and Mixed (Anuradha, Perera, & Mallawarachchi, August 2018). There, the qualitative approach is adopted to collect the opinions of people / professionals and quantitative approach is used for numerical

and development related works (Anuradha, Perera, & Ekanayake, 2019). Mixed approach is a method that combines both of these (Anuradha, Perera, & Mallawarachchi, August 2018). Thus, this research followed mixed research approach for the analysis. In accordance with the aim of this research, it was intended to develop a web based cost effective virtual communication and information management system for the constructions sites in Sri Lanka. Specially a system such as Enterprises Resource Planning (ERP) is too costly (millinons in SL rupees) to implement for a construction company and not affordable for many of the construction companies in SL. Moreover, they have been developed as it is more suitable for the construction conditions of other countries. Therefore the system was designed as a low cost application mainly focusing the SL construction conditions.

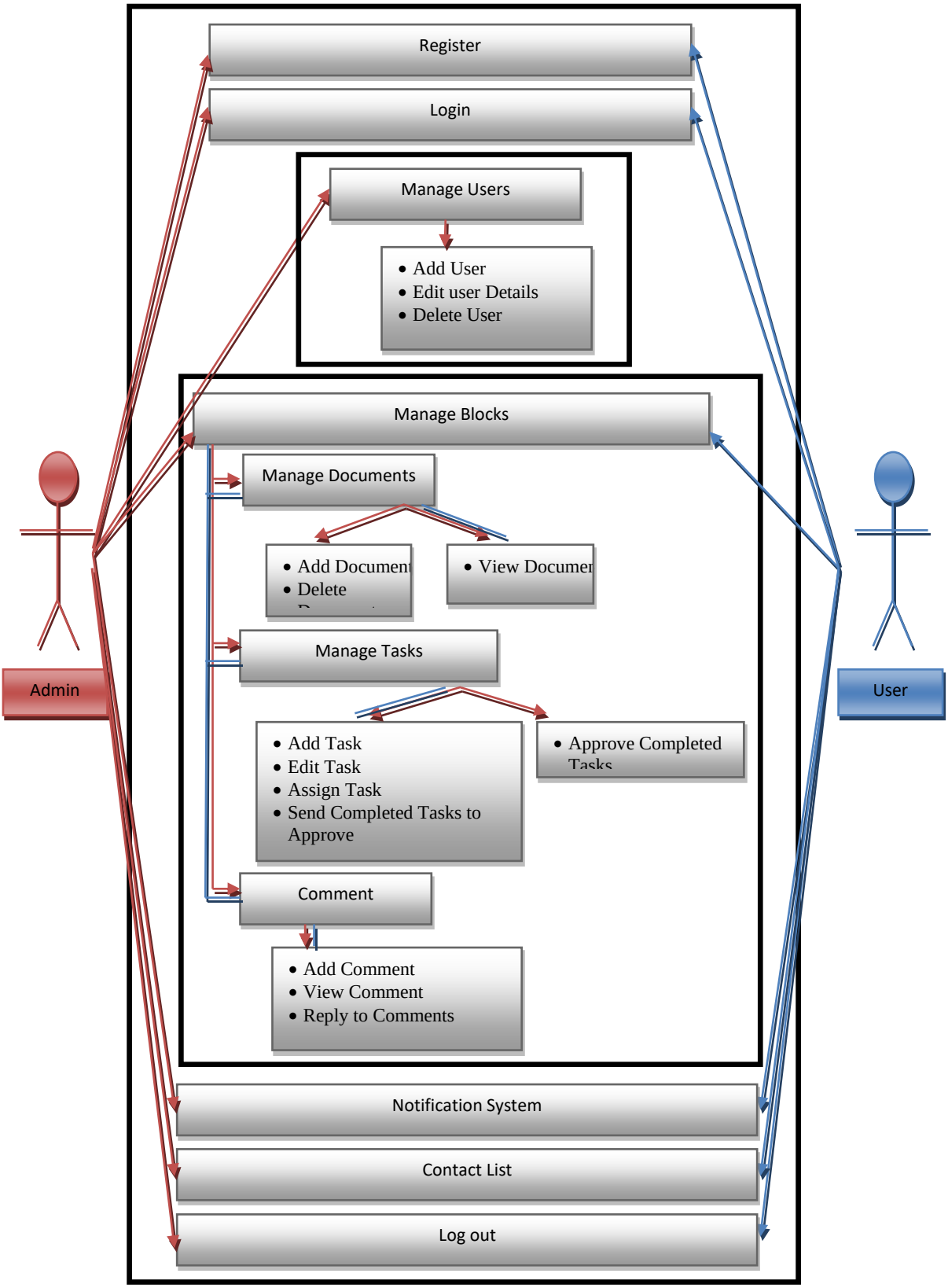
As the first step, it was necessary to collect the ideas of the construction professionals (who are handling the construction documentation and make decisions based on those) to develop the system as it suit for SL construction sites (refer table -1 for the profiles of professionals). Next, collected data were analysed through content analysis. Then the web based model was developed using Windows 10 operating system, Node.js Server and MongoDB as the database. The figure 1 (use case diagram) shows the main functions that can be accessed by the user and admin separately. Furthermore, this model includes a security system that has been designed to restrict unwanted access, a notification system, a quick access contact list and other privileges.

While the back end of the system was designed in accordance with above, the front end of the system was developed as a user friendly interface. The front end of the system includes various pages as eg:- Login page, Home page, User profile, User management, Admin profile, Blocks layout, Task Management etc… and all these are connected internally with the back end. The login page was designed to restrict the unwanted access by providing a password for each user and home page was designed with project details and the block identification.

The admin profile of the system has been designed to manage users (add a new user/ edit user details/ delete a user profile) manage tasks (add tasks/ assign tasks/ edit tasks/ send completed tasks for the approval/ approve completed tasks, etc.) and manage files in a particular block (add documents/ delete documents/ view documents, etc.). The user profile of the system has been developed mainly in viewing to-do tasks, add new task, assign relevant officials, submit completed tasks for approval, give comments, view comments, view documents, access contact list and view notifications, etc.

Table 8: Profiles of the interviewees

Interviewee	Designation	Experience
A	Project Manager	10 years
B	Civil Engineer	08 years
C	Quantity Surveyor	15 years
D	Civil Engineer	07 years
E	Services Engineer	08 years
F	Quantity Surveyor	07 years
G	Senior Site Supervisor	06 years
H	Architect	10 years
I	Quantity Surveyor	08 years
J	Civil Engineer	08 years
K	Senior Site Supervisor	10 years
L	Project Manager	09 years
M	Senior Site Supervisor	14 years
N	Architect	06 years
O	Services Engineer	08 years
P	Senior Site Supervisor	07 years
Q	Civil Engineer	06 years
R	Services Engineer	11 years
S	Quantity Surveyor	08 years
T	Services Engineer	08 years


Register
Login
Manage Users
• Add User
• Edit user Details
• Delete User
Manage Blocks
Manage Documents
• Add Document
• Delete
• View Documer
Manage Tasks
• Add Task
• Edit Task
• Assign Task
• Send Completed Tasks to Approve
• Approve Completed Tasks
Comment
• Add Comment
• View Comment
• Reply to Comments
Notification System
Contact List
Log out
Admin
User

Users receive a notification when new comment added, a document added or when they have

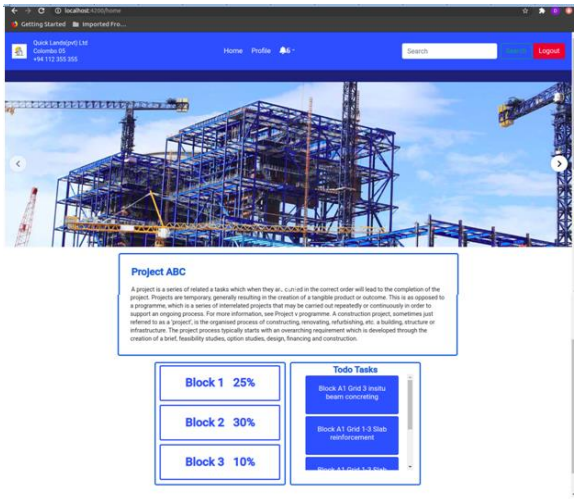


Figure 21: Home Page

been assigned to a new task in the system irrespective of the block or the place they work. This is a bonanza to manage communication within large scale construction sites easily. Then the particular block within the developed website has been designed including relevant document section with document categorization,

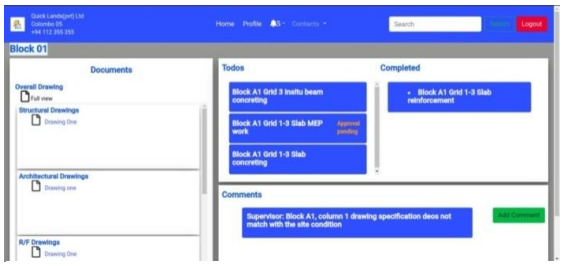


Figure 22: Block Layout

view tasks (to-do), completed tasks and providing a comment section. Further, the tool bar within the home page provides quick access to the contact details of each member in the site and admin has the full authority to make changes to the details and he is responsible about unnecessary changes in contact details. This contact list provides the mobile phone number and official mail addresses of each official. These facilities of the system help to communicate and manage the information in many ways, such as new documents (e.g: updated site instructions, RFIN (Request for Information), method statements) are accessable in any place of the work site. If any issue arise at any location of the construction site, the user can insert a comment to the system (in the relevant block) by

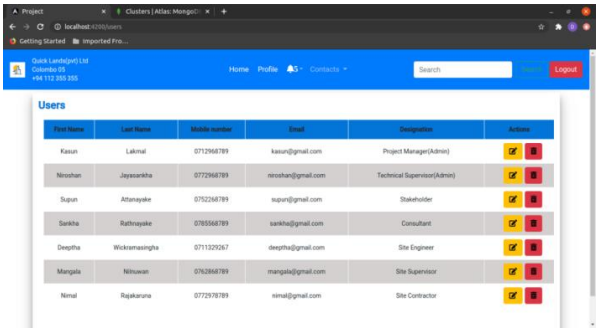


Figure 20: User Management

mentioning relevant officials to get quick solutions. The officers receive reminders at the beginning of the particular task so they can

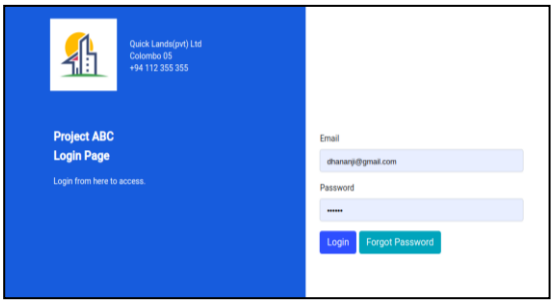


Figure 24: Login Page

access the places easily. This function is really helpful for the relevant Mechanical, Electrical and Plumbing (MEP) professionals as they do not stay in a particular single block.

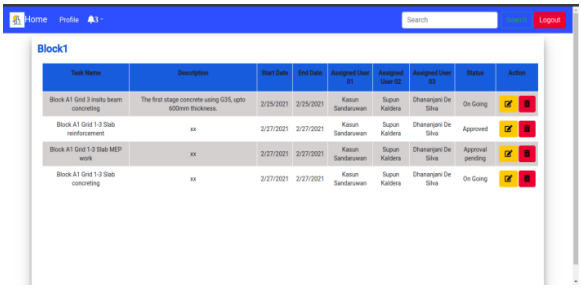


Figure 23: Tasks Management

Moreover, this system helps to reduce the wastage of time by providing the relevant details and information in quick time, reminding the to-do tasks, inquiring the issues in the comment section and get solutions and feedback without

any further delay and access the contact details of the officials easily.

IV. CONCLUSION

This study was basically focused on developing a cost effective web based system for the construction sites in Sri Lanka as a solution for the communication and information management. This model can manage tasks within the site, manage users, manage documents and provide a common discussion section in the comment area and targets the primary requirements of the site which is basically subjected to the day to day activities of a construction site.There are certain benefits of adopting this web based application rather than using any other system or the conventional manual communication management process. First and foremost thing is this is really economical and saves a significant amount of money. Further, time saving, having the accessibility for the users with different devices (smartphones/ tablets/ personal computers/ laptops) and differenet locations, easy customization in different devices, easy integration with various operating systems (windows/ android/ Ios/ mac os), and maintenance requirement, adoptability, etc. can be highlighted as other advantages. Moreover, this system can be considered as a formal communication platform as it has only the authorized documents and officials are responsible for their behavior in the system. Therefore, no one can insert irrelevant information to the system. It leads for high efficiency in communication to deliver accurate and quality information on time.

This system has a limitation as all the responsibilities are handled by the admin. If this system can be upgraded with artificial intelligence, most of the works of admin can be converted to a self controller by the system.

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Compact City as a Response to the New Normal: Designing Resilience to Encounter Pandemics

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Abstract— The Coronavirus is a pandemic that defined the greatest crisis of the modern world, and it is the most critical challenge that the world has faced since World War II. Considering the effect and the scale of the outbreak, WHO declared Covid-19 as a global pandemic and identified the epidemic as an unprecedented socio-economic crisis and not just a health challenge. From early 2020, most of the countries in the world have been in lockdowns to prevent the spread, and these lockdowns critically restricted mobility resulting in empty city-scapes. The critical problem of the present is the incompatibility of the city forms to cope with the pandemic triggered by the inability to locate the 'New Normal' concept in the field of Urban Design. Non-resilience of cities is not a unique case to this pandemic but was common in the pre-pandemic world too. Modern cities being dependent on auto-mobiles had created an urban crisis, and the desire of the designers to initiate sustainable alternatives was always defeated by automobile transportation. The pandemic has however created a temporary momentum towards active transportation restricting car-travel, and the study identifies the necessity of concreting these temporary trends for the long run. Analysing the initiatives that the cities of the globe have taken, three main concepts could be identified as cycling, Avoid-Shift-Improve paradigm and 15-Minute city. The latter part of the study brings these concepts to the city fabric of Colombo and concludes by stressing the compatibilities of adapting these concepts to Colombo city.

Keywords: *COVID-19, walkability, cycling, 15 - minute city*

I. INTRODUCTION

The Coronavirus (Covid-19) is a pandemic which defined the greatest crisis of the modern world and it is the most critical challenge that the world faced since World War II. On 31st of December 2019, a cluster of pneumonia caused by an unknown source was found in Wuhan, Hubei, China and was reported to the World Health Organization (WHO). This novel virus was then termed as the Coronavirus Disease 2019(Covid-19) by WHO in February 2020. Since its initial emergence from Asia to its widespread to all the continents of the world, the effect of the virus has created an outbreak in the whole world. As for the statistics, by 15th May 2020, over 4,444,670 cases have been identified globally covering 188 countries. This has made the WHO to declare a global pandemic at the beginning of the year 2020. The term 'pandemic' is defined as "occurring over a wide geographic area and affecting an exceptionally high proportion of the population" which makes the present crisis lacks nothing to be a pandemic at it all senses. Yet the Covid-19 pandemic is not sloley a health crisis but also an unprecedented socio-economic crisis of global scale. All these countries and communities are now facing unprecedented restrictions, and the world population are deemed to stay indoors. With the declaration of the pandemic the WHO recommended the world population to support the containment of the virus by quarantine, social distancing, and self-isolating themselves from the general public contacts. These essential procedures of pandemic containment indeed contradict with the desire of individuals for their social encounters and also conflict with the way our urban built environment are designed. Modern cities are not designed to cope with these new

restrictions or with this new way of life but instead designed to cope with the pre-pandemic world where millions of people working, commuting, sightseeing and being part of numerous forms of social encounters on a daily basis, but that pre-pandemic world seems a long way off now. Though the covid-19 pandemic and its causes are unprecedented, this is not the very first pandemic that the world faced. Over all these pandemics, the cities have evolved and the modern cities are a result of this long and continual evolution. When the evolution is considered the historical data evidence that the city designs have been always affected by these historical pandemics, and they have always resulted new forms of the city.

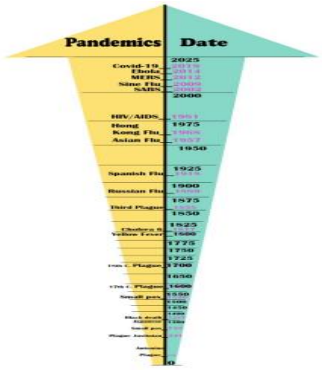

Figure 2. History of deadliest pandemics

Source: S. Elbatry (2020) *Post-Pandemic Cities - The Impact of COVID-19*

When this history of epidemics is concerened, particularly the respiratory epidemics enhances isolation as the main precaution which ultimately transform the image of cities and all its public spaces are empty without people. It is further evident that these pandemic typologies always result in changes in the form of the city as a result of trying to intergrate the community health and social interactions into then prevailing urban design trends. Reviewing the history of pandemics clearly showcases that these pandemics were a powerfull means of change in urban designs over the years. First evident case was the Black Death in Europe in the 14th century, which called up for the expanded public spaces that connects with natural environment within the densed urban built environment. Cholera epidemic in 19th century introduced the sewerage systems to London as a precaution of preventing the drinking water being mixed with waste water. Similalrly in 1908 in Philadelphia, due to an outbreak of typhoid fever and cholera, caused by mixing the drinking and sewer at the Schuylkill river. As a precaution at the early phase the urban planning authorities relocate the housing and commercial amenties away from the river bank and this resulted a massive park at the river edge, which ultimately changed the image of the city as a whole. From 1918 to 1919 the deadliest 'Spanish Flu Pandemic' created a similar case as Covid -19 pandemic of 2020s, in which public transportation had been replaced by walking and most of the population was restricted to their indoors in order to reduce the spread of the virus. This witnessed situation is very similar to today's situation. Based on these historical lessons, it is clear that when the Covid-19 pandemic subsides our urban built environment will not bounce back to where it was, and it is further essential to create more resilient cities for possible future outbreaks. It is today more than ever that our modern cities needed a reform to sustain over the future pandemics and on the other hand it is the greatest opportunity of all times to initiate resilient urban designing trends behind the concept of the 'new normal' of the futuristic post pandemic world.

From the early 2020 upto date, most of the countries in the world have been in lockdowns time to time, to prevent the rapid spread of coronavirus disease and these lockdowns critically limited and restricted mobility. These restrictions have caused a significant improvement in the global ecosystems, which is severely apparent in the air conditions around the globe. In contrast, once the economic impact is concerned these lockdowns have greatly contributed to the rising poverty all around the world. As the major portion of the economy lies on the population that leaves their houses to make a living or to provide essential services, transportation is a crucial and a defining factor. Studies in relevant fields have emphasized the need of transport to avoid the economic collapse and transport is identified as the main means which sustains the agglomeration effects that turns the urban economies attaractive and simply make the urban labor market work. But transportation of the pre-pandemic world was

solely dependant on automobiles and the reliance on automobiles is not sufficient enough, specially for the developing countries, since the population that own vehicles are very less in these countries and mass public transporatation is a risk when the spread of coronavirus disease is concerned. The research problem identified is the loss of social encounters due to the new 'stay at home' concept arose with the Covid-19 pandemic and the possibility in recurrence of future pandemics as evidenced in the past and the incompatibility of the present city forms to cope with the pandemic situations triggered by the inability to locate the 'New Normal' concept in the field of Urban Design.

Considering the health risk and restrictions, the demand for sustainable transportation alternatives such as Walking and Biking have gained the highest ever demand without any special infrastructure improvements. In the United States of America, the state parks witnessed a 30% to 50% increase in use and some of the national and state parks were forced to close due to overcrowding in the time of pandemic. It is also accounted that the increase in demand for walking has been increased by 200% and the study shows that this time the pandemic had the most clear and visibale statistics in the rise of demand for high walkability scores in the USA. This is common to most countries and walking and cycling have become the best options left in the prevailing pandemic. Therefore, it can be claimed that the Covid-19 pandemic has paved its way towards a walkable city form. Sustaining transportation by making cities walkable was identified as a crucial necessity even in the pre-pandemic world, but the desire of urban designers and relevant authorities were defeated by the priority gained by the automobile transportation. With the prevailing pandemic, the designers and policy makers are given a greater opportunity where automobile transporatation is restricted as a health precaution and walking and cycling kind of sustainable forms of transportation are only permissible. A number of reaserch work in the field showcase that the proper designs and implications could convert this temperory trend of walking into a long run even when the pandemic subsides in the future. Therefore, it is necessary to emphasize the need of identifying design sollutions that can turn these temperory trends of walking into permanent behavioural patterns. The research is done to provide an insight for the designers to conduct their work in sustaining future urban built environment through the identified opportunity created by the pandemic and the study will compare the concept of walkability as a remedy for the pre-pandemic world and the reliability of the same concept in sustaining the post pandemic world with reference to the concept of 'new normal'.

II. SUSTAINING THE PRE-PANDEMIC WORLD: THE CONCEPT OF 'WALKABILITY' AS THE REMEDY

A. Urbanisation and modern urban crisis

Historical studies on the human civilizations have identified three main incidents in history that transform and altered the human life and were also the driving causes of modern world. First among them was the revolution in 7000BC which resulted agriculture and Neolithic settlements (Pacione M, 2001), the second was the pre-industrial revolution that occurred before the 18th century. Third and the most crucial incident was the industrial revolution in the 18th and 19th centuries. According to Kevin Lynch's (1981) *A Theory of Good City Form*, these kind of incidents that created a very sudden and independent jumps to a new form of social settlement was the primal cause of cities. Cities were evident to be occurred in the pre-industrial age and evolved into the modern cities as a result of industrial revolution. According to Wheatley (2012), 'Urbanisation' is the process in which functionally intergrated set of institutions constructed on a kin-structure is changed and transformed into a socially stratified, politically organized, territorily based societies. Urbanisation can be a result of both natural increase of urban population and net immigration to urban areas from the rural communities, yet in either way urbanisation ultimately results the Urbanism[1]. This urbanisation is the dominant force of 21st century

[1] Urbanism is the spread of changed social and behavioral characteristic due to urbanisation

and the modern world has faced a rapid urban growth all around the world, due to which 68% of the world population is living in urban built environment as per to the census of year 2020. This dominance claimed by the urban built environment have made them the sole player in the global economy. But as per the British council report on 'Global City Challenges' in 2018, the urban built environment is described not just as an economic centre but as a complex entity with social, cultural, political, technical and economic aspects.

The rapid urbanisation and Urban sprawl[2] being the typical from of urban expansion, most of the cities have witnessed a crisis spanned over social, environmental, cultural, political and economic aspects of a city. Patric Sisson (2012) in 'Upward and Outward Growth: Managing Urban Expansion for more Equitable Cities in the Global South' argues that the modern cities are not simply building up but indeed they are expanding out, through this it is predicted that by the year 2030 cities are to be expanded by 80%. In historic form of cities people used to walk for their work and needs and the city structure was compacted to support this life style, but with the industrial revolution and with the invention of affordable and developed automobile transportation accelerated the urban sprawl in the modern cities. Implication of public transit further enriched the situation and separated the residences and workplaces. These long and continuous transportation means of cities have affected the society, environment and economy arising an urban crisis as mentioned above.

B. Sustainable Urban Mobility

Based on a number of studies and the identification of the 'urban crisis' sustaianing cities have been narrowed down to sustaining urban mobility. Providing adequate public transport, densifying the urban built environment with mix land use and compacting the cities are few sustainable amendements (Pacione M, 2001;260).

Continuous technological advancement that took place in the society since the industrial revolution has made the modern urban communities strive to move faster and almost all the service provisions, urban design implications and infrastructure developments were done to facilitate this fast transportation which was further fostering an 'automobile oriented' city structures. Identification of reducing the scale and effect of urban spaces being dominated by automobiles have led the modern urban planning towards the phenomenon of 'walkable cities' (Turon K et al, 2017). The walkable city model involves walkability concepts. Walking in general meaning is a *movement* which is also *the simplest form of transportation* (Rafiemanzelat et al, 2016). In the urban context the verb, 'walking' is defined as *a short distance movement from one point to another* (Rafiemanzelat et al, 2016). With the industrial revolution and technological advancements walking and even public transport became less prioritized in the urban planning agenadas. But with the identification of negative impacts of transportation being oriented on automobiles brought back the need of creating walkable environments which promotes walking. Concept of 'Walkability' is a more recent and rarely used word in the general vocabulary, but often used in the professional fields and this concept is defined as '*measurement of pedestrian friendly degree of a certain area'* (Rizali et al, 2017). According to Jeff Speck (2012) getting walkability right is the most crucial factor and the vitality of the concept is believed to be the correction for all other concerns. A study done by Leinberger (2011) on real estate performance, shows that the real estate markets in USA demands for walkable environment over the commonly supplied drivable sub-urban areas (Leinberger, 2011). Furthermore, the same study concludes by emphasizing the probability of loosing economic opportunities by non walkable urban built environment. Speck in another study done in Philadelphia and Detroit in 2006 also found that the well educated professionals choose walkable neighbourhoods over non walkable neighbourhoods (Speck, 2012;22). Moreover Speck identified the prominence given to 'Walk score'in the field of real estate markets. Catherine Lutz and Anne Lutz in a study identified an inverse relationship between the car dependency and land values, all these studies

[2] Urban sprawl is defined as unplanned or uncoordinated low-density expansion, & involves rapid land consumption (Bhatt,2010)

show the economic values and attractions gained by the walkable city forms over non walkable, automated zones.

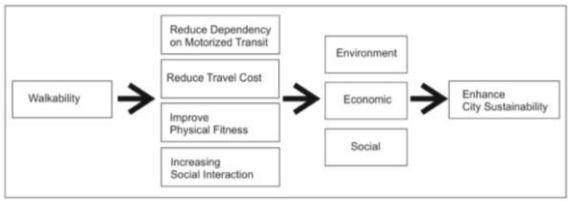

Figure 2. Relationship between Walkability and Sustainability

Further in studies, the author brings up a practical notion which is simple in implying and sustainable in functioning. It is termed as the 'General Theory of Walkability' (Speck, 2012;10). The theory includes four main qualities and 10 steps to acquire those four qualities.

Table 1. Four qualities of a walkable environment

USEFUL	Daily routines are organized in a way that walking serve them well and walking help the user to reach much of the daily life
SAFE	The streets must be free and safe from car accident and most importantly the environment should make the user perceive it as a safe place
COMFORTABLE	Streets, street furniture, building, landscape should ultimately transform the street into '*an outdoor living room'* eliminating wide open spaces which usually effect the attractiveness
INTERESTING	Sidewalks to be organized with interesting and unique elements with friendly faces that accommodate humanity

Source: Speck.J, 2012: *How Downtown can Save America:*

one step at a time.

Table 2. The ten steps of Walkability

CRITERIA	STEPS TO ACHIEVE THE CRITERIA
1. the USEFUL walk	1. Put cars in their place 2. Mix the uses 3. Get the parking right 4. Let transit work
2. the SAFE walk	1. Protect the pedestrian 2. Welcome bikes
3.the COMFORTABLE walk	1. Shape the spaces 2. Plant trees
4. the INTERESTING walk	1. Make friendly and unique faces 2. Pick your winners

Source: Speck.J, 2012: *How Downtown can Save America:*

one step at a time.

III. SUSTAINING THE POST-PANDEMIC WORLD: THE CONCEPT OF 'WALKABILITY' AS THE REMEDY

The prevailing pandemic has caused unprecedented measures in the use of present cities. However, the present cities were shaped to resist these pandemics over time by changing its form time to time based on the epidemics they were facing. With this unprecedented measures of Covid-19 pandemic it was made clear that the present city forms are not coping up with the prevailing disease. Any pandemic can be divided into five main segments and third among them is the containment which the world tried and failed with Covid-19 pandemic. Therefore, the world is at the next phase at the present which is the Mitigation. When the precautions for mitigation is considered, a huge number of surveys have stress the necessity requirement of urban reform that make our cities more resilient to this pandemic and for the possible future pandemics too.

Mitigation of the pandemic initially involves travel restrictions and isolation to prevent further spread of the virus due to which millions of people all around the world were restricted to their homes. The world was under lockdowns for an year and a half now, and when the real situation is considered respective to its geographical locations, not all the counties were in lockdown for this long. Throughout this one and half years different countries were in lockdowns in different times, for an example when New Zealand and Taiwan were in lockdown, USA was not when USA was under the lockdown New Zealand and Taiwan were not. This is the initial concept of sustaining post pandemic world. These countries were considered as clusters and professional studies emphasize the ablity of adapting this natural form of clusters into initial neighbourhood of a given urbanity. This simply brings back the concept of compact and densed city form with higher land use mix. When the transmission of corona virus is concerned higher density can be identified as a negative implication. The New York city which is recorded with the highest rate of covid cases but its density (10,400 people per Km^2) is not as high once compared to Singapore (8,130 people per Km^2) but Singapore didn't have the alarming rates as USA . According to statistics Seoul, Korea was one of the most successful countries to contain the first wave and the density of Seoul is at 15,763 people per square

kilometer which is even higher than New York city based on which, it can be stated that the density is not the most effective component for the spread of the virus. Therefore, the crucial need of present could be identified as to design sustainable and healthier cities that successfully accommodate the prevailing densities without reducing them. **Higher densities**, **compacted cluster development** can therefore be identified as the initiatives of sustaining post-pandemic cities and it is then required to enrich its sustainability in the aspects of economy, environment and society.

Pandemic has made **Walking** more appealing mostly because its covid-safe in the present and due to mobility restriction, lockdowns, preventions of public transport have naturally increased walking as a means of physical and mental well-being. Furthermore, prior to the pandemic also walking was found to be the most sustainable form of transportation and also while the pandemic it is still sustainable since it typically avoids the three **Cs** of covid spread (**C**losed spaces, **C**rowded spaces and **C**lose contact situation). While avoiding the possibile contacts of the virus spread walking tends to provide the human a sense of social encounters and prevent them from many possible mental disorders that may occur due to the norm of 'stay at home'. The main issue that the pedestrians of the pre-pandemic world faced was the constant competition that they were engaged with automobiles. But the main difference of the pandemic is that this competition is now lost.

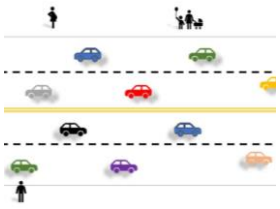

Figure 3. Relationship between Walkability and Sustainability

As shown in the figure 3, some cities in the world have added 'pop-up sidewalks' in which a portion of road where vehicles were moving were converted into sidewalks, and some cities have initiated 'al fresco streets' in which retail and resturants on the either side of the road allowed to expand their shops to the road. Both these two concepts have given a number of benefits, first among them is the avoidance of 3Cs with the widened up pedestrian spaces and the next benefit is the reduction of automobile usage which reduces the traffic and congestion, improving the both environmental and economic standards of the city. And the last benefit is the improvement of social encounters through which the society is strengthened.

However, the concept of walkability and promorting walking is only designed to connect public transit to work places in the pre-pandemic world and above mentioned general theory of walkability is designed to those short connections. But the present requirement of the pandemic is somewhat different as public mass transportation is a risk when the disease spread is concerned. The studies on this regards have identified two solutions and one is **Cycling** and the other one involves a structural **reform** in the urban built environment.

A. Cycling

Cycling has been identified as a sustainable form of transportation in the initial stages of pandemic mitigation as it is an open-air form of transportation. Except for that nature, a bike with its physical footprint enriches social distancing and the active form of cycling further influences distancing. With this identification both the developed and developing countries have initiated pop-up bike lanes to enhance the sustainable transportation and support walking. These initiatives can be seen from London, Paris to Berlin, Bogota and Wuhan. When the infrastructure provisions are concerned initiating these cycling lanes cause a very little cost when compared to automobile infrastructure and very little time span to initiate the project. All these initiatives are temperory and it is essential to transform these into permanent cycling tracks as cycling kind of active transportation means can lead the urban built environment on the right direction. A study in the field shows that 56% of Londoners have conveyed their want in pavements to be permanently widened up making more pedestrian spaces in the city and 57% wanted the cycling tracks to be established permanently. Moreover, by the case of Bogota, it was evident that the initiation of permanent and proper

cycling tracks can sustain the urban built environment. An addition of 583km long permanent cycling track in Bogota absorbed 800,000 rides on a daily basis which accounts for a 6% of all the trips that take place in a day.

B. Avoid- Shift- Improve Paradigm

Pandemic has forced the modern world to take emergency measures and stresses the urban designing profession to alter the urban mobility into sustainable urban transporation. As per the evidences, the pandemic has positively influenced towards a paradigm shift in the field of urban transportation by restricting unnecessary travel and promorting walking and cycling kind of active transport mediums as covid-safe options of mobility. The noticeable reduction of auto-mobile usage has given the planners an opportunity of lifetime to improve infrastructure for active transportation (walking and cycling) as the necessity of prioritizing automobile provisions in the urban agendas is not much needed when the present pandemic is concerned. In the pre-pandemic world the issue was how to prioritize and initiate active transportation in a world which is oriented on automobiles and in the post-pandemic world the issue is how to concrete this organically occurred trend of active transportation for a long time run preventing the cities being bounced back to where it was prior the pandemic. This is where exactly the 'New normal'should be located, and the new normal can simply be this '**Avoid-Shift-Improve**'paradigm. If the designers and authorities were able to get this momentum right the post pandemic world will transform into a sustainable entity with sustainable urban mobility, recovering the environmental standards, reviving the urban economies while creating 15 million jobs worldwide. Therefore, this is the most fortunate opportunity of our times and nothing will be able to make it affordable if this opportunity is neglected.

Table 3. The paradigm of Avoid-shift-improve

Shift	Avoid	Improve
- Walking - Biking - Public transport	- Commuting by car - Unnecessary travel	- Broadband - Frequency of service - Quality of infrastructure
- Telecommuting		

C. 15- Minute City

Researches in the field of of sustaining post-pandemic urban built environment often emphasize the acceleration on negative impacts of pandemic, that have been created by pre-pandemic urban models which were depending on automobiles. With this typical form, most of the urban built environment in the pre-pandemic world were not easily accessible without a heavy resilence on automobiles and which is the main reason of causing a bottleneck in providing essential services in the pandemic. It is now evidenced that most of the cities in the world have adapted some temperory initiates to sustain through the pandemic and the City of Paris bears a winning story. The concept used in the city of Paris is the '15-Minute City' concept. With this concept, the City of Paris has led it way to boost their economy, while reviving the social cohesion and sustaining the city as a whole even after experiencing a brutal wave of Covid-19. Based on this success, a number of cities have already adapted the concept as a temporary initiative and implying it as a permanent urban reform is highly viable in sustaining the post-pandemic cities. The 15-Minute city model is based on 'chrono-urbanism' which outlines an inverse proportion between quality of urban life and amount of time spent on automobile based transportation. The concept of 15-Minute city was founded by Carlos Moreno, who initiated an urban set up in which the local residents were able to reach their essential needs within 15 minutes of time using active transportation such as walking or cycling. The updated form in concern to pandemic, Moreno states the need of fulfilling six essential urban social functions, such as, *living*, *working*, *commerce*, *healthcare*, *education* and *entertainment*. To attain these social functions, according to Moreno the urban built landscape needs to reform essentially including components such as, proximity, diversity, density and ubiquity. The 15-Minute city model is characterized by ubiquitous deployment of Information Communication Technology(ICT). Following the success, a number of cities reformed their city structures adapting this concept and the vitality is proven in almost all

those cases, due to which the concept gained recognition in the C40 Cities, WHO, UN-Habitat and Organisation for Economic Co-Operation and Development (OECD).

Figure 4. The 15-Minute city framework

Based on the practical success, vitality in sustaining cities, the concept of 15-miuntes city model is one resilient urban reform framework that promote, walking, cycling and social encounters while accommodating digitalization through which economic growth is acquired.

IV.THE CASE OF COLOMBO

The city of Colombo is defined to be the most distinguished urbanity in Sri Lanka due to its origin. The vernacular urban patterns and kinghoods never gave its concerns to the city of Colombo. The city was elevated up to the city level by the colonialists (Munasinghe.H) by starting its evolution as Portiguese outpost in 1505, and later fell into the hands of Dutch and British respectively. Irrespective to its non-organic origin the city claimed its place as the capital of the country even after the independence in 1948. In the modern world, city of Colombo recorded the highest urbanisation rates and Urban sprawl is the base means of urban expansions. Over years the city has been expanded and prior to the pandemic majority of the city users were living in dormitory suburbs travelling to city on a daily basis, which made Colombo, a sole dependent on automobiles. The statistics show an urban crisis affecting environmental, social, and economic aspects of the city. A study done on the Colombo city to figure the compatibility of the socio-spatial structure of the city with the concept of walkability, have proven that the city form and its social component is highly prospective to be sustained through the concept of walkability. The study concludes by emphasizing the possibility of sustaining the city with the general theory of Walakability and it further clarifies the users' perception on walkability, being relied on safety above all the other universal criterions of walkability.

With the pandemic, urban cityscapes of Colombo have become literally empty and this showcases the non-resilient characteristic of the city form that prevailed prior to the pandemic. Sustaining the city in the futuristic post-pandemic world needs specific field studies, but this section of the study is intended to provide a broad insight to the process of sustaining the commercial capital of Sri Lanka which is the epicentre of Local economy.

A. Compatibility of the city with the Avoid-Shift-Improve (ASI) Paradigm

The city structure of Colombo, highly demarcate and separate the CBD (Central Business District) from Domitory Suburbs, which prevents the sudden adaptation of active transportation means such as walking and cycling due to the considerable gap of distance. When the distances are concerned walking all the way from home to workplace is impractical and need of a proper cycling infrastructure is crucial in order to support the *ASI* paradigam. With the case of Colombo the total cut-off of public transport will not work and public transit being connected to this active transportation means will be effective. Furthermore, provision of adequate public transport with higher standards according to health concerns will help to reduce and avoid the commuting by car in the Post-pandemic Colombo when the pandemic subsides. To create a vibrant pedestrian environement the Colombo city inheritance (natural environment, land use mix, vibrant culture) are sufficient.

B. Compatibility of the city with the 15-Minute City Model

The 15-Minute City model demands an urban reform rather than a modification unlike in *ASI* Paradigm. But according to the 15-Minute city framework the four pillars of the concept, Diversity, Density, Proximity and Digitalization. The city of Colombo already possesses 'diversity'

and 'density'. As per to the original idea of the model, if the urban development authorities could improve the divisions of Colombo city into 15-Minute city models by introducing the 6 social functions, the factor 'proximity' too could be achieved. Introducing *working*, *commerce*, *healthcare*, *education* and *entertainment* into residential areas will easily fulfill the framework and making the residential zones into these models will surely increase the resilience of the city in future epidemics. In that case, 'Digitalization' is the only aspect that requires a whole new introduction into the system.

V. CONCLUDING REMARKS

City of Colombo possesses a number of potential possibilities that could make the city sustainable in the time of this pandemic. This sustainability could be reached by adapting the above mentioned conecepts (ASI Paradigm & 15-Minute city model). Out of these, two ASI paradigms would be the easier method to adopt during this pandemic since all it demands is a modification rather than a whole new urban reform. In contrast, the 15-Minute city concept by Carlos Moreno, would be comparatively harder in adaptation since it demands a new urban restructuring. However, the ASI Paradigm is also unlikely to be 100% efficient due to the noticeable distance between CBD and suburbs but the sustainability might be achieved at least partly through this concept if public transport could be restricted to the greatest possible extent and improving it health-wise during this pandemic. These mobility restrictions could be enhanced by introducing digitalization to the city functions. However, the 15-Minute city concept is the most effective, versatile and the appropriate option that could make the city resilient for all time and also during any possible future outbreaks. It will also overcome the most general issue, 'Urban Crisis' that existed in the pre-pandemic world. Even though this adaptation is costly, time consuming and difficult in adaptation with emergency measures unlike ASI Paradigm, the adaptation is not impossible since residential areas of Colombo already possess the two factors; 'density' and 'diversity'. Thereby implying other five essential social functions (as per the 15-Minute city model) could create a group of 15 minute cities. This pandemic time is the most appropriate time to initiate this concept since constant and concrete behavioral patterns of the pre-pandemic world are changed and the general public is now in the process of adapting to the new normal concept. Therefore, this is the greatest opportunity for the policymakers and designers to initiate this 15-Minute city concept which is more suitable to make the city sustainable in the longer run. If this concept could be initiated during this pandemic, it will sustain the city of Colombo at all times, with or without pandemics. In conclusion, it could be stated that ASI paradigm is the timeliest and convenient adaptation that could be used to overcome this ongoing pandemic and the 15-Minute city model is the most versatile, appropriate and efficient method to sustain the city in a longer run. The study can be concluded on the note that city of Colombo is compatible with both the concepts and adaptation of ASI paradigm as the initial step will make the city survive in the pandemic and implying primal steps of 15-minute city model in to Colombo city structure will sustain it in the longer run.

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Use of Urban Pockets to Enhance Walkability in Office Neighbourhoods in Colombo Urban Context with Special Reference to Fort, Colombo

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Abstract- Urban pockets have been recognized as resourceful collective spaces for urban functions in a modern-day city. Also, urban design and planning of major developed cities incorporate the walkability concept in order to minimize traffic, environmental, and health problems. Colombo is considered the commercial capital with a high density of office neighbourhoods that attract high density of vehicular movement. Fort is recognized as office neighbourhoods in the Colombo area where the traffic congestion is higher. Previous research considers the physical factors of the street in order to enhance walkability. They lacked consideration of the walking behaviour-flow, junctions, and small urban spaces in the process. The study aims to identify the undefined urban spaces that can be used as urban pockets by studying public behaviour patterns regarding walkability in office working hours in Colombo. In order to identify the possible urban spaces that can be developed as urban pockets, the research indemnify the current walking patterns and walkability of the area. The identified walking pedestrian flow laid over the identified leftover spaces which have the possibility to develop without changing the current urban context. Overall images for study area were developed with the existing and possible urban pockets based on walking patterns and the lack of walkable routes in order to enhance the walkability of office neighbourhoods.

Keywords: *walkability, walking behaviour, urban pockets*

I. INTRODUCTION

Since modern cities became urban islands with a dense network of roads, people, and enclosed building morphology sense of place, Imageability and legibility degraded, as many people need the technology to navigate in the city. Large vehicle transportation and lack of pedestrian-friendly sidewalks and streets make walking a less important factor in urban design. Even with the modern-day sustainable city concept which has become merely a fashionable statement, we prefer vehicle transportation over walking which creates a negative impact of vehicular use varies to fields of health, safety, environmental and social behaviour. Older cities like Paris, Via del Corso Paseo de Gracia, and Brooklyn have more walkable streets, alleyways, and sidewalks created social experiences and social encounters leading to a sustainable city foundation. Yet, the modern cities neglect the social and health factor while developing the pedestrian infrastructure. Later, most of the urban and town planners understood the impact and taken certain policies and design changes in town planning like Colombo and Megacity urban planning. The research considers some foreseen development issues like safety, comfortability, and convenience where pedestrians led to a lack of navigation, legibility, and overall image of the Colombo.

A. Need of study

Colombo is considered as the commercial capital which is the hub for transportation, trade and administration. This creates more office neighbourhoods in central Colombo which is leading to higher traffic congestion. Colombo has undefined spaces, niches and alleyways that can be used as urban pockets. The study will be addressing the issues in walkability in Colombo office neighbourhoods where the inner city experienced a higher amount of destination trips

Hollie. The research focuses on the destination target walkability rather than the street itself.

B. Research Aims

The study aims to identify the undefined urban spaces that can be used as urban pockets. It explores the possibilities of the architectural implication of urban pockets in Colombo- Office neighbourhoods to enhance walkability and to identify possible physical urban features that affect urban walkability around Office-Colombo, current walking patterns, current urban pockets and to identify possible urban area that can be developed as urban pockets.

C. Literature Review

Overview of walkability:

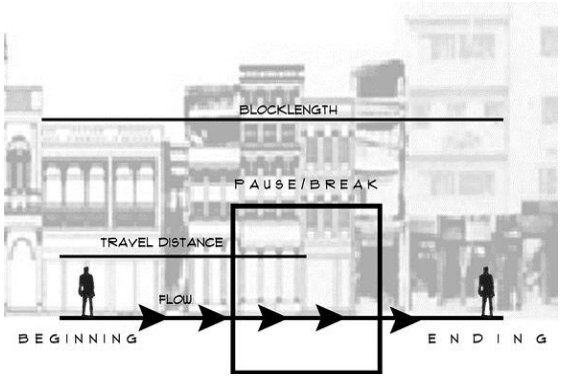

Figure 25 Factors that affect Walking Journey
Source: Author

Walkability is described as the extent to which the built environment is friendly to the presence of people walking, living, shopping, visiting, enjoying or spending time in an area. It considers the factors and variables of physical and built environment, socio-economic environments rather than giving a specific definition. The general theory of walkability describes how, walkability satisfies four main conditions of human useful, safe, comfortable, and interesting. (Forsyth and Southworth, 2008: Lo,2009and Jeff Specks, 2010). When a human travels from one place to another, there are some factors in his journey affecting the walkability: His beginning, ending, travel distance, flow, building facade and length of the block. This consists of 'The Street, node and the street edge.

Five elements of the city Paths, nodes, edges, districts, and landmarks act as whole. These elements act in micro context as reference points increase legibility and increase ones' individual reaction. Lynch (1960) Ewing and Handy (2009) designed a conceptual framework for Measuring the Unmeasurable defining physical features that influence the walking behaviour.

Research evidence suggests urban morphology factors like building orientation and setbacks, block length, building height and street enclosure and building scale and variety contribute to the walkability. Based on the direct connection between block length and walking distance increasing number of intersections is beneficial. Furthermore, activities in edges increase walkability. Softness and the vitality of the street façade increase the safety feeling of pedestrians therefore the pedestrian movement as well. (Dunay et al., 2000: Singh., 2016)

Also, Stoner (2002) identified the flow of travel can affect the walkability. Moudon and Appleyard (1970) emphasised that liveable streets are more walkable and Gehl (1971) categorized the social activities that create the liveable streets. Mehta (2008), combine the conceptual framework of Ewing and Handy's (2009) model of the environment with the ecological model of Alfonzo's (2005) to create a comprehensive model for walkability along the main street setting to analyse the sociological impact to walkability. It is emphasis on both micro and macro sociological factors.

Overview of the walking behaviour:

The individual human can choose his own movement or walking relaying on other factors. According to Daamen and Hogendoorn, walking behaviour can be measured by walking speed, walking direction, walking experience, group formation and density of the pedestrian street. According to Choi, E (2012) walking behaviour of a group effect with the surrounding and formulation change according to the street and crowd. The impact of built environment differs from the land use patterns, urban grid and services etc. Levine and Frank (2007) discussed the resident group tend to walk and favour walkability in a reference of supporting physical characteristics like compact urban form, good pedestrian infrastructure, green spaces and local amenities.

Overview of Urban pockets:

A public space can be a street, node, square or edge which is accessible to public realm for occasional ceremonial moments, entertainment, and meeting people. An urban space is more of an external space between building in the urban context. They are more of urban voids that eventually become public space within human activities. (Krier 1979: Trancik Roger 1986)

One of the dominate public space is the square. A square or plaza is both an area framed by buildings and an area designed to exhibit its buildings to the greatest advantage. Consider the physical form and function of a node, a square is the larger form of a node. It is a strategic point of physical context where the activities concentrate and attract and often identity, symbolic meaning and a landmark. (Cliff Moughtin,1992: Lynch,1960: Alexander C. ,1977: Schulaze and Alexander C.)

Udayarathna (1999) defines urban pocket as small external space between building and geometrically bounded by the variety of elevations of built structures that are closed to each other. Considering the location and the function of the urban pocket, it can be regarded as a positive urban element which is create active actions. According to Blake, urban pockets are small size and located in 1-3 block/lot size. It is visually connected with base level or ground level mostly located in ground level of the street. Identifying the patterns of these urban pockets, they are mostly targeting on the local community, based on four block radius walking groups. There spaces can be niches, nodes, end of alleyways, street corners and left-over spaces of the urban grid. Urban pocket concept is a modern concept emerged after modernism left out large number of leftover spaces. Urban designers use urban pockets as green space, breathing space and community gathering space. These spaces are interconnected by road network creating ecological and social network in the city

II. METHODOLOGY

A. Introduction to Study areas

Colombo Fort:

Fort Colombo had been origin by the strategic location of the Colombo- the Fort. The Land use of Colombo fort is based on administrative and commercial based pattern. Fort area urban grid has course grain pattern and it is interconnected by streets and urban solids are connection one to another. In Fort area, even though it lacks green areas voids and public open spaces, urban voids can be identified within the building mass linking building to the street.

With support of literature review a conceptual framework was developed to identify the pedestrian routes based on walkability, identify urban leftover spaces favour as public spaces and higher activity spaces. Three research areas were selected to follow the methodology. They are, walkability, walking behaviour and Built environment. Observations, figure ground map were used for data collection. A questionnaire was distributed among the selective areas, taking a sample of 150 individuals to identify the overall walkability of the selective areas. Observation methods were used for identifying the walking behaviour in the selective area. Mapping, Station Survey and Tracing methods were used to identify the walking behaviours and activity patterns in one station and movements.

B. Background for walkable behavioural analysis: An analysis on Questionnaires

Questionnaire was developed to identify the satisfaction of the overall walkability conditions: Safe, Comfortability, Interesting and Usefulness and identify walking behaviour and how far the built environment impact to its behaviour. Based on the questionnaires, majority of the walking population are coming from outside the central area and majority of them use public transportation. Among these walking population people who used private vehicle, tend to leave their vehicle at parking space and walk to the destination. Majority of Fort walking population who hired vehicle for their transport were drop of at near the destination and walk to their destination. Also, majority of the walking population felt exhausted, and require pause or a break during their walk. Considering their response to navigation, walking distance and time suggested pedestrian prefer to walk small distance, during small time and they tend to increase the walking distance when they are encouraging by the pauses, resting points, shades, and well-maintained sidewalks.

III. ANALYSIS PHYSICAL FORM

The analysis refers to four main areas which are existing urban pockets, identified leftover spaces, the walking behaviour, and its linkage to the leftover spaces. The analysis will recognise the functional urban fabric in order to develop and interlinked urban pockets system which will enhance the walkability of the office neighbourhood. Data collection was conducted on selected streets. Street observations were targeting to identify the walking behaviour and leftover spaces.

Existing Urban pockets and its activity patterns

Front of Dutch Hospital:

The front of Dutch hospital is the one of recollecting urban pockets in Fort area. It is located between two high-rises BOC tower and WTC tower and front of renovated Dutch Hospital. This urban strip act as collector to working occupants in Fort area. Vast open space and low height building background create a noticeable pause.

Based on the primary observations, a common pattern was identified. The walking behaviour was directly linked with the spatial quality of the urban pocket. The small alleyways linking it to

Figure 3 Activity pattern in Urban Pocket 02 and 03 Lakehouse and NHDA
Source: By Author

Chatham Street create a continuous pedestrian flow which can be linked to leftover space. Most of the occupants use outdoor pocket as a resting or meeting space.

There are no long stay active activities and most of the activities are based on passive activities.

The soft edge of this Urban pocket create progression to the building smooth and quality of waiting, pause of resting space. Even though space lack of shades such as trees etc. people tend to sit and sunbathe. This space acts as an urban pocket and a destination target space in Fort, Colombo.

Lakehouse Urban Pocket and NHDA Urban Pocket:

Figure 3 Activity pattern in Urban Pocket 02 and 03 Lakehouse and NHDA
Source: By Author

These two urban spaces have been identified by the Fort occupants as the starting points of their journey to Fort and Pettah. The Lakehouse urban pocket is built in soft edge. It acts as an in-between space within road and Lakehouse. The spatial quality of the space specified as short-term waiting space and support the walking-by with long façade of continuation. NHDA urban pocket developed as niche with the large over shadowing tree and bend in road. Space provides more space to linger and create obvious landmark between Fort and Slave Island.Since both urban pockets act as bus also stops a higher pedestrian flow to be identified and many pedestrians tend to move forward rather than staying at the pocket even though space provide seating and shading mostly because of the behaviours of the pocket presented.

Identified leftover spaces

Figure 5 Identified Non-Built, Under us spaces In Study Area 01 Fort
Source: By Author

Leftover spaces can be defined as spaces that were left-over by the planning development of the townscapes. When considering Fort-Colombo area, it has been undergoing with tourism-based development proposal to re-establish abandoned buildings. This initiative changed the Fort façade as the administrative capital to an administration centre with a commercial base. Most of the unbuilt spaces were acquired as parking spaces considering the lack of parking in Fort region.

Identified walking patterns

Almost 80% of the walking crowd/pedestrian flow are adults who work or visit Fort area to obtain services. They tend to walk as individuals considering the time and traffic flow: Limited vehicular movement of the area. They were 'fast as individuals' during office working hours. 80% of users were dropped off at nearby which required them to walk to the offices and 50% occupants who use personal vehicles park at another car parking space and walk to their destination.

D R Wijewardena Mawatha and Sir Chiththampalam Gardiner road feed the walking population to the Fort area and main streets. Lotus road and York Street divide these populations to the other streets and roads. Main three bus stops act as active starter points in the pedestrian flow. Highest pedestrian flow is concentrated on the WTC-BOC-Central Bank block and other pedestrian flow direct to SLT Head Office, Port Authority, State Sectary Office (Old Parliament) and Presidential palace. 80% of users were dropped off at nearby which required them to walk to the offices and 50% occupants who use personal vehicles park at another car parking space and walk to their destination.

During lunch hours walking behaviour expands further to Galle face south.

Identified interconnections between leftover spaces and walking patterns

Figure 6 Pedestrian Tracing and Pauses during Moderate Traffic hours
Source: By Author

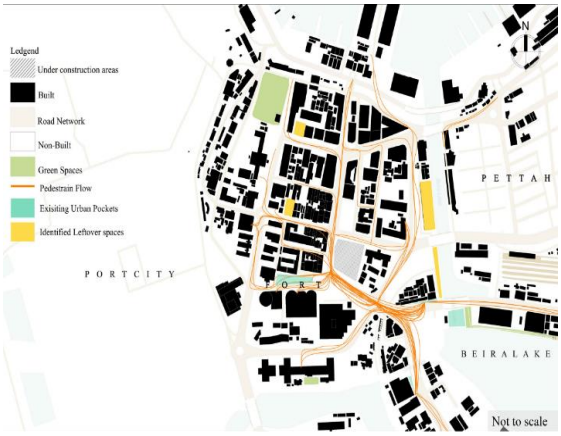

Figure 7. Identified Leftover spaces, Existing Urban Pockets and Pedestrian flow in Fort
Source: By Author

The occupants of the Fort favour walking considering the interconnected lobbies where built mass created spaces as niches, corners and street grid allowing to walk in alleyways. These spaces were grown to be public corridors and public spaces and respectively as urban pockets. Though later developments diminished the interconnected lobbies, the overall sense of

interconnected walkways has remained intact. Following figure overlays the leftover spaces and existing urban pockets with the pedestrian flow during moderate traffic time.

Identified Urban Left-over space and possibility of developing it as Urban Pockets: Niche 01:

Selected leftover space 01 is interconnected with existing urban pocket in front of Dutch with 400m of walking distance away from two blocks. The total of three alleyways and Chatham Street feed the walking population to this identified leftover space.

Also, it is in directly focused with the BOC and Dutch Hospital. This space can be identified as niche, taking square formation and it can interlink with adjacent unbuilt space. The base plan of the niche is at same level as the road. The boundary of the space is not well-defined due to lack of well-developed building edges. This increases the probity of defining and expanding the space to other building blocks and occupy by adjacent users of Banks, Navy and Hotels.

Figure 8 Identified Urban Left-over space and its' interconnection to the surrounding
Source: By Author

Identified Urban Left-over space and possibility of developing it as Urban Pockets: Niche 02:

Figure 9 Identified Urban Left-over space and its' interconnection to the surrounding
Source: By Author

Selected leftover space is an abandoned building which linked to another leftover space behind Ministry of Foreign Affairs. Like the niche 01, this space is fed by the Janadipathi Mawatha and York Street. Also, it is directly connected to Sir Baron Jayathilaka Mawatha connected to the Pettah pedestrian flow. Most of the Pettah occupants who need to visit Fort use Sir Baron Jayathilaka Mawatha. Space in between is next to proposed urban pocket 02 within walking distance of 174m. Building line and façade are clear enough to understand the boundary and it is also located at same level as the road given easy access to space.

Identified Urban Left-over space and possibility of developing it as Urban Pockets: Edge 01

This space is in edge of the Lakehouse and McCullum canal and is identified as positive developing urban element. The edge is a hard, contrasting edge which can be linked to the Olcott road and Lotus Road. It is also connected with the Urban pocket near SLECC and Beira Lake walkway. Lack of public occupancy and lack of access to the site appear to have caused the abandonment. The strip of the space is linked to the current public parking. This space is near the initial vehicular drop for the Fort, which creates the possibility of increasing walking patterns fort to Pettah.

Outline

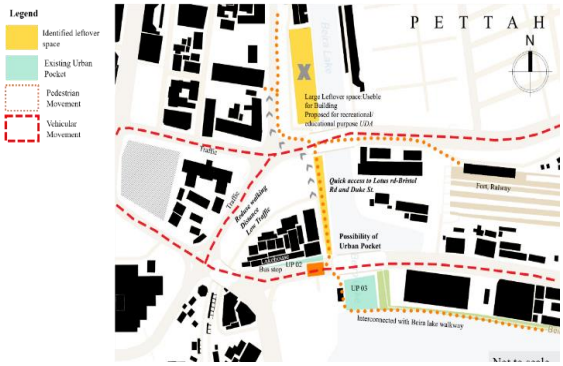

Figure 10 Identified Urban Left-over space and its' interconnection to the surrounding
Source: By Author

Based on the questionnaire occupants preferred a maximum walking distance of 400m and comfortable walking distance of 300m. 400m radius circles were placed within the range of

walking patterns that were identified. The Urban Pocket 02 and Urban Pocket 01 is on the edge of the 400m radius and the identified leftover that proposed as Urban Pocket Niche 02 is also on the edge of 400m. Proposed Urban Pocket-Niche 01 and proposed urban pocket edge 01 is also placed within the 400m range. Based on the activity patterns, UP niche 01 can be created to create continuity of walking distance of 174m almost close to 200m. The left-over space can be proposed as an urban pocket edge near Lake House to create shortcut to the Pettah increasing pedestrian walking toward Pettah rather than an increase in vehicular input to the centre.

IV. CONCLUSION

Walkability is a growing need in Colombo city considering the vehicular increment and air pollution. Even though the development considers pedestrian infrastructure the quality, security and comfortability of the pedestrian walkways have been neglected throughout the years. This research identified research gap in walkability research field that the effectiveness use nodes, junction or urban space. Considering the effectiveness to the walkability from small urban spaces-pockets in well-designed cities, this approach can be used in Colombo city too. Leftover spaces that have been built up by recent development create unnecessary wasted spaces around Colombo city. Research targeted on finding the leftover spaces that can be used as small urban pockets in order to enhance walkability of Colombo.

Overall image of Fort designed with linking to identified existing urban pockets and identified three leftover spaces. Each space is connected by the street grid system and each space locate within maximum walking distance of 400m. Fort built mass designed as soft edges where corridors and lobbies presented to the pedestrian streets. This physical factor and interconnected urban pocket network complete the model of walkability factors of pedestrian flow and the pause.

Figure 11 Conclusion Layover on Urban grid and Active walking linkage Source: By Author

Considering existing urban pockets in Fort area, only Front of the Dutch hospital pocket acts as significant destination pocket. Dutch hospital front pocket connects to two leftover spaces respectively leftover space 01 and 02. Both spaces are interlinked to the Dutch hospital pocket by alleyways and street grid. Other two existing pockets were stimulated by pedestrian activities to be developed as urban pockets which has significant destination sense in traveling routes.

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Contribution of Architecture on Juvenile Rehabilitation Process in Sri Lanka

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Abstract— The process of reintegrating juveniles to society from juvenile rehabilitation facilities is as important as the process of rehabilitation. If the rehabilitation process is not conducted properly it would rather be difficult to control the reconvicted/recidivism rates. Hence, the rehabilitation methods must adhere to certain attributes relating to the rehabilitation process, one key aspect being the built environment of the rehabilitation facilities. Humans by nature have an undeniable connection with their environment through physical, mental, emotional and spiritual means. This connection helps to keep a balance within ourselves. Most of the time, unlike adults, juveniles commit crimes or become victims without their own will. It is of paramount importance that this is understood and they are attended with the required special attention in the rehabilitation process. At the stage of admission to the rehabilitation facilities, these youngsters are more likely to be in a very weak state of mind, with the need of protection, self-value, freedom, and to obtain the sense of belongingness in the society as they are reintroduced. This requires improvement of interpersonal and intrapersonal skills before leaving the correctional facility to avoid reconviction/recidivism. The rehabilitation process influenced by architectural attributes was followed in this research would be to understand by location and site planning, spatial organization, provision amenities, supervision and security and visual character. In the Sri Lankan context, it shows that most of the juveniles from facilities that have considered these architectural attributes show comfort when reintegrating with the society as adults whereas others from contradicting facilities show difficulties when reintegrating with the society as adults.

Keywords*: juveniles, rehabilitation, architectural attributes*

I. INTRODUCTION

A. Healing Process and built environment

Human beings have an inner connection with the environment by physical, mental, emotional and spiritual means. This connection with our environment is the key in keeping a balance within ourselves. Healing does not limit to psychology or medicine. By the definition itself, healing is the process of re-establishing harmony within the organism. In our built environment we often interact with the buildings without even realizing the great influence such built environments and surroundings hold. This great power holds influence in our lives for good or bad, happy or sad, stressed or relaxed in every physical, emotional and spiritual way. This natural state, when in check or harmonies allows our body to be in both mentally and physically healthy state. Architecture has various definitions from different points of view. It always deals with the built environment and can be described it as an art of composing meaningful spaces.

B. Juvenile rehabilitation

The term juvenile in common dialect could be defined as a child or a young person who is in age below 18. It can also be defined as a child or an adolescent between childhood and man/womanhood. (Niriella) According to the world health organization definition of the rehabilitation refers to “the combined and coordinated use of medical, social, educational and vocational measures for training the individual to a highest level of functional ability”. In Sri Lanka, there is a number of juveniles who are although under the guardianship and the custody of parents but were neglected, involving

in antisocial behaviour or becoming a prey for crimes which the relevant authorities should pay their serious attention. It should be noted that the juvenile generation is a vital social entity who will eventually grow up to take over the responsibility of the future of any country. Therefore, it is very important to build a good physical and psychological condition within them. And their education, vocation and the future programmes need to be ensured. Therefore, through the authorities, these children are admitted into juvenile rehabilitation facilities for rehabilitation.

C. Legislation and Procedures

Since 1939 Sri Lanka had has separate legislation governing the administration of juvenile justice. Children and Young Person's Ordinance (CYPO) 1939 was introduced for children age under 16. Children who are in conflict with law and children in need protection deals with following ordinance. In present situation there are several legislative enactments which currently deal with the law relating to juveniles.

The Children and Young Persons Ordinance (CYPO) No. 48 of 1939

Youthful Offenders (Training Schools) Ordinance No.28 of 1939

Probation of Offenders Ordinance No. 42 of 1944

Penal Code Act No. 2 of 1882

Code of Criminal Procedure Act No. 15 of 1979

Prison Ordinance No. 16 of 1877 (also contain some special legal provisions applicable to juvenile offenders)

However, CYPO is out of date and fails to fulfil the standards of CRC (United Nations Convention on the Rights of the Child 1989); therefore, there is a growing need of reformation of the system. The National Child Protection Authority has taken a leadership role in the process of reviewing and revising the legislation. (UNICEF, 2006)

D. Juvenile Rehabilitation Facilities in Sri Lanka

The department of Probation and Childcare Services is providing care, protection and shelter for orphaned, abandoned, destitute and abused children in Children homes in the entire country. The administration of these services has been functioning under the Ministry of Women and Child Affairs since 2015. There are appointed commissioners in all 9 provinces covering the entire island.

According to them, they have classified children's homes as below,

Voluntary Homes

Remand homes

Certified schools

Detention homes

State Receiving homes

Approved schools

And there are some international organizations which are also providing care, protection and shelter for these children. After the court procedures, the department of probation and childcare services admit juveniles into these facilities. One of these organizations is,

SOS Children's Villages

II. OBJECTIVES

To identify the relation between rehabilitation and reintegration process and built environment

To identify the architectural attributes which effect on rehabilitation and reintegration process of juveniles

To study the architectural character in juvenile rehabilitation facilities in Sri Lanka

To identify the architectural contribution on rehabilitation and reintegration process of juveniles

III. RESEARCH METHODOLOGY

This research follows both qualitative and quantitative methods. The qualitative part will follow a literature survey done on the principles of environmental psychology and the child psychological theories related to the built environment that will enable a view on legal background of the juvenile delinquency and existing correctional methods and correctional institutes whilst also identifying the correct architectural attributes which are already applied in local and foreign examples. And the quantitative part is obtained via questionnaires. The questionnaire will be based on the theories

from the literature survey, analysing the social and psychological behaviour of the inmates. Onsite interviews will also be conducted with the children and respective guardians of the children. After choosing case studies, the correctional institutes will be inspected via visual and photographic survey. The exterior facades, special progression and other main architectural aspects such as conditions of natural light and ventilations, colours, textures will mainly be examined in the onsite survey. The measured plans and sections will also be taken into account. Afterwards there will be a comparison between the correct architectural attributions and current attributes in case studies. And finally provide a design solution with suitable examples for the correctional institutes.

IV. DATA ANALYSIS

The scheme of analysis for this study focusses on attributes which effect on rehabilitation process and the rehabilitation and reintegration of the juveniles. There are main two parts in the analysis to understand the following aspects;

Architectural attributes in the facility

Perception of the primary user on the facility

A list of architectural parameters synthesised from the literature review will be used to understand the architectural attributes in the facilities and a list of statements are synthesized to perceive the perception of the primary user on the facility. Following figure below presents the parameters synthesized from the literature review on the architectural attributes, which will be studied under the case studies through a visual survey.

Table 9. Architectural Attributes

Location and Site plan	i.	Respond to the micro context
	ii.	Respond to the macro context
Special Organization	iii.	Identification of functions
	iv.	Physical, visual connection with the outdoor
	v.	Scale and shape of the spaces related to the functions
Provision of amenities	vi.	Sports and recreational facilities
	vii.	Skill acquisition facilities
	viii.	Religious facilities
Supervision and Security	ix.	Visibility of the corridors, pathways
	x.	Number of blind spots
Visual character	xi.	Architectural language
	xii.	Colours, Textures and Materials

To check the perspective of the child about the built environment of the facility, the list of statements was listed related to the literature review.

List of statements

The facility is isolated from the community and promotes the image of punishment

The landscaping of the facility is pleasing and encourage outdoor activities

The layout of facilities and circulation system encourage active participation

Adequate sports and recreational facilities are provided to prevent idleness and antisocial behaviour

The presence of common facilities encourages healthy social interaction

I feel normal being watched at the facility

The visual characteristic of the building is pleasing and inspiring

The interior colours of the buildings are pleasing

The design promotes the image of incarceration, beggary and contribute to depression

V. CASE STUDIES

A. SOS Children's Village - Piliyandala

In December 1981 SOS children's Village in Piliyandala was established as the first ever SOS village in Sri Lanka. It was established with 16 family houses in the village. First, a group of mothers were trained by local NGO named Saravodaya and then moved to the village with the children as family units. Up to now the village has been accommodating three generations of families and at present it accommodates 135 children in 16 families as fourth generation. In the past 35 years the facility has successfully integrated more than 307 children into society.

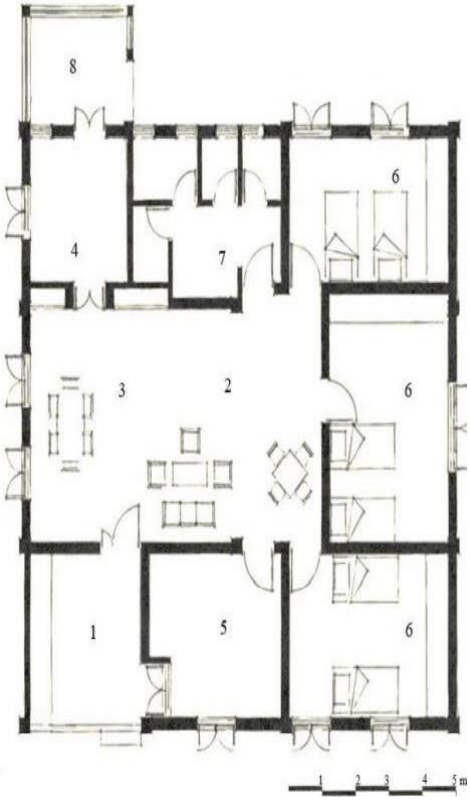

Figure 26. Plan of House – SOS Children's Village- Piliyandala [Drawing](Source –By Author)

1.Front Porch 2.Living Area

3.Dining Ares 4.Kitchen

5.Mother's bedroom6.Children's Bedrooms (nos. 03)

7.Washroom 8. Backyard

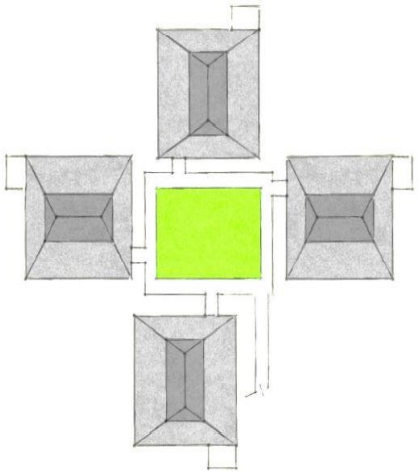

Figure 27. Courtyard arrangement between house units – SOS Children's Village – Piliyandala [Drawing] (Source –By Author)

B. SOS Youth Facility for Boys – Piliyandala

This facility is a non-government juvenile rehabilitation facility and also a part of a SOS village. This was the first facility built for the SOS youth in Sri Lanka and could accommodate up to 40 youth who are yet in high school. The Youth Facility is situated on the far end of the 15 acres that is the campus for the Children's Village and

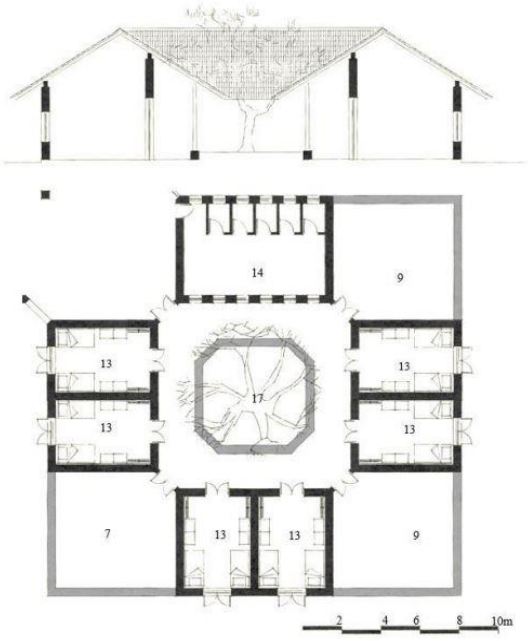

Figure 3. Section & Plan of children's Accommodation Area - SOS Youth Facility for Boys – Piliyandala [Drawing] (Source – By Author)

all other projects at Piliyandala. The building was designed by Archit. C. Anjalenden and it was established in 1989. The facility is a part of SOS village and after the age of fourteen the boys are moved to this facility from the SOS children's village.

7.	Classroom	9.	Common Area
13.	Bedrooms	14.	Washroom
17.	Open to sky courtyard		

C. Certified School – Hikkaduwa

The certified school at the Hikkaduwa was established in 1952 as the first Sri Lankan child rehabilitation facility later converted into the first certified school in the country. Initially the facility was named as "Lake School" referring to its context. The land of the facility is surrounded by a lagoon. The vision of the facility is to bring the children who were offended to the correct path, under orders directed from the jurisdiction. The mission of the facility is to rehabilitate and reintegrate the boys who are admitted from the jurisdiction at age between 12 to 16, and boys who need special protection. At the present facility, 55 boys are accommodated. The area of the land is 14 acres and the facility

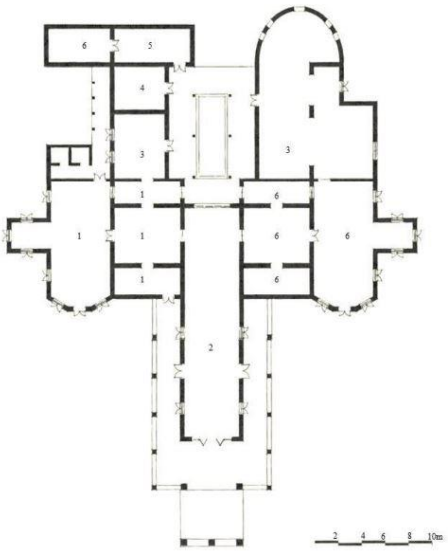

Figure 4. Plan of Manor – Certified School at Hikkaduwa [Drawing] (Source – By Author)

1.	Administration	2.	Lecture Hall
3.	Dining areas	4.	Library
5.	Kitchen	6.	Storages

D. Case Study: 04 – Voluntary Home

This facility is a non-government juvenile rehabilitation facility and also funded by a foreigner, the facility has been registered under the department of probation and childcare services. Therefore, the children in the facility and the administrative functions are monitored by the probation officers. This facility was established in 1999. The building was initially a residential unit which was later converted into a rehabilitation facility. With time they have added new parts for the building following necessary requirement. The facility accommodates 22 girls aged between 10 to 18 years.

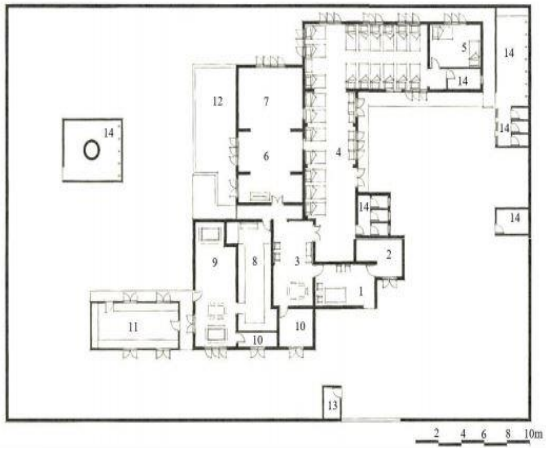

Figure 5. Voluntary Home Plan [Drawing] (Source – By Author)

1.	Veranda	2.	Office room
3.	Living	4.	Bedroom
5.	Kitchen	6.	Storages
7.	Study area	8.	Utility
9.	Dining area	10.	Store
11.	Kitchen	12.	Working Space
13.	Guard room	14.	Toilets /Bathing

VI. RESULTS

Table 10. Summary of Survey Results

Location and Site Planning
Integrate into community

Deinstitutionalized and homely built environment			
SOS Village	**SOS Youth facility**	**Certified school**	**Voluntary home**
Integrated with the community	Integrated with the community	Isolated from the community	Less integrated with the community
Deinstitutionalized and homely built environment	Environment appeals homely	Environment appeals normal and institutional	Environment appeals less homely
Spatial Organization Allow for surveillance Functional clusters or linear sequence			
SOS Village	**SOS Youth facility**	**Certified school**	**Voluntary home**
Central courtyard plan which aids supervision and surveillance	Aids supervision and surveillance	Separate surveillance required for different buildings	Aids supervision and surveillance, need to improvement
Arranged around the main space	Linear sequence	No identification of functional clusters	No identification of functions
Provision of Amenities Sports and recreational facilities Skill acquisition facilities Religious facilities			
SOS Village	**SOS Youth facility**	**Certified school**	**Voluntary home**
Playgrounds and play areas were provided	Playgrounds and indoor games were provided	Playground has provided	Play area has provided
Skill acquisition facilities were provided	Skill acquisition facilities were provided	Skill acquisition facilities were provided	Skill acquisition facilities were provided
Outdoor shrine has provided	Indoor shrine has provided	Outdoor shrine has provided but not in use	Religious facility has not provided
Supervision and Security Avoid blind spots Promote freedom and unobtrusive supervision			
SOS Village	**SOS Youth facility**	**Certified school**	**Voluntary home**
Openness and courtyards avoid blind spots	Openness and courtyards avoid blind spot	Abundant buildings, attics, forest areas provide blind spots	Avoid blind spots, but need to improve
Promote freedom and unobtrusive supervision	Promote freedom and unobtrusive supervision	Promote freedom and unobtrusive supervision	Demote freedom by the rampart
Visual Character Inspiring and foster self esteem			

Familiar, homelike environment Eliminate image of incarceration/ punishment or beggary			
SOS Village	**SOS Youth facility**	**Certified school**	**Voluntary home**
Inspiring and foster self esteem	Inspiring and foster self esteem	uninspiring and foster humble	uninspiring
homelike environment	homelike environment	Prison environment	Institutional environment
Eliminate image of incarceration/ punishment or beggary	Eliminate image of incarceration/ punishment or beggary	Image of incarceration/ punishment or beggary	Image of beggary

Summary of Interview results

Table 11. List of Statements

Statement 01	The facility is isolated from the community and promotes the image of punishment
Statement 02	The landscaping of the facility is pleasing and encourage outdoor activities
Statement 03	The layout of facilities and circulation system encourage active participation
Statement 04	Adequate sports and recreational facilities are provided to prevent idleness and antisocial behaviour
Statement 05	The presence of common facilities encourages healthy social interaction
Statement 06	I feel normal being watched at the facility
Statement 07	The visual characteristic of the building is pleasing and inspiring
Statement 08	The interior colours of the buildings are pleasing
Statement 09	The design promotes the image of incarceration, beggary and contribute to depression.

Table 12. Summary of interview results

	SOS village Number of Participants 50	**SOS youth** Number of Participants 40	**Certified school** Number of Participants 50	**Voluntary home** Number of Participants 22
Statement 01	None (0%)	None (0%)	48 (96%)	15 (68.2%)
Statement 02	40 (80%)	35 (87.5%)	12 (24%)	10 (45.4%)
Statement 03	45 (90%)	38 (95%)	8 (16%)	9 (40.9%)
Statement 04	50 (100%)	40 (100%)	44 (80%)	17 (77.27%)
Statement 05	48 (96%)	35 (87.5%)	20 (40%)	12 (54.5%)
Statement 06	3 (6%)	2 (5%)	50 (100%)	16 (72.7%)
Statement 07	47 (94%)	38 (95%)	14 (28%)	14 (63.6%)
Statement 08	48 (96%)	38 (95%)	11 (22%)	16 (72.7%)

Statement 09	None (0%)	01 (2.5%)	49 (98%)	20 (90.9%)

VII. CONCLUSION

Unlike adults, when a child is admitted into a rehabilitation facility there is a high chance of that child being a victim of depravation and derogation. Due to that, the juvenile may have adoptive problems to strange place. Therefore, it is a necessity to launch gradual and methodological adaptation methods with adaptation systems. Through research, psychologists and environment behaviour studies have recognized the role of the built environment in behaviour control. The studies prove that the built environment can support or inhibit human behaviour change. It also affects cognitive behaviours of an individual, and an understanding about this relationship can help to determine and predict the activity and behaviour of its users. Positive behavioural interventions help to prevent juveniles from engaging in negative behaviours by changing the environment in which the behaviours occur. Interventions also help juveniles to develop social skills and individual behavioural skills which they need to succeed in an inclusive environment. The built environment includes the infrastructural elements, utilities, and all other structures created by humans. Therefore, it is the integrated built context in which individuals live, and it affects the attitude and behaviour of people in many ways, and built environment has a significant influence on the development of individuals and their activities and social interactions.

According to the United Nations, one of the ways of reducing juvenile delinquency is by altering the physical features of the environment through architectural and landscape planning and providing opportunities to engage young people's interest.

By following the case studies of SOS facilities initially designed by architects and the buildings of both certified school and voluntary home converted as juvenile facilities. According to the results, SOS facilities have achieved much architectural attributes that has affected in the rehabilitation process much more positively than the others; certified school and voluntary home. According to the interview results juveniles at the SOS facilities have good impression and better psychological state comparing to the certified school and voluntary home. SOS facilities show that the architectural attributes helped to improve and enhance the rehabilitating and reintegration process through both visual survey and interviews. The facility has been designed specifically for the main user. And the juveniles who are released as adults to the society have a good image among the society and they are properly integrating. According to the SOS facility records, these children have good achievements in both education and extracurricular activities. Most of them are having good marriages and the proper higher education. When considering certified school at Hikkaduwa, the architectural character of the main building appears unnecessarily powerful and intimidates the juveniles in the facility. And the character of the accommodation buildings brings sense of punishment or imprisonment to the juveniles. The hierarchy of the spaces, the identification and response to the main user is very poor. Many juveniles who are reintroduced to the society have not had a good image in the society and they tend to reoffend in the future.

Character of the voluntary home also brings the sense of incarceration and the juveniles at the facility are much introverted and their relationship with the society is poor. This shows that the perception of such facilities varies from one juvenile to another or among groups of juveniles, and the design of such facilities must take these peculiarities into consideration.

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Rethinking of the Adaptability in Mass Housing for Pandemic Situations

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Abstract— Pandemics spread due to poor housing conditions. Diseases have resulted in inducing the concept of mass housing, evident from housing projects initiated after the Great Plaque in London. Current pandemic, i.e., the spreading of the COVID-19 virus affected physical health of humans at alarming rates. The relationship between the spread of pandemics and living environments is unexplored. The study intends to bridge the gap in literature, and explore methods that could be implemented to mitigate situations in future scenarios. The parameters by the WELL Building Standard®, of air, water and light have been considered. Results explicitly prove mechanical systems of residential housing units need a (MERV) of 8, as 70-85% of particles can be captured. Relative humidity between 40%-60% can limit spreading of COVID19 within housing interiors. Pressure difference between corridor spaces and rooms will prevent air circulating from source to another in hospitals, minimising spreading of pathogens. Similar strategy can be adopted into the housing context via mechanical ventilation systems. The most effective method to limit spreading of pathogens from room to room in hospitals is to design a buffer space. This can be adopted in the housing context, such as powder rooms in apartments. Airborne viruses that contain single-stranded RNA are reduced by 90% with a low dose of UV light and is eliminated through building glass layers. A set of adaptive guidelines have been derived, to be applied in designing mass housing and also in managing Built Environment in similar situations.

Keywords*: pandemic, mass housing, adaptability*

I. INTRODUCTION

The rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-Cov-2) has caused massive destruction across the globe. The virus has affected physical health at most alarming rates and imposes emotional, social, and economic crisis for the people living in the world. Thus, the world has taken global and national measures to minimize the spread of the Virus. However, global recognition of mitigation measures for the COVID-19 pandemic has not been translated into effective planning of housing built environments.

From history, it is evident that the transmission of diseases have inspired architects in the design of healthier hygiene oriented living built environments. These have led to development of cities, as in 17th century, as almost 87% of the city of London was destroyed by the Great Plague of 1665 and the Great Fire of 1666. These disasters resulted in the destruction of a large number of houses, however it also provided opportunities for housing. Architect Christopher Wren proposed replacing crowded buildings and narrow streets (once a hotspot and launching pad for plague and the fire) with wider avenues and richer spaces. Unplanned crowded housing, lack of proper sanitation and a lack of health knowledge of the people resulted in haphazard and poor living conditions in early industrial cities of Europe. In 1882 , tuberculosis bacillus was discovered and the disease associated with the unhealthy, crowded conditions in which the working-class people lived in urban areas. In the 20th century the modern movement in architecture was influenced by historical factors such as the need for healthcare to fight diseases like tuberculosis, and the success of modernism is inseparable from its close relationship with health.

However, the modernisation of the interior spaces of houses and other buildings do not primarily mitigate the spread of diseases. As

modern buildings propose several risks in health, as Legionnaires' disease outbreak in Philadelphia, Pennsylvania. The disease spreads due to the contamination of cooling water in air conditioning systems. The current spread of COVID-19 in buildings is associated with poor building design, ventilation and planning.

World Health Organization (WHO)'s investigation of the spread of COVID-19 in China indicated that 78% to 85% of transmission occurs within families rather than communities as a whole. Lockdown restrictions lower the lockdown restrictions lower the chances of the virus being transmitted outside of a family home. However, self-isolation can be difficult when living with other family members, and there is a high risk of household transmission. Thus, it is of paramount importance to provide mitigation methods to minimize the risk of household transmission.

In the 1990s, WHO put forward the concept of "healthy housing", which means "housing that enables the occupant to be in a completely good condition physically, mentally and socially. In 2014, the United States issued the WELL Building Standard®, the first standard for healthy buildings and the world's first people-oriented building certification standard focused on living conditions. The WELL Building Standard® is a performance-based assessment system that measures, certifies, and monitors the characteristics of the built environment that affect human health and wellbeing, such as air, water, nourishment, light, fitness, comfort, and mind.

Out of these assessment concepts, air, water and light are closely associated with the spread on the COVID-19 virus. According to previous investigations into SARS (Booth etal, 2005), spread through aerosolization remains a potential secondary transmission method, especially within the interior spaces. These aereosols are released naturally and through mechanical ventilation methods. These natural and artificial methods highlight on the importance of assessing the parameters of air, water and light of the WELL Building Standard® within the housing built environment.

Inadequate attention has been given to the spread of the virus under indoor microclimatic parameters of air, water and light. As literature stated that the effect of microclimate of an interior is very relevant to the propagation of droplets, where dispersion is enhanced by indoor and outdoor microclimatic profiles (Guerrero, 2020). As an example, current research depicts that respiratory particles exhaled after a sneeze can be dispersed by turbulent wind more than three times further than the physical distancing measures recommend. Thus, the microclimatic parameters of air, water and light is of vital importance when designing pandemic resilient housing interiors.

The aforementioned assessment system by WELL Building Standard® can be considered for design standards, and can be used to assess current housing and to prioritize interventions. This paper provides contributions based on the framework in the assessment system by WELL Building Standard® of the the microclimatic concepts of air, water and light of interiors as a foundation to re-think the current safety measures and to re-imagine the housing spaces to assure human well-being amidst the ongoing COVID-19 pandemic.

II. METHODOLOGY

The features that impact the spread of COVID-19 in the built environment (these built environments vary from hospitals to other public spaces) is examined upon and it is translated in terms of effective planning of housing environments. Firstly, through a qualitative systematic review the features reported by researchers as impacting the spread of the coronavirus were recorded and organized into three domains, i.e. - the concepts of the three domains of the WELL Building Standard® which form the structure of the framework.

The research papers for the systematic literature review were searched on, Emerald Insight, Scopus, ScienceDirect and PubMed. They were selected because of their different main subject areas, which could provide a thorough overview of the topic. The titles and the abstracts the papers were examined to determine if they were suitable for the research purpose.

The literature review led to the outline structure of the framework of mitigating the spread of COVID-19 in housing units in which the most

recurring determinants of housing quality were reported. The structure of the framework is based on the checklist proposed by the WELL Building Standard®. It brings together the major concerns to consider when assessing the suitability of dwellings to the needs of housing during a pandemic situation. The framework has therefore been structured into three domains as follows- air, water and light.

III. RESULTS AND DISCUSSION

Table 1 indicates the results of the systematic review with the three selected domains.

Table 1. Classification of referemces sccording to paper number

Domain	Reference Paper Number
Air, water	4, 5, 8, 10, 3,9, 13,6, 2,12,1
Light	7, 1, 15, 16

Source: Author

When the concepts of air and water are considered, the microclimatic conditions of the interiors of residential units is of paramount importance, this includes air temperature, humidity and air quality. The air within the interiors is of natural and artificial sources. With the installation of HVAC systems in the modern context, the risk of COVID-19 spreading is relatively high within interiors.

The prevention and mitigation of transmission of viruses through the built environment relies of inline filtration mediums (Chan etal 2020, Chang etal 2020). The mechanical systems of residential housing units generally need a minimum efficiency reporting value (MERV) of 8, as with this efficiency rate 70 to 85% of particles ranging from 3 to 10µm can be captured. The housing units of condominiums usually are installed with package thermal air conditioners (PTAC). A majority of viruses, including CoVs, have a size range between 0.004 to 1.0 µm (Goldsmith etal, 2004). It is proven that SARS-CoV-2 virus lies in aerosol particles in a spectrum of sizes from 0.25 to 0.5 µm(Liu etal, 2020). This aspect highlights on the need for filtration mechanisms with a high efficiency to reduce the transmission of these virus particles. Residential buildings require MERV-5- MERV-11 whilst hospitals and other health care settings utilize a MERV-13 or higher (Goldsmith etal, 2004).

Research as indicated that viruses including CoVs struggle to survive in typical indoor air temperatures and relative humidity above the range of 40% (Kim etal 2007, Biospace 2020, Noti etal 2013). Moreover, the changes in humidity levels effect on the susceptibility of an individual to viruses (Eccles, 2002). Humidity levels of interiors also impact on how far the virus gets deposited along the respiratory tract(Marr etal, 2019). However, humidity levels of interiors should not exceed 80% as high levels induce mold growth which have negative effects on human health (Block, 1953). According to ASHARE 170-2017, the current ventilation standards highlight on a RH range between 20% to 60%, however, with the above findings from literature, a relative humidity range between 40%-60% can aid in limiting the spread of the SARS-CoV-2 within housing interiors. This will help maintain thermally comfortable interiors in the long-run for occupant comfort (ASHARE 2017, Noti etal 2013).

The next part of this paper indicates about a strategy which is used in hospitals to prevent the risk of pathogens spreading from room to room. These aspects can be incorporated when designing the air systems of housing units. For example, in hospitals, high risk patients are stationed in rooms known as the protective environment (PE) rooms. This is to limit the exterior airborne infectious particles from entering the interior of the rooms. For this to be achieved, these rooms require a negatively pressurised HEPA air supply relative to the corridor space and adjacent other rooms (ASHARE 170-2017). This pressure difference between the corridor space and PE rooms will prevent the air from circulating from one source to another. Thus, the spread of the pathogens can be minimised. This similar strategy can be adopted into the housing context with regard to the pressure difference by the mechanical ventilation systems. However, in the medical context, the most effective method to prevent and limit the spread of pathogens from room to room is to design a buffer between common areas and high risk spaces, these are called anterooms. In the housing scenario, powder rooms cater this

similar function or a buffer room can be designed to limit the pathogens from spreading.

The third concept of light also help in the control of the existence of infections particles indoors. Daylight is an element of paramount importance in architecture as it has been proven that bacteria particles inside households to become less associated with human interaction than in darker spaces (Fahimpour etal, 2018). In buildings the spectrum of the sun is been filtered through windows, especially glass. The resuting UV rays are been absorbed with finishes indoors while preventing the reflection of the UV rays into the surrounding spaces.

The effect of daylight on indoor viruses and SARS-CoV-2 is still not examined, the use of UV rays has been explored. As electric lighting is already used as engineering controls for disinfecting the indoor spaces. UV rays are of short wavelengths and these are germicidal and these are successfully used in clinical spaces to deactivate viruses and also reduce the survival rate of viruses (Rutala etal, 2017)

Most UV light rays are eliminated in the atmosphere, while much of the UV rays is eliminated through building glass layers. Airborne viruses that contain single-stranded RNA (ssRNA) are reduced by 90% with a low dose of UV light, and the UV dose requirement increases for ssRNA viruses found on surfaces (Tseng 2007, Lytle 2005). Thus, in terms of the concept of light these startegies of using UV light can be used in housing units to limit the spreading of viruses.

IV. CONCLUSION

It can be proven from history that pandemic situations have led to new designing startegies for housing. For example the Great Fire and Great Plaque in England during the industrial revolution. The same scenario needs to looked upon within the prevailing COVID-19 sitaution. The WELL Building Standard® , was the first standard for healthy buildings and the world's first people-oriented building certification standard focused on living conditions. The WELL Building Standard® is a performance-based assessment system that measures, certifies, and monitors the characteristics of the built environment that affect human health and wellbeing, such as air, water, nourishment, light, fitness, comfort, and mind. The performance parameters of air, water and light were examined closely in this paper through a systematic literature review. Inadequate attention has been given to the spread of the virus under indoor microclimatologic parameters of air, water and light.

When mass housing in taken into context with the pandemic situation further research needs to be done. As the different types of mass housings such as flats, high risers, row houses etc…need to be examined with the pandemic situation. These are of paramount importance for further research within the housing context. This research paper is a steeping stone for further studies. As the paper presents set of adaptive guidelines which have been have been derived through a systematic literature review. These can be applied in designing mass housing and also in managing Built Environment in similar pandemic situations.

The conclusions derived from the detailed analyses and discussions are as follows-

The installation of HVAC systems in the modern context, the risk of COVID-19 spreading is relatively high within interiors.

The mechanical systems of residential housing units generally need a minimum efficiency reporting value (MERV) of 8, as with this efficiency rate 70 to 85% of particles ranging from 3 to 10μm can be captured.

It is proven that SARS-CoV-2 virus lies in aerosol particles in a spectrum of sizes from 0.25 to 0.5 μm.

This aspect highlights on the need for filtration mechanisms with a high efficiency to reduce the transmission of these virus particles.

Residential buildings require MERV-5- MERV-11.

Viruses including CoVs struggle to survive in typical indoor air temperatures and relative humidity above the range of 40%.

Humidity levels of interiors also impact on how far the virus gets deposited along the respiratory tract.

Humidity levels of interiors should not exceed 80% as high levels induce mold growth which have negative effects on human health.

A relative humidity range between 40%-60% can aid in limiting the spread of the SARS-CoV-2 within housing interiors. This will help maintain thermally comfortable interiors in the long-run for occupant comfort

A strategy which is used in hospitals to prevent the risk of pathogens spreading from room to room can be implemented in housing designs.

The high risk rooms in hospitals require a negatively pressurised HEPA air supply relative to the corridor space and adjacent other rooms.

This pressure difference between the corridor space and PE rooms will prevent the air from circulating from one source to another. Thus, the spread of the pathogens can be minimised.

This similar strategy can be adopted into the housing context with regard to the pressure difference by the mechanical ventilation systems.

The most effective method to prevent and limit the spread of pathogens from room to room is to design a buffer between common areas and high risk spaces, these are called anterooms.

In the housing scenario, powder rooms cater this similar function or a buffer room can be designed to limit the pathogens from spreading.

It has been proven that bacteria particles inside households to become less associated with human interaction than in darker spaces.

In buildings the spectrum of the sun is been filtered through windows, especially glass.

The resuting UV rays are been absorbed with finishes indoors while preventing the reflection of the UV rays into the surrounding spaces.

Airborne viruses that contain single-stranded RNA (ssRNA) are reduced by 90% with a low dose of UV light, and the UV dose requirement increases for ssRNA viruses found on surfaces

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