EDITOR IN CHIEF

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FOREWORD

The International Research Conference 2018 of General Sir John Kotelawala Defence University (KDU IRC-2018) was on the 13th and 14th of September on the theme, Securing Professional Excellence through Collaboration. It was held for the 11th consecutive year under the guidance of the Vice Chancellor, Rear Admiral JJ Ranasinghe. The inaugural ceremony of the conference was held at the auditorium of the Faculty of Graduate Studies, under the patronage of the Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne. Many distinguished guests: Tri-service Commanders, members of the Board of Management of KDU, representatives of the Diplomatic Corps, Vice Chancellors of other state universities, senior officers of the Tri-services and the Police, graced the event.

The session was opened by the Vice Chancellor, and he warmly welcomed all the dignitaries and participants. Further, he briefly explained the significance of the theme of the conference and KDU's commitment to fulfill national responsibilities. KDU IRC-2018 awarded honorary professorships to two internationally eminent Sri Lankan born scientists, Professor Mohan Munasinghe and Dr Sarath D Gunapala, in recognition of their contribution to their respective fields of science, and to mankind.

Delivering the keynote address, Mr. Waidyaratne commended KDU for playing a leading role in moulding the future of the military as well as civilian youth who are in pursuit of high quality tertiary education in Sri Lanka. He also stated that KDU contributed immensely to the much needed research and innovation, despite being an excellent institution for learning and disseminating knowledge that empowers the youth by helping them to develop sound attitudes and skills.

KDU IRC - 2018 continued with the tradition of bringing together researchers, academics and professionals from all over the world. This conference particularly encouraged the interaction of scholars to present and to discuss new and current research. Their contribution helped to make the conference as outstanding as it had been. A significant increase in the number of research papers received was noted at this conference. Out of 573 research papers received from both local and international scholars, 370 research papers were selected for presentation through the double blind peer review method. Each paper was reviewed by two independent experts in the field prior to selecting them for either oral or poster presentation. The selected papers were presented in nine research sessions, such as, Defence and Strategic studies, Basic and Applied Sciences, Engineering, Medicine, Allied Health Sciences, Computing, Built Environment and Spatial Sciences, Law and Management Social science and Humanities.

Technical Sessions were conducted on the first day of the conference in each faculty which drew approximately 55 guest speakers internationally and locally. Similarly, on the second day, parallel Plenary Sessions were conducted in the faculties under sub-themes, with the participation of approximately 370 experts delivering speeches related to their respective disciplines. The international guest speakers numbering more than 14 represented countries such as Japan, United States of America (US), United Kingdom (UK), India, New Zealand, Malaysia, Pakistan, Philippines, Burma, Indonesia, Bangladesh and Maldives,

KDU IRC-2018 was a unique research conference due to reasons, such as, international authors were facilitated to present via Skype remaining in their country; articles were automatically uploaded to Google Scholar in order to generate individual citations (H-indexing); the best papers of each category were published in the KDU Journal of Multidisciplinary Studies; and the best oral and poster presentation of each session were awarded.

This book contains proceedings of the sessions conducted under the disciplines of The plenary speeches and selected research papers presented at the technical sessions of the faculty are also included in this book, in addition to transcripts of the speeches delivered at the inaugural session. These Proceedings will no doubt furnish scholars of the world with an excellent reference book. I also trust that this will be an impetus to stimulate further study and

research in all areas. I also trust that this would stimulate enthusiasm among scholars to engage in further study and to demonstrate the national and international importance of conducting research. I thank all authors, guest speakers and participants for their contributions.

A conference of this magnitude could not have been realized without the tremendous and generous support of the academic and administrative staff of KDU, who contributed to making it all happen.

Dr. Upali Rajapaksha
Editor
Conference Chairman 2018

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Content

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WELCOME ADDRESS

Rear Admiral JJ Ranasinghe VSV, USP, psc, MSc(DS) Mgt
Vice Chacellor

A very good morning to you!

I cordially welcome the Hon. Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne, and I pay my gratitude to you Sir, for accepting our invitation and for being with us today at this 11th International Research Conference of General Sir John Kotelawala Defence University.

Next, I wish to extend a warm welcome to our Keynote Speaker, Prof. Mohan Munasinghe; and the Guest Speaker, Dr. Sarath D. Gunapala, both of whom are very eminent and distinguished Sri Lankan scholars who have made their imprint in the international arena. We are proud of your achievements and we consider your presence here today, as truly encouraging and inspiring us at KDU, as well as for all conference participants.

Let me also warmly welcome the Tri-service Commanders and all the other Members of the Board of Management of KDU.
Also it is my pleasure to welcome Your Excellencies of the Diplomatic Corps; Vice Chancellors of other State Universities; and Senior officers of the Army, Navy, Air Force, and the Sri Lanka Police.

I also wish to extend a warm welcome to all dignitaries, scholars and participants; especially those of you from our friendly countries, who have come all the way to adorn this international conference in Sri Lanka.

Ladies and gentlemen, let me bid all of you present here today a very warm welcome this morning; and extend our appreciation for participating in this important event of our calendar.

We at KDU consider this annual conference very seriously due to several reasons. First, it is instrumental in establishing and strengthening the much needed research culture within the university, and it permeates the same into other universities and higher educational institutions in the country as well as into the industry through collaborations. Secondly, it gives local participants and institutions invaluable opportunities to establish links and networks with international counterparts, which is essential for progression in respective fields of specializations. Thirdly, it directly and indirectly contributes to the national growth and development in the long run. So, we consider this international research conference as an investment for the future.

As you are aware ours is primarily the National Defence University of Sri Lanka and our primary mandate is to produce academically and professionally qualified officers for our defence services, and we have been doing this for the highest satisfaction of the services. But today KDU has identified the need to establish firm civil military relations to face the complexities in national defence today, and hence the commencement of day-scholar programmes has helped us to achieve that goal while reducing the burden of the other state universities in providing adequate

higher educational opportunities for our youths. The well-developed infrastructure, state-of-the art facilities as well as the dedicated human resources at KDU are now being meaningfully utilized to extend its services to deserving civilian youths to follow standard degree programmes in diverse disciplines, and the success of our achievement is seen in the increasingly higher number of foreign students who join our courses from countries, such as, the Maldives, India, Pakistan, Bhutan, Nepal, Uganda and Japan; along with expatriate students from Australia, Canada and the Middle East.

Ladies and gentlemen, in the modern times, it is essential not to compartmentalize varied fields, but to instill multidisciplinary collaboration among them. Hence relationships with different fields of innovation help to bridge gaps and inculcate professional excellence, which is the challenge of the 21st century. This explains the validity of the theme of our 11th International Research Conference, "Securing Professional Excellence through Collaboration".

KDU IRC is an ideal opportunity for the academia and professionals, to meet, discuss and exchange views in an academic environment. What is special about our conference is that, it is enriched with the participation of many local and foreign academics in varied disciplines; along with individuals from all three armed forces and the Police Department. Therefore, this is the only conference in Sri Lanka that brings together civilian professionals and their military counterparts.

I extend a warm invitation to the local and foreign students, academics and professionals present here today, to present their research findings; engage with other researchers in your field of study; have fruitful discussions and build life-long friendships with each other.

I welcome all to the 11th International Research Conference of KDU.

Have an inspiring and unforgettable day at KDU!

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SPEECH OF THE CHIEF GUEST

Mr. Kapila Waidyaratne
President's Counsel Secretary

Good morning, everyone !

Chancellor, Vice Chancellor, Secretaries to the Ministries, Commander – Sri Lanka Navy, Chief of Staff of the Army, Dampath Fernando and the Air Force, Sumangala Dias, Your Excellencies of the Diplomatic Corp, international organizational scholars and other distinguished invitees.

It is my privilege and honour to be present here as the Chief Guest of the inauguration ceremony of the 11th International Research Conference organized by the Kotelawala Defence University, at which I happen to be the Chairman of the Board of Directors of its management. Let me first express my thanks to the Vice Chancellor, and conference organizers for inviting me as the Chief Guest of this very significant event.

Ladies and Gentlemen, as the Defence Secretary and also the Chairman of the Board of Management, I am aware of the outstanding role played by KDU in the tertiary landscape of Sri Lanka. With the donation of this beautiful estate along with the Kandawala mansion by the late General Sir John Lionel Kotelawala, the third Prime Minister of Sri Lanka, KDU was founded in the 1980s as the only tri-service academy in the country to provide much needed university education to the officers of the tri-services. Since then, KDU has come a long way over the last several decades reaching heights that may not have been dreamt at its inception.

For the last thirty years, KDU has produced thousands of graduate officers of very high calibre to lead the Army, the Navy and the Air Force, as highly disciplined and professional forces. In most recent times with its expansion to provide higher education opportunities to deserving civilian students, KDU has earned a name within and outside the country as a university that provides high quality tertiary education in diverse fields in a disciplined environment.

Today, with nine academic faculties, the Southern Campus and the recently established University Hospital, KDU has come to the forefront with determination to serve the nation in the best possible way. Therefore let me congratulate the Vice Chancellor and his able staff for the tremendous job, the excellent job done by them. Also let me take this opportunity to salute the pioneers of the university, specially the late General Sir John Lionel Kotelawala and Deshamanya Late General Dennis Perera, and let me not forget the political leadership of His Excellency the former President, J.R. Jayawardena, for the foresight to establish this University far back in the 1980s. Ladies and Gentlemen, the 11th International Research Conference that we are inaugurating today is a testimony for the significant role played by KDU in the field of higher education of Sri Lanka. As you are aware, it is not at all an easy task to successfully organize an annual conference of this magnitude considering the previous years. This itself indicates the strong commitment and responsibility of KDU to provide opportunities for the all-important task of knowledge creation and dissemination.

As you have already heard, and what I gathered from the Vice Chancellor, every year the number of research

papers submitted for this conference is on the increase. It is heartening to know that thousands of researchers from all over the country as well as the world consider this conference an appropriate platform to present their papers. Therefore in my capacity as the Chairman of the Board of Management of KDU, I too share with KDU the pride of the leading role played by this defence university in popularizing research, which I believe is an essential, key aspect in the nation's growth.

Ladies and Gentlemen, the conference theme, Securing Professional Excellence through Collaboration, is timely particularly for countries like ours in our quest for appropriate development strategies in the face of new global challenges.

We do need meaningful collaborations across diverse professional bodies, and we cannot be completely looking after our own interests in isolated compartments. So time has come for all professionals to unite in sharing the burden of developing our nation economically, socially and culturally, so that the future generations will have a safer world to live in.

I believe it is our professional responsibility, irrespective of lables of distinction such as scientists, doctors, engineers, lawyers, academics, administrators, military professionals or any other, to find opportunities for innovative collaborations. And in such initiatives we all must reach excellence in our own professional domains and it is in this respect that universities and higher education institutions play an important role.

Ladies and Gentlemen, it is my belief that in this respect General Sir John Kotelawala Defence University is discharging its duty to the nation in a commendable manner. So let me conclude without taking much of your precious time as there are two eminent internationally recognized Sri Lankan intellectuals to deliver key note addresses at this conference. Let me once again thank the Vice Chancellor and the organizers for inviting me as the Chief Guest this morning. And let me also congratulate them for organizing a conference of this nature on a very timely and an important theme. Finally let me wish the two-day conference and both national and international participants a highly productive conference with intellectually stimulating deliberations.

Thank you very much.

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KEYNOTE SPEECH

Professor Mohan Munasinghe
Professor of Sustainable Development, Sustainable Consumption Institute,
University of Manchester, UK
Founder Chairman of the Munasinghe Institute of Development, Sri Lanka

Good Morning to everybody!

Distinguished Audience, Vice Chancellor, Secretary, Service Commanders, Distinguished Guests Excellencies and of course fellow academics - I'm going to talk to you very briefly about Sri Lanka's sustainable mission and how we can achieve security, peace and prosperity through the green growth path. I would like to emphasize that we are looking for win-win solutions for people, the planet and prosperity for the entire globe. Now let me talk very briefly about the major issues that we face, i.e. threat for global security, and threats, such as, poverty and inequality due to resource shortages, shortfalls in the financial sector, disasters, conflicts and unfortunately weak leadership at the global level.

There is a concept called ecological foot print of humanity, which tells us how much of the planet resources we are using in total. In 2012, we were using one and a half times the equivalent of what the earth can sustainably produce, and by 2030 If we continue our present pattern of development we will need two planets! We know that we have only one planet. Sri Lanka is also exceeding its own ecological balance; it means we are chopping down the forests, polluting the water and so on. Now we have another question. It is the question of over consumption because if you look at who is doing the consumption, the richest people on the planet or the top 20% is consuming 85% of the resources, which is sixty times more than the poorest.

Sri Lanka has a dynamic nonaligned strategy; friend of all and enemy of none, which is something the President emphasized to me very much. The multipolar world order will be hopefully much more dependent on soft economic power rather than military power. And you have many poles of influence in the world. As we move to that, there will be disturbances, but Sri Lanka has a very key geostrategic position, and we can play a role in this. In case of climate change and global warming, there are two key facts which are the most important. The first point is; poor countries in poor groups suffer the most, which is manifestly unfair because the poor countries and the poorer people had the least to do with creating the problem. The problem was mainly created by the rich countries but the poor suffer. The second important point is that we follow this balance inclusive of a green growth path and make development more sustainable.

We can meet the challenge of climate change, as well as, all the other problems like poverty and so on. In the history, we have had many civilizations which lasted thousands of years. Whilst the Han civilization in China, Maurya Gupta Empires in India, Mesopotamian and the Roman Empire collapsed, eventually because of environmental and social factors, mainly over consumption of resources, there will be social divisions between rich elites and poor masses. So, these are very important aspects. We can learn a lot from the past history. If you take for example the hydraulic Systems in Sri Lanka, we had a wonderful

sustainable vision. For example, we believe that land belongs to the people and all living things while the ruler is only the guardian of the land; and King Parakramabahu had said not even a drop of rain water should flow into the ocean, without serving the man. If you look at the old dam anicuts, you will see that they were positioned exactly where the modern instruments tell us where they should be. They were ecofriendly and we had systems like the Velwidhana system and social system, controlling the flow of water which was extremely sustainable. So we have to be very much aware of these environmental and socio economic factors, scarcity of resources, inequality and conflicts which can also affect our present civilization. It could lead to some process of Barbarization where you have unrestrained market forces combining various problems like poverty, inequality and climate change, which would lead to a total breakdown of the planetary system. We also see the mass movement of refugees and other people which is more and more difficult to control, which is really a threat to global security in the future.

So, we now come to the last hope for mankind in a sense in this era, which is the 2015 sustainable development goals and the UN 2030 Agenda. How can we move forward towards a 21st Century Earth Eco-Civilization for a safer and better future? It is through the Balanced Inclusive Green Growth (BIGG) Path. The "Inclusive Green Growth Path", if you analyze the words- 'inclusive' means social; 'green' means Environment; and 'Growth' means Economy. These three elements are in the sustainable development triangle. And one of the core concepts that are extremely important here is, making development more sustainable. It is a call for empowerment and action. It basically says that sustainable development maybe very mysterious like a mountain peak covered with clouds. But we don't need to be discouraged. We will take one step at a time and climb up the hill, and eventually, we will reach the top. And the important thing here is that you and I, individuals, can make a difference.

We don't need to wait for Presidents, Prime Ministers and others to tell us what to do. Many of us know what we need to do. When we leave this room we switch off the light, we can turn off a tap, we can plant a tree, many things we can do that are extremely sustainable; so empowerment is extremely important. At the company level, we have corporate social responsibility and many other things. At the city level we can practice sustainable cities, and we come to the second core concept which is essentially what I told you before, that we need a prosperous economy specially with many millions of poor people in the world, we need to bring them out of poverty, but we also need to look at the environmental side that is the process of growth. So we don't want to destroy the environment and we need the social side which is the most neglected part. Unless we have social harmony none of the other things will be helpful. We can understand nature quite well, such as, forests, lakes and the air we breathe. But we have neglected social capital, human and cultural capital, and we had a 30 year war which eroded a lot of our social capital, this is the glue that binds the society together. All of us have a major role to play in that.

Just to remind you of the 2004 Tsunami in Sri Lanka, which is a shining example of social capital work. We were in the middle of a civil war, a poor country, one in every five hundred people was affected by the Tsunami, and other countries thought our society would collapse. But we rallied; people went out onto the beaches, voluntarily helped other people and cleared the bodies. There was social capital at work. If you look at the following year, in Hurricane Katrina in 2005 in one city New Orleans, what happened? There was no social capital: there was a complete breakdown of law and order, looting, raping and other things were going on. It was shocking because it's a very wealthy country and a small city. Hence social capital is not necessarily the property of the rich. Poor countries have effective social capital networks; we have it in Sri Lanka; we must build it and we must continue with it. I must also tell you very briefly that we need to transcend boundaries within our own mind; also this is for innovation that is what universities have to do.

Values are extremely important. We have to replace unsustainable values with more ethical values. We need to think in terms of multi-disciplinary issues. We need to think in terms of the whole planet and not just our own backyards. We have to think in terms of long time spans, decades and centuries; and as military practitioners, I'm sure you understand that it should be a long range plan, not just today or tomorrow. And we need to work with all stakeholders, i.e. the Government, not only the Government but also the civil society and businesses. Just to emphasize the question of social values, it is unethical social values that actually drive our society towards injustice, violence, greed and selfishness. That has created the state of what I call not as economic development, but as maldevelopment. We are growing based on debt, poverty, inequality and so on, which is not a very healthy way to go, and that has created what is called the environmental death over-using our planetary sources and also causing climate change. When we deplete our natural resources,

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there is more conflict. So, you have unethical social values. That is a vicious cycle. If you look at the pattern of wars today, there are no wars on weapons of mass destruction, the wars are all for resources for oil, water and land.

So, this cycle has to be broken, and we have to transcend disciplines to do that, we need to think in multi-disciplinary terms, and we need to bring the civil and business societies to work with the government to push them to strengthen democratic space and provide good governance. So, let me just briefly tell you that climate change is in a precarious situation today. We have 280 parts per million, and the main indicator is the Co2 level in the atmosphere. That was at a safe level 100 years ago or more. Today it's over 400. So, we are exceeding the safe level of Co2, and what will happen is that we will have global warming, we will have more rainfall in wet areas so you have more floods, landslides; and more droughts in dry areas and more deserts; and we will have storms, cyclones and other things in addition to sea level rise and overall temperature increase. So the economic damage over the last 50 years is rising and it's going to continue to rise. We need to survive climate change, specially to protect the vulnerable people, poor children and the elderly, in some parts of the world, such as, small islands like the Maldives, and others which will be completely submerged, and particular sectors and systems like agriculture, coral reefs and so on, but unfortunately we are not doing those things.

Talking of sustainable production, there are two key points to consider. The first one is sustainability and triple bottom line, i.e. finance and economy, environmental and social. Those three have become much more important, it's not only a question of profits any more. The second one is effective usage of resources. If you are producing shoes, if you can produce shoes using less leather, less energy and less water; it is a win–win situation, because you are reducing the burden on the environment, and also reducing your cost. So this is very attractive and now we have technologies, which are win-win. There are many technologies which we have applied, for example, in case of a garment factory in Sri Lanka, MAS Holdings, which shows you how resource efficiency works. We have looked at how carbon and energy are used in the life cycle of the product from raw material to manufacturing, to distribution to use and disposal. The main carbon emissions of a garment come from raw material, not only from manufacturing. What is the lesson for us? If you want to reduce emissions of carbon, you are not going to tinker with the manufactory process; you are going to talk to your procurement officer. The procurement officer must buy raw material from the sources, which uses the least amount of carbon. It is not an engineering problem, it's a procurement problem. So this kind of analysis tells you where the hot spot is.

For energy, the hot spot is in manufacturing and distribution and in final endings. Why? Because people wash garments, that is energy, because of hot water. So these are methods on improving production processes; and let me just tell you that what we are planning here is to have sustainable consumers and sustainable producers working together because what you see in advertising today in the TV is mainly very unsustainable; it tells you to buy more and tells you to buy very unsustainable products. We have to break that side and eventually if we get these sustainable consumers and sustainable producers working together, we can eventually have a sustainable society and use modern tools. Traditional markets fall, so we can have organic markets and other things, where you go and buy the stuff, but for young people, it's online marketing. I'm supporting start-up companies which have huge sustainable online markets. Most young people who are in their twenties do not want to visit a shop; they go to the computer and shop online. So you have to have the tool to do the right thing and through these sustainable markets you can build a sustainable society.

In the sustainable Sri Lanka vision, we have hope for a thriving economy. We don't want to be poor. Being green and inclusive does not mean poor. We want to be prosperous and to lead a high quality life in an advanced stable economy, but it is green; it should be built on our traditional respect for nature, use resources efficiently and in an inclusive society. If you look into cross cutting issues, it has things like values, gender, international relations, security and peace; so all of these are integrated. This is one of the failures of Sri Lanka in every department of the Government. It is up to people like you, thought leaders, who can contribute to bring this integration about.

Let me just finish by saying we need to harmonize the economy, society and environment to build the democratic space in Sri Lanka. We need to work with the business society, civil society, the government, or all working together; and let me just end by reminding you that the situation in Sri Lanka has to be improved quite substantially because inequality has become much worse in the last two decades. Although GDP is growing, it is not reaching down. That is a very important aspect. Spatially also, the western province and so on are much better off than for example - the dry zone. We are not

investing enough in health; we are not investing enough in education rather low as a percentage of GDP.

There are also other things, for example, the Belt and Road Initiative (BRI). The Chinese government is very important for us strategically. If you want to be an Indian Ocean hub, we have to understand that we are right in the middle of the maritime BRR. So we need to be a friend of everybody and enemy of none. We have two major ports, Hambantota and Colombo right in the middle. So Sri Lanka's geostrategic position allows us to play a key role and the investments in the BRI will also help us to bring that about. But we have an important balancing act to play. And I think, the Foreign Ministry and security forces establishment of the country have a very important role in maintaining that balance and bringing prosperity to Sri Lanka. So, for the defense services you have to be good professionals; as professionals you have to be the best. But you have to also understand the economic, social and environmental dimensions of your job. And you have to broaden your perspective to bring those aspects this is difficult.

Although it is a difficult task, our graduates and others need to narrowly focus on their expertise and to be the best in the world. I think you can do much for building the nation, one nation and one flag, protecting the democratic space. And you have to understand the concept of National Identity. We all are Sri Lankans. We have a role in disaster, this is a peace time role going from conflict to resolution; through education and training, raising the standard of national conduct especially among young people; service to the nation; honesty; integrity; respect for nature and environment; respect for the society; law; tolerance and harmony; discipline; leadership; accountability; effectiveness and impartiality, and all of these values have to be rebuilt. My final message is that we face multiple problems, but we know how to address them. Unfortunately we need to do more; we have to go on the balanced inclusive green growth path. The Indian Ocean is a key area where we can do this. We need also to bottom up leadership; we don't have to wait for global leaders to tell us what to do. I think KDU and the Sri Lanka Defence Services can lead the way to peace and prosperity in the 21st century global civilization.

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GUEST SPEECH

Dr Sarath D Gunapala
Solid-state Physicist and Senior Research
Scientist, Jet Propulsion Laboratory, NASA,USA

It's my pleasure to be here today, and I'm going to talk about the exploration of our solar system and beyond in the next thirty minutes or so. I have small stories to make it memorable, and I hope you will enjoy it.

I work at NASA Jet Propulsion Laboratory (JPL). Our main business at NASA is exploration of solar system and beyond, using robotic space-crafts. If you hear anything in the news, such as, going to Mars, Rovers, Jupiter, Saturn or beyond solar system, that is what we do.

We design and build space-craft, and seven minutes after launching we take control of it. With the space network, we can listen to our satellites even beyond the solar system. Two of our satellites, Voyager 1 and Voyager 2, are stationed about sixteen billion miles away, so if you have to send a radio signal at one hundred and eighty six thousand miles per second, it takes twenty six hours to go and then acknowledgement comes twenty six hours later, and it keeps changing.

Our deepest space network system has three antennas set in Basku in California, Madrid in Spain and Canberra in Australia. So when the earth spins, we have 24/7 coverage. Why do we do this? When I fly for a long ride, if my neighbour sitting next to me somehow learns that I am a physicist working for NASA, ten out of nine times, irrespective of gender, colour of skin, religion or ethnicity, they ask, "Are we alone? Is there life in outer space?" Looks like the question, "Are we alone?" is somehow genetically quoted into us. It's fascinating! It's interesting to note as to why we call this a solar system and not an earth system!

For nearly a few million years we believed the earth was flat, we were at the centre and everything and the universe spun around us. Normal people, also called Homo Sapiens; in Latin, homo is "man" and sapien is "wise" – "wiseman"- were very egocentric and less tolerant, so they thought everything was around us; but some people thought otherwise. Some thought there were other worlds, and they were put to silence very quickly by execution. Aren't we glad we live in more tolerant times today? We can say, "It's flat", "It goes around or not", "I don't believe in it", etc. People may argue with you, but not get physical. I'm going to talk about different types of space-craft we use, one example for each satellite class, such as, Voyager, Cassini, Phoenix and Curiosity. Then I'll talk about the hunt for other earth-like planets and recent developments in the search for life in our solar system and beyond.

JPL was formed by the California Institute of Technology in 1936 as a graduate student experiment with the involvement of six students. JPL gave the first orbiting spacecraft called Explorer 1 to the United States of America in 1958. The first two Russian spacecraft were Sputnik 1 and Sputnik 2. We have about 9000 staff, located in Pasadena in California at the foot of St. Gabriel Mountain. In 1940, JPL's first claim to fame was the development of something called jet assisted takeoff, during the World War II, for planes to takeoff at very sharp angles, so in enemy

territory it was very helpful. In 1950, they developed the first guided missile for the United States Army, and in 1958, they designed the first orbiting satellite called the Explorer. Today, we have thirty one robotical spacecraft, two beyond the solar system and the balance twenty nine are around different planets. The four types of spacecrafts we use today are: Flybys, Orbiters, Landers and Rovers. Sometimes planets align; in that case it is much more cost effective to send one satellite to observe few planets. It happens once in one hundred and seventy six years; they are the major plants: Jupiter, Saturn, Uranus and Neptune. Voyager is a Fly-by. We built two voyagers, Voyager 1 and Voyager 2; and launched them to Jupiter in 1976. Jupiter, the largest planet, is a thousand times larger than the earth and does not have a terrestrial land; instead it's just a gas bowl with many moons. Before sending the Voyager, we knew of only four moons, discovered by Gailio called Galilian Moons, bigger than our moon, but Voyager 1 discovered fifty four moons, so Jupiter has fifty eight moons. It's fascinating! In one of the Galilean moons, we observed a big volcanic eruption. This was the first time we observed a volcanic eruption beyond the earth. All the planets of the solar system are on one plain called the Solar Plain.

Voyager 2 was sent two weeks behind, in case something goes wrong with Voyager 1. Saturn is a magnificent planet, also a gas bowl. It has a fantastic ring system, first observed by an Italian astronomer. Its density is so low, if you can take this serene and beautiful Saturn to the ocean, it will float. Its rings are formed with ice particles; some are like sand pebbles and some are big chunks of ice, as big as ten meters. Close to about sixty moons were observed in Saturn; the biggest moon is Titan, at which temperature is very low and ice water is frozen. Another moon of Saturn is called Enceladus. It is a very small moon covered in ice and it has water-rivers. Hence, it has a lot of interest. Voyager is very interesting. Professor Carl Sagan, Professor of Cornell University, encouraged JPL to put a message if there is any intelligent life elsewhere. So we made a copper record quoted in gold with greetings from fifty five languages including "Ayobowan", one hundred and fifteen pictures, a variety of natural sounds of birds, whales, giraffes, lions, etc., and also President Carter's and the then UN Secretary General Waldheim's message, classical and western music, and also we put a needle and sign language if intelligent life captures it they will figure out how to play it. We put a map of the solar system so that they would know from which planet it came from. We also put sign language indicating where we are and where it came from. It is hoped for someone to find it; similar to in early days when people got lost in the ocean or stranded on an island, they would put a message to a bottle, hoping someone would find it.

The first Lander was launched to Mars in 1975. An Italian astronomer found canals in Mars. So, Hollywood movie makers hypothesized Marshians; little men with big heads, complied with Darvin's theory of evolution. We believed Martians were more brainy. Of course now we know Mars does not have intelligent life, but there could be microbian life.

Curiosity is the largest rover we built; it has ten instruments, cameras and very powerful lasers, which would analyze signals coming from vapour to find out what kind of minerals it has. Curiosity has been working on Mars since 2012, and we are building the next one called Mars 2020, and it will be launched in 2020, it will take eight months to go to Mars. We will launch when Mars and the earth are close, so it doesn't have to travel across the solar system, which would otherwise take years. Mars and earth get close every other year. We are about one hundred million miles away. One Martian year is two earth years. We landed on a crater with a five kilo metre high mound. Why did we select this location? From previous Rovers, Landers and Orbiters there is evidence that Mars has running water. We know on earth, life was formed as soon as it had water. So we thought if Mars has running water, this crater could have water. We wanted to explore whether there are rivers. There were pebbles without jaggered edges, instead they were circular, because for millions of years they would have rolled over. One hundred to two hundred years ago Mars had frozen ice like frozen mud, so in Summer times, it melts. The question is if it had water, what would have happened to it? Scientists believe that when the inner core gets colder and becomes solid, it is called a dead planet as nothing moves, and there is no current and no magnetic field. Therefore, due to blasting of high energy solar wind, the water would have vapourized.

Cassini orbiter launched in 1997 on a journey to Saturn, landed in Venus. Until Cassini, we didn't know Enceladus had rivers. We sent Cassini five miles above the surface of Enceladus. It was a very risky maneuver. We found it has geyzers, everything that a primordial soup needs. Now we know of four places that have water: Mars, Europa (icy moon of Jupiter), Titan and Enceladus. We want to investigate all four. We are very much interested in sending a very specific satellite to Titan to explore the possibility of life. We encourage NASA to fund. Actually NASA funded Europa Clipper Mission last year. Europa

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is one of the large moons of Jupiter discovered by Galilio. In Europa ice cracks all the time, but we don't know the cause. By 2020 we are going to find out whether there is life.

In 2009 we launched the Kepler telescope to find extra planets orbiting around our neighbouring stars. So far we have found five thousand planets. Out of three thousand five hundred of them we found only two earth-like planets; and in one we think there is water. We shouldn't get discouraged; as the Galaxy has two hundred and fifty billion stars. So far we have discovered about two hundred and fifty billion galaxies. If each star has ten planets, there are so many planets more than all the words uttered by human beings in the last several million years; probably one hundred thousand planets in our solar system that can probably have life.

Now we are building a lot of big telescopes for astronomy. The current largest telescope is a ten metre telescope located in Hawaii. We think with large space telescopes we can hopefully find life elsewhere, within our neighbourhood and in the near future. When looking for life, we look around for earth-like blue planets (blue for water), medium in size, hovering around. Bigger stars or giant red stars burnout fast as their life time is short. Medium size stars like us survive longer for about a million years and their biological process is lengthy, so there is plenty of time to evolve.

The building blocks of life are carbon and hydrogen. There is plenty of these in the universe found by NASA's Spitzer space telescope developed about twenty years ago, still in space. Life must be around carbon and water base. Life can come in surprises. Look at life on earth? Take a bird, lion, jelly fish, human, snake and a giant tree. To explain a snake to a person from another planet – how do you explain? We have this animal as long as a rod, no hands, can swallow his prey five times bigger than his mouth, can move two feet per second, can kill a person like me in a couple of hours by biting and injecting some proteins allergic to us, etc. So when we look for life, it can be in different forms, but water and carbon base.

Our ancestors, probably two and a half million years ago, never thought we would walk on the moon; escape the gravity of earth; become the second kind of species, not the first generation, etc. What's happening? Scientists are making new life! A couple of years ago, French scientists made an artificial rabbit. They took the glowing florescent of a jelly fish and mixed and made a glowing rabbit or a luminous rabbit. Now homosepians are creating life. Many cultures or societies in the East and mostly the West thought only God can create life. Homosepians can play the role of God, too! A question for you!

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VOTE OF THANKS

Dr Upali Rajapaksha
The Conference Chairman,
KDU International Research Conference 2018

Honourable Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne, Keynote Speaker, Professor Mohan Munasinghe, Guest Speaker, Dr. Sarath D. Gunapala, Tri-service Commanders, Members of the Board of Management of KDU, Your Excellencies of the Diplomatic Corps, Vice Chancellors of other State Universities, Senior Officers of the Tri-forces and the Police, Our most valued invited guests, Academic and Administrative Staff of KDU Distinguished Ladies and Gentlemen.

It is my privilege to propose the vote of thanks on this occasion. An event of this magnitude cannot happen overnight. The wheels started rolling months ago. It required planning and a bird's eye view for detail. I have been fortunate enough to be backed by a team of motivated and dedicated colleagues, who were willing to take on the completion of tasks beyond their comfort zones.

It is with pride I announce that we received more than 573 manuscripts, from local and international authors, and approximately 350 of them are published. Moving with the times, this year's conference offers great opportunities to presenters, such as the ability to deliver presentations via Skype; and to upload Google Scholar in order to generate individual H-indexing citations.

It is with utmost pleasure I announce that we have also given many opportunities to internal and external undergraduates to share their research findings at our conference, as either poster or oral presentations.

On behalf of KDU, or let me call it fraternity of the one and only Defence University of Sri Lanka, I extend very hearty thanks to our Chief Guest, Honourable Secretary to the Ministry of Defence, Mr. Kapila Waidyaratne; for gracing this occasion. The Support we received from the Ministry of Science & Technology and Bank of Ceylon was immense.

It is my pleasure to acknowledge our gratitude to the Guest Speakers, Professor Mohan Munasinghe and Doctor Sarath Gunapala, for sharing with us their findings and opinions. We are all inspired by your great words. You are an enormous pride to our motherland.

My special thanks go to our Vice Chancellor, Deputy Vice Chancellor Defence and administration and Deputy Vice Chancellor Academic, for your consistent guidance throughout this journey.

Ladies and gentlemen, we thank you for being with us this morning.

Have an inspirational and fruitful day!

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Plenary Session

USE OF HIGH RESOLUTION AND ACCURATE LIDAR DATA FOR UNDERSTANDING AND SOLVING PROBLEMS OF URBAN LANDSCAPE

Prof Bharat Lohani, (PhD)
Department of Civil Engineering, IIT Kanpur, India

LiDAR technology uses laser to measure coordinates of large number of points on an object. The unique characteristics of LiDAR technology is that it gathers these data at a high speed, very accurately, and without missing any detail on the ground. In view of these properties, LiDAR has been found to be in use has been finding use in several applications including urban landscape. Urban landscape is marked with complexities of high order in terms of scale of objects present, details that are required to be known, variety of the objects and difficulty in carrying out traditional surveys. LiDAR therefore becomes the most appropriate technology to measure urban landscape. The data generated are coordinates of billions of points which represent every object present there. Along with LiDAR a digital camera is also often employed. This complements the geometric information given by LiDAR with the colour information thus making the data completed. LiDAR data from all three platforms, viz., aerial, mobile, and terrestrial are useful for urban landscape. There is a trend worldwide now to capture cities with these data. Recently we have captured such data for the City of Chandigarh and Bangalore in India.

The LiDAR data along with photographs provide several options to develop solutions for solving urban problems. These include urban drainage planning, urban flood modelling and forecasting, roof top solar potential estimation, revamping municipal property tax collection from buildings and billboards, urban transport planning, safe city, urban biomass estimation, air pollution modelling and disaster management.This talk will cover the principle of LiDAR technology, its operation in field, and some case studies on city mapping including developmental planning and roof top solar potential estimation. The talk will also outline the possibilities of financial models which should be adopted in order to generate these data and use the same for cities.

ENERGY POVERTY OF OUR LUXURIOUS BUILDINGS

Dr Upendra Rajapaksha
Head, Department of Architecture, University of Moratuwa, Sri Lanka

With the issues arising due to lack of buildable land plots, high-rise office complexes and apartments can be considered as appropriate solutions in space utilization and green land conservation. This can be seen as a trend in global context where Sri Lanka is no exception. However, at the same time the urge to live in urban contexts has paved way to popularize extensively luxurious buildings. Thus, the more concern for high end luxury living has intensified the craving for energy. Available data demonstrate that Sri Lanka's contemporary urban building sector consumes excessive amounts of energy – national average of energy foot print of our typical office and multi-level apartments is around 250-300 kWh/M2/a or well above whereas some buildings have energy foot prints as high as 400 kWh/m2/a. This situation is problematic for a country with no renewable resources to produce energy.

The most luxurious buildings that do exist in Colombo demand excessive levels of energy for operation and show poverty in respect to energy demand. The reason for this is poor climate response of architectural design. A recent on-site thermal performance investigation performed on luxurious building sector in Colombo City on weekends reveals that indoor air temperature reaches 40 Degrees C or above easily during the day when the air conditioner is in off mode and when there are no occupants and equipment is not in operation. This suggests that solar heat gain through the building facades which make the building indoors hot ovens. Another investigation on air conditioned mode of office buildings reveals that there are situations where indoor air temperature during office hours in multi zones across the plan depths and lengths deviates up to 10.50 from the set point temperature (240 0C). The work highlights the severity of heat stress on indoor environments and thus energy sustainability, an issue to be addressed by optimizing the interplay of architecture with climate. Poor daylight efficiency and stressful behaviour of occupants due to overheated indoor environments are other concerns that need to be addressed. It is becoming vital to introduce a new definition to Luxury buildings; which in turn will enable the occupants to enjoy all comforts but without disabling the ability of the future generations. There are a number of design interventions that can be integrated with the plan form, sectional form and envelope at the design stage to achieve the above. Yet, it is unfortunate that we in Sri Lanka have failed to explore this through architecture, design and construction, rather, following trends and applying just only mechanical gadgets to claim buildings as energy efficient or carbon neutral.

ECUMENOPOLIS: GLOBAL COLLABORATION AND ASIAN RENAISSANCE: QUANTITY SURVEYOR'S ROLE

Prof Kanchana Perera
Department of Building Economics, Faculty of Architecture,
University of Moratuwa, Sri Lanka

Ecumenopolis is a fictitious city, a single planet-wide city, where all inhabitants of the Earth live. Science fiction writers have long dreamed of a completely urbanized planet - a planet that is no longer "natural" and consisting of only a vast city. Ecumenopolis can be considered as a development arising out of urbanization and the growth of population, transport needs and human network. Ecumenolois is overlooked as a city where the technology is used as an enabler and solution. We continue to witness the way technology progresses and changes the ways in which work is produced and maintained. The move will be first from metropolis to megalopolis and then to Ecumenopolis. Since this evolution is inevitable, it is important to start planning now itself for the Ecumenopolis to make it fully livable and comfortable for the mankind. With the concept of high urbanization, concerns on spatial development and related planning efforts, dynamics of modernization, utilizing information and communication technology, problems specific to urban areas such as flooding, garbage disposal, global warming and air pollution, fundamental changes in lifestyles, consumption behavior and production conditions do arise. Under circumstances, global collaboration will be very much necessary for the type of urban development envisaged. This is in other words, a global consensus as to how people should live in 'one city'. In global collaboration, people across the world communicate with one another for learning, knowledge sharing etc., using on line tools. Professionals can play a significant role in global collaboration to fix problems associated with the setting up of the Ecumenopolis. Complex interactions among human settlements, ICT and collaboration of professionals will help to build new urban spaces and landscapes of innovation and promote economic development, cultural interactions, political dynamics and social inequalities within cities and urban regions. Quantity surveyor as a professional involved in the built environment can help to properly manage the cost and value dimensions involved in city development. The future quantity surveyor will indeed be a smart technologist, who can collaborate with other professionals to develop integrated urbanization (Ecumenopolis) by simultaneously playing the roles of a BIM manager, cost manager, dispute manager, sustainability and cost coordinator, value management team leader, carbon accountant, data manager, interpreter, and manipulator. With this increased and diversified roles the quantity surveyors have to inculcate the skills and competencies expected of him in an Ecumenpolis. Professional bodies will also have to have a fresh look at their professional boundaries. Redefining of the role, skills and competencies of quantity surveyors is required to develop in themselves in ecological and political awareness, notions of public good, epistemological feelings at least provisionally, self-reflection and a knowledge on networking and information security and people management as they are to ensure a livable Ecumenopolis.

EVOLUTION OF THE GEODETIC CONTROL NETWORK OF SRI LANKA

Mr A Dissanayake
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Geodetic control network provides a common reference system for establishing the coordinate positions of all geographic data. The main features of geodetic control network are geodetic control stations, which are precisely measured horizontal or vertical locations on monumented points used as a basis for determining the position of other points. These stations have published the datum values derived from observations that tie them together in a network of triangles. Establishing a network of stations with precise horizontal locations in Sri Lanka commenced in 1857 by selecting these stations on top of prominent hills and forest areas which were not fairly possible to reach, with two base lines, one being at Negombo between Kandawala and Halgasthota and other being at Baticaloa between Vaunativu and Tavelamunai. The two base line distances were measured and pre-determined accurately using INVAR tapes.

This network of horizontal stations comprised of 110 locations formed with 159 triangles across the country starting from Negombo base line and ending up with Batticaloa base line, computing sides of each triangle of the network by physically measuring its included angles with the help of accurately measured initial base line distance of Negombo. Finally, the computed distance based on included angle observations of the side of triangle comprising of Battcaloa base line was compared with its pre-determined distance and the network of triangles were adjusted fixing the pre-determined distances of the two base lines. The computation of this horizontal network was done by Mr. J. E. Jackson, and published in 1932, in which the accuracy was found around 1:20,000. In the computation, the shape of Sri Lankan region was approximated to the local ellipsoid - Everest 1830 - to determine the geographical coordinates in Latitude and Longitude, and finally Transverse Mercator projection was applied to derive Two Dimensional (2D) horizontal coordinates. In 1992, with the advancement of survey measurement technology, the network was recomputed and adjusted physically by measuring all the sides of triangles in addition to measuring included angles of all the triangles of the network, known as Triangulateration. In this technique, the included angles were measured using Wild T3 survey instrument while MRA7 distance Tellurometer was used to measure distances between stations, which were apart at significant distances. It was able to improve the horizontal accuracy of the network to around 1: 40,000 with the method of Triangulateration. In this approach, the network adjustment of observations was performed by using a special geodetic network adjustment software.

During the period of 1996 - 1999, a new horizontal control network was established by using Global Positioning System (GPS) observations with establishing eleven (11) principal stations known as AA points in the country at the accuracy of 1: 700,000 and densifying the network further, it was carried out establishing two hundred and seventy-three (273) primary control stations, known as A points. In determining these control stations, GPS baseline observations were adjusted using the same network adjustment software used in Triangulateration. Due to the prevailing unrest of the Northern part of the country at that time, densification was not able to be carried out in that region. However, in between 2010 and 2012, primary control network was expanded to establish control stations in Northern area, adding 69 points. The secondary control network, comprising of stations known as B points to the accuracy of 1:100,000 and the tertiary control network comprising of stations known as C points to the accuracy of 1:50,000 were established in further densification. The new horizontal network is based on global ellipsoid WGS84 and SLD99 datum, which was established using seven (7) parameter transformation (Bursa Wolf) to select Everest 1830 local ellipsoid as the reference ellipsoid for subsequent determination of horizontal coordinates.

Due to the refinement of the old systems with Triangulation and Trilangulateration and the establishement of the present horizontal control network using GPS, some control stations have three different sets of coordinate values, and stations which were not incorporated in establishing present coordinate system have only coordinates on old systems. As a result, all the coordinates of old surveys and maps prepared based on such surveys have to be transformed into the present system in order to be aligned with the SLD99 datum.

With the difficulties of maintaining the horizontal control network due to the cost involved in its establishment and maintenance, which would mainly include cost for monumentation, replacement of damaged or destroyed control stations and densification, a necessity arose to move to a more robust and reliable system. Moreover, with the increase of users in the application of geographical information with ubiquitous computing supported by high use of Mobile Phones and Personnel Digital Assistants (PDAs) connected on the Internet for various Geographical Information System (GIS) based applications and advancement of state of the art of surveying equipment, control stations are required to be established efficiently to meet the accuracy standards at various levels depending on the purposes and time lines of the tasks.

Considering the high demand for geospatial applications by GNSS users, who need control stations to meet expected spatial accuracies to collect reliable terrain information, Survey Department took an initiative to establish a Continuously Operating Reference Station Network (SLCORSnet), which comprises of GNSS reference receivers installed at well-established control stations at designated places, each is spaced approximately at a distance of 30-50 Km. These stations transmit continuously collecting GNSS raw data live to the control center based in Colombo at the Surveyor General's Office. The advantage of this system is that, it provides accurate position real-time position at any place within the corpus of this network with a survey grade Global Navigation Satellite System (GNSS) receiver, known as a rover receiver to accuracy less than 2-3cm. The present network is operational only in the Western part of the country with six reference stations established in Colombo, Kaluthara, Katana, Awissawella, Rathnapura and Kegalle. In determining position with this method, a rover position is determined through Virtual Reference Station (VRS) technology by applying RTCM correction transmitted from the control centre software based on the raw data collected continuously at reference stations. Also the online delivery of GNSS raw data in RINEX format and online post processing services of GNSS static observations are provided as online web services from the SLCORSnet website of the Survey Department. Once registered under the SLCORSnet website, a user can obtain these services during the subscription period. It should be emphasized that with a single receiver, a user connected to the system can perform RTK positioning, setting out surveys and establishing control points for subsequent detail surveys depending on the type of application.

Furthermore, the vertical control network of Sri Lanka is another essential reference network to determine the elevation of points of interests for various development projects. It consists of control stations with a series of Benchmark heights connected to the Mean Sea Level (MSL). MSL had been determined by great Trigonometrical Survey of India by observing sea level fluctuations with Tide Gauges established near coast in Colombo, Galle and Trincomalee during the period of 1884 to 1895. Establishment of the primary level net was carried out during 1926 to 1930 with fifty seven (57) Fundamental Benchmarks on large masses of rocks and seven (7) Standard Bench Marks built on large concrete blocks using precise levelling. The present vertical control network consists of fifty-two (52) FBMs, three (3) Secondary Benchmarks (SBMs) and twenty-one (21) new SBMs.

In future, possibility of establishing mobile CORS networks as and when required depending on the magnitude of the survey tasks and applications has to be studied. Another important task ahead in the responsibility of the Survey Department is to model height anomalies known as undulation using a GEOID model, through which orthometric height (heights based on MSL) at any place can be determined once ellipsoidal height of such a place in reference to global ellipsoid (WGS84) or local ellipsoid (Everest 1830) is known.

GEOSPATIAL TECHNOLOGIES BEYOND INFORMATION AGE

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Geospatial technology is a term used to describe the range of modern tools contributing to the geographic mapping and analysis of the Earth and human societies. At present, the advancement of geospatial technology is increasing at a mind-blowing pace by creating innovative opportunities in many fields. Traditionally, Governmental agencies, private corporations and consulting firms have been using the Geospatial technology as geographic information systems (GIS), the global positioning system (GPS), satellite-based and airborne remote sensing and computer simulations to acquire, manipulate and store geographic information for analysis and decision-making. However, the spread of geospatial technologies to the general public, and the geo-enabling of everything offer application benefits beyond Information age. We are approaching a new era of living, production, and work, where geospatial location becomes an integral dimension of any data, allowing connected information and decisions to be viewed through a hand held smart devise. Bolstered by innovative developments and growing user awareness of its potential, geospatial technology has become an essential element of major contemporary technology developments, notably including the Internet of Things, Big Data, Health, Augmented Reality, and Smart Cities. This talk will summarize the capabilities, challenges and state of the art applications of key developments in geospatial technologies that have allowed more widespread use of digital geographic information by the professionals and general public.

Technical Sessions

URBAN VEGETATION CHANGE AND ITS IMPACT ON COLOMBO CITY TEMPERATURE

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Abstract - Land Surface Temperature (LST) varies with the nature of different land-use and land cover features. Therefore, in parallel to urbanization the increase of urban temperature is becoming a critical issue in most cities. This study is focused on an analysis of vegetation and built up change in Colombo municipality from 1996 to 2016 and its impact on LST. The relationship between LST with Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) is discussed using data collected by Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIRS satellite imageries of 1996, 2001, 2006, 2011 and 2016. Built-up and green area changes were identified by the NDVI and NDBI. Accordingly, vegetation and built up areas were changed rapidly in last two decades. The vegetation areas were reduced from 21.9 km2 to 6.05 km2 from 1996 to 2016 and built up areas were increased from 1996 to 2016 by 13.92 km2 to 26.37 km2 due to the rapid urbanization with the increment of population density. According to that, within the past two decades, Land Surface Temperature has also increased. The observed maximum LST has ranged from 26.36 0C to 35.70 0C and the minimum LST has ranged from 18.99 0C to 24.45 0C. There is an apparent inverse correlation between NDVI and LST and a strong positive correlation between NDBI and LST. According to the increasing trend of temperature, when the area of vegetation decreases, future city planning should be focused more on urban greening.

Keywords: LST, NDVI, NDBI, Landsat

I. INTRODUCTION

Colombo city is the commercial capital and the largest city of Sri Lanka and its vast development during last two decades caused higher temperatures inside the city. With the increasing demand of population urban spaces expanded and built up areas became higher and vegetation areas and water areas became lower.

However, with development activities, a well-structured urban green space management plan has to be maintained in order to retain the minimum green cover requirement of the city. Therefore mapping and quantification of the existing green cover is mandatory for developing such management plans. In addition, understanding of the changing pattern of greenery over the past few decades provides a clear insight for city planners to take necessary actions to enhance and maintain the adequate green space. Rapid changes of urbanization and vegetation cover in urban areas have become a major environmental concern due to environmental impacts, such as reduction of the green spaces and increase of land surface temperature. Monitoring and management plans are required to solve this problem effectively. Therefore, it is important to identify whether the temperature is increased in Colombo city due to its urban and vegetation change.

Integration of Remote sensing data and techniques, and geographic information systems (GIS), provide efficient methods for assessing and monitoring the urban vegetation change and Land Surface Temperature in last two decades. This study tries to identify the vegetation change according to the urbanization and its impact on Land Surface Temperature of Colombo city from 1996 to 2016.

II. STUDY AREA AND MATERIALS USED

Colombo city is used in this study. When compared to other urban areas of the country, approximately 15% of the total urban population of the country lives in the

city of Colombo. The city area of Colombo consists of two divisional secretariat divisions: Colombo and Thimbirigasyaya covers the area of 37.29km2 in extent.

Satellite images were obtained from the United States Geological survey (USGS) Earth Explore web site. At the beginning gross check was done manually to find out the images without cloud covering in the Colombo municipal council area. Total of 15 Landsat images were downloaded for year 1996, 2001, 2006, 2011 and 2016 and all images were already geo-referenced. Therefore additional changes were not required. Landsat 5 images were used in 2006 and 2011 instead of Landsat 7 images due to stripping error.
Other spatial and non-spatial data was obtained through several government agencies of Colombo municipality. The spatial data consists of GN divisions of Colombo municipal area was acquired from the survey department of Colombo.

III. METHODOLOGY

All satellite images used in this research were geometrically corrected by the USGS. DOS1 atmospheric corrections were done by using Semi-Automatic Classification plugin in QGIS 2.18 version to remove the effects of surface reflectance, scattering, solar irradiance curve, topography and instrument response, absorption effects from the atmosphere to obtain the surface properties. To remove clouds and cloud shadows from the Landsat imageries a cloud mask was generated applying F mask for cloudy images by Cloud Masking tool in QGIS 2.18 software. The Normalized Difference Vegetation Index (NDVI) shows that the indices derived from remote sensing data under visible and near infrared bands of the electromagnetic spectrum. Eq.01 is used to calculate the NDVI of the study area. The value ranges from -1 to +1, where positive values represent vegetated areas and negative values represent non-vegetated areas.

$$NDVI = (NIR - RED)/(NIR + RED) \quad \text{(Eq. 01)}$$

Normalized Difference Built-Up Index (NDBI) was used to extract built-up features and have indices range from -1 to +1. NDBI values can depending on the spectral signature, range from medium infra-red to near infra-red band.

$$NDBI = (SWIR - NIR)/(SWIR + NIR) \quad \text{(Eq. 02)}$$

Land Surface Temperature (LST) values were retrieved using band 10 which corresponds to thermal band to different wavelengths and band 11 which also corresponds to thermal band from the Thermal Infrared Sensor (TIRS) of the Landsat 8 imageries and band 6 which corresponds to thermal band of the Landsat 5 and Landsat 7 satellite imageries. In Landsat 8 images LST was calculated by retrieving mean temperature from both band 10 and band 11. By using Eq.03, the DNs of thermal band from the Landsat 5 TM and Landsat 7 ETM+ images and by using the Eq.04, the DN values of thermal band 10 and band 11 from the Landsat 8 OLI/TIRS images were firstly converted to spectral radiance. The spectral radiance was calculated using the radiance scaling factors provided in Metadata file.

$$L\lambda = (LMAX\lambda - LMIN\lambda)/(QCALMAX - QCALMIN)) * (QCAL - QCALMIN) + LMIN\lambda \quad \text{(Eq. 03)}$$

$$L\lambda = MLQcal + AL \quad \text{(Eq. 04)}$$

TM and ETM+ band 6 imagery and OLI/TIRS band 10 and band 11 imagery can also be converted from spectral radiance to a more physically useful variable as Brightness Temperature. Eq.05 is applied to convert spectral radiance values for At-satellite brightness temperature using the thermal constants provided in Metadata file.

$$T = \frac{K2}{\ln\left(\frac{K1}{L\lambda} + 1\right)} \quad \text{(Eq. 05)}$$

Eq.08 is applied to convert At-satellite brightness temperature to Land Surface Temperature values. To estimate the corrected LST, emissivity was retrieved by Eq.07. Proportion of vegetation was calculated by corresponding NDVI data using Eq.06 to derive the emissivity values. Eq.09 was used to convert the Kelvin to Celsius values of the LST. Three Landsat images were taken in each year to obtain annual LST by using the Cell Statistics tool in ArcMap 10.1. Those images were taken at the beginning, middle and end of the year and assumed as cover the whole climate changes of each year. Annual LST maps were produced for year 1996, 2001, 2006, 2011 and 2016.

$$Pv = \{(NDVI - NDVImin)/(NDVImax - NDVImin)\}^2 \quad \text{(Eq.06)}$$

$$e = 0.004Pv + 0.98 \quad \text{(Eq.07)}$$

$$LST = BT/1 + W * (BT/P) * \ln(e)) \quad \text{(Eq.08)}$$

$$Tc = T - 273.15 \quad \text{(Eq.09)}$$

Scatter plots were created and a linear regression analysis was performed to determine the relationship between LST with NDVI and NDBI. To do this, more than thousands of random points were created and raster values of these points were extracted from the LST, NDVI and NDBI imageries. Scatter plots were created relate to LST, NDVI and NDBI values. The trend line was produced in each scatter plots to get the Coefficient of Determination (R2) and Correlation Coefficient (R) to identify the nature of the relationship. ArcGIS 10.1 was used to determine the mean LST values by using Zonal Statistics Tool in each GN divisions of the Colombo municipality.

IV. RESULTS AND DISCUSSION

The vegetation cover of Colombo city in 1996, 2001, 2006, 2011 and 2016 is analyzed based on NDVI values. The pixel values of the NDVI images are distinguished in table 4.1 as minimum and maximum values to illustrate the distribution range of the NDVI. According to that the NDVI values ranged from -0.34 to 0.84 in 1996, -0.43 to 0.78 in 2001, -0.30 to 0.73 in 2006, -0.35 to 0.74 in 2011 and 0.27 to 0.74 in 2016.

Table 1. Descriptive statistics of NDVI values in the Colombo city

	Minimum	Maximum	Mean	Standard Deviation	Vegetation Area (km2)	Threshold Value
Feb. / 1996	-0.34	0.84	0.32	0.15	21.90	0.15
Dec. / 2001	-0.43	0.78	0.24	0.14	17.72	0.16
Jan. / 2006	-0.30	0.73	0.22	0.11	13.39	0.16
Jan. / 2011	-0.35	0.74	0.22	0.12	7.43	0.21
Jan. / 2016	-0.27	0.79	0.30	0.13	6.05	0.23

Using the distribution range of NDVI the threshold values for vegetation area are determined for each year to analyse the vegetation cover of respective years and those threshold values are shown in table 1. In here imageries were classified in to two classes as vegetation area and built up and other areas using the identified threshold values. The land use and land cover of greenish areas such as grounds, home gardens, parks, cultivated areas, scrub covers, marshy lands and forest areas were classified as sub vegetation areas. Other land use and land covers such as buildings, roads, water, bare soil and sand were classified as built up and other areas.

The vegetation cover extents can be clearly observed that there is a destruction of vegetation cover extents in the area with time as a result of the rapid urbanization and population growth of the Colombo city. The results show that the total extent of the Colombo city has changed due to the result of Colombo port expansion project and vegetation area reduction has rapidly since 2006. The vegetation cover extent of 21.9 km^2 in 1996, 17.72 km^2 in 2001, 13.39 km^2 in 2006, 7.43 km^2 in 2011 and 6.05 km^2 in 2016.

Built up area of the Colombo city in 1996, 2001, 2006, 2011 and 2016 is analyzed based on NDBI values. Distribution range of NDBI is indicated in table 2 from -0.71 to 0.35 in 1996, -0.82 to 0.32 in 2001, -0.62 to 0.34 in 2006, -0.49 to 0.36 in 2011 and -0.33 to 0.20 in 2016.

Table 2. Descriptive statistics of NDBI values in the Colombo city.

Month / Year	Standard Deviation	Built-up Area (km^2)	Threshold Value
Feb. / 1996	0.12	13.92	0.02
Dec. / 2001	0.13	16.51	0.02
Jan. / 2006	0.11	20.09	0.02
Jan. / 2011	0.11	24.85	0.02
Jan. / 2016	0.06	26.37	0.02

According to the NDBI range threshold values were determined to analyse the built up area of the Colombo city. The threshold value of the NDBI was identified as 0.02 in every year as shown in table 2. All imageries were classified into two classes as built up area and vegetation

and other area. Buildings, roads, pavements and parking lots, etc. were classified as built up area. Other land use and land covers such as vegetation, water, bare soil and sand were classified as vegetation and other areas. In here, built up area with high NDBI values were concentrated mostly near the city centre and along the coastal belt. Beach area and middle part of the city contain mostly the residential and commercial buildings. These are mainly related to the tourism industry, commercial activities and residential activities.The built up areas can be apparently observed that there is an increment of the built up area in the Colombo municipality with the time. It shows the rapid urbanization of the city. The built up area is distributed 13.92 km^2 in 1996, 16.51 km^2 in 2001, 20.09 km^2 in 2006, 24.85 km^2 in 2011 and 26.37 km^2 in 2016.

Annual Lst Of The Colombo City

The annual LST maps of the Colombo municipality in 1996, 2001, 2006, 2011 and 2016 are shown in figure 1 and the descriptive statistics of the retrieved LST values are summarized in table 3. In 1996, the LST in Colombo city ranged from 18.9-26.3 ^{0}C with the mean of 21.8 ^{0}C, in 2001 LST varied from 23.5-34.5 ^{0}C with the mean 29.2 ^{0}C, in 2006 it ranged from 19.2-29.3 ^{0}C with the mean of 25.2 ^{0}C, in 2011 LST varied from 24.1-33.4 ^{0}C with the mean of 29.1 ^{0}C and in 2016 LST ranged from 24.4-35.7 ^{0}C with the mean of 29.4 ^{0}C

Table 3. Descriptive statistics of LST values in the Colombo city

Year	Minimum (°C)	Maximum (°C)	Mean (°C)	Standard Deviation
1996	18.9	26.3	21.8	0.8
2001	23.5	34.5	29.2	1.3
2006	19.2	29.3	25.2	1.2
2011	24.1	33.4	29.1	1.2
2016	24.4	35.7	29.4	1.5

According to the LST maps different temperature levels can be observed with the time. The highest LST values were mostly concentrated in the Colombo city centre and near the Colombo harbour. These areas were more urbanized and low vegetated part of the Colombo municipality. Low LST values can be observed around the water features such as Kelani River, Beira Lake, etc. Because water bodies such as the ocean or a large lake will lower the LST of surrounding areas through breeze and evaporative cooling.

By 2016 however, areas with high LST had greatly expanded towards the northern, south eastern parts of the Colombo city following the spatial pattern of urban development in the area. That means the low vegetation areas are consistently observed the higher LST values. Due to the increase of the built up area which absorb the solar radiation and release as heat and reduction of the green areas which absorb the solar radiation using evapotranspiration and photosynthesis thus emit water vapour and oxygen, the overall outcome is the increasing thermal environment of the urban area. The LST is always lower in areas covered with vegetation relative to non-vegetated areas. In some instances, there are sharp LST boundaries between regions with high LSTs and regions covered with vegetation. This is another example where vegetation reduces the LST of its surroundings. Vegetation can reduce the surrounding temperature through a number of mechanisms.

Relationship Between Land Surface Temperature And Ndvi

The coefficient of determination (R2) values ranged from 0.2 to 0.4. The lowest R2 value is found in in 1996, while the highest R2 value is found in 2016. In addition, the increasing trend of the R2 values indicates that the explanatory or predictive power of NDVI on the spatial variations of the LST became stronger between 1996, 2001, 2006, 2011 and 2016 as the area became more urbanized. The trend line between data points of NDVI and LST had a negative slope indicating a negative correlation with all five time points. The resultant correlation coefficients between LST and NDVI were tabulated in the table 4. The correlation coefficient values have a ranged from -0.46 to -0.64. The lowest value of correlation coefficient is found in 1996 and the highest value is found in 2016.These trends give an overall idea of the relationship between vegetation and Land Surface Temperature. Therefore it can be conclude that, with the decrease of NDVI, the LST is increased. Hence, areas with least vegetation are experiencing more LST.

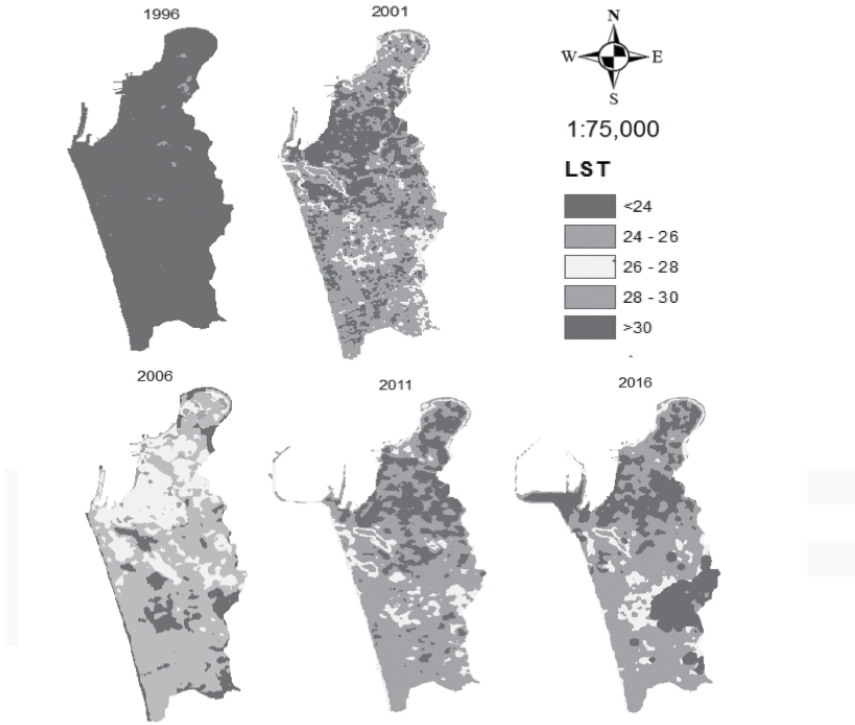

Figure 1. Annual LST maps of the Colombo city for 1996, 2001, 2006, 2011 and 2016

Table 4. Correlation coefficient between NDVI, NDBI and LST of 1996, 2001, 2006, 2011 and 2016 in Colombo city

Correlation Coefficient	Year				
	1996	2001	2006	2011	2016
NDVI and LST	-0.46	-0.59	-0.49	-0.56	-0.64
NDBI and LST	0.521	0.645	0.637	0.715	0.718

Relationship Between Land Surface Temperature And Ndbi

The relationships between NDBI and LST at the five time points can be observed the spatial pattern of NDBI values and the spatial pattern of the LST values indicating a positive linear relationship. That was illustrated the LST and NDBI deviate in parallel. The correlation between NDBI and LST was low in 1996, and this could be because the area was still urbanized. It can be noted that the correlation increased considerably as the area became more urbanized. A strong correlation between NDBI and LST can be seen in 2011 and 2016 due to the rapid urbanization. The coefficient of determination (R2) values ranged from 0.27 to 0.52. The resultant correlation coefficient between NDBI and LST were tabulated in Table 4. The correlation coefficient values can be ranged from 0.5 to 0.7. These trends give an overall idea of the relationship between NDBI and LST. Generally, the relationship between NDBI and LST was stronger than the relationship between NDVI and LST. This indicates that the predictive or explanatory power of NDBI with regards to the spatial pattern of LST in the study area is stronger than that of NDVI.

IV. CONCLUSION AND RECOMMENDATION

Vegetation cover and built-up area were mapped for identify the vegetation and built-up area over the Colombo

city. According to that, the vegetation and built up area was changed rapidly in last two decades. The vegetation area is reduced from 21.9 km2 to 6.05 km2 from 1996 to 2016 and also built up area was increased since 1996 to 2016 by 13.92 km2 to 26.37 km2 due to the rapid urbanization with the increment of population density. Natural environment or vegetated areas contribute to absorb sunlight and carbon dioxide then they emit oxygen and water vapour through the process of photosynthesis and it also provide the shade. As a result, natural environment is an important factor for maintaining a healthy thermal environment. On the other hand, built up areas consist of concrete, asphalt materials which absorb sunlight and release heat in to the environment. With the urbanization induced developments green areas are reduced and built up areas are increased in the Colombo city. As a result, higher temperature area is increased. It reflects that the temperature in Colombo city is increased. Therefor it could be overcome with increase of vegetation cover and

greeneries space in form of urban forest and garden, green paths, greenery around the buildings in order to reduce built-up and increase the vegetation cover in the city.

LST was retrieved as annual LST using three Landsat images for each year of 1996, 2001, 2006, 2011 and 2016. According to that within past two decades Land Surface Temperature is increased. Observed maximum LST can be ranged as 26.36 0C to 35.70 0C and the minimum LST can be ranged as 18.99 0C to 24.45 0C. It can be clearly identified the increment of LST with the time. But, when consider the minimum and maximum LST values in 2006 are significant deviate than the other years. Since, cloud cover effects could be greatly influenced on the calculated LST. Because thermal band cannot penetrate the dense cloud, hence dense clouds represent very low temperature values and cannot calculate the accurate surface temperature values. With the seasonal changes and weather events, a clear output that can indicate the increase of temperature in Colombo city is not easy to identify. Maximum instantaneous value for global radiation at 13.00h LST of clear sky condition reached 900 Wm-2 and for overcast day's maximum value was 400 Wm-2 to 500 Wm-2 (Emmanuel & Johansson, 2006). Atmospheric effects could also be most important error sources of LST retrieval. Due to the cloud cover, the selection of satellite images of a similar months and date was difficult. Therefore selection of satellite imageries with minimum cloud cover is the simplest way of overcoming the problem due to clouds. Finding series of satellite images for each year is better due to the clouds. To remove the clouds it is better to apply a mask and it is better to get mean temperature with series of images to fulfil the temperature of masked area. It is also better to applied advanced atmospheric corrections to retrieve the highly accurate LDT values.

For analyze the correlation of urban and vegetation change with LST of Colombo city from 1996 to 2016 by five year interval, correlation coefficient (R2) values were generated. The significant strong positive correlation between LST and NDBI confirm the strong influence of urbanization on the LST increment in the Colombo city area. There is an apparent inverse correlation between LST and NDVI since 2011 to 2016. According to this temperature tend to increase when area of vegetation decrease. Therefore, future city planning should be focused more on urban greening. Albedo which is reflectivity should be increased such as shining roof in order to reduce radiation absorption. Environmental impact assessment should be mandated before any development.

This study was mainly focused on analysis of urban vegetation change of Colombo city and its impact on Land Surface Temperature (LST) from 1996 to 2016. In here low LST values can be identified in highly vegetated areas and also higher LST values can be identified in lover vegetated and highly built-up areas such as near the city Centre, port and along the coastal belt. Nowadays due to urban expansion there is no space left on the ground for further development, cities are developing in vertically. As a result lots of high rise buildings appear in cities. These changes cause urban canyon effect which affects wind flowing, sky view factor, surface reflectivity etc. These factors will contribute to change the thermal properties in the city thus vertical development of the city it important parameter for analyzing temperature change with the urbanization. Therefor it could better to aggrandize greenery space in the city to overcome the increment of LST. It could be getting more data in same time period of each year to illustrate the annual LST. Due to the poor temporal resolution of the Landsat imageries it is better to used high temporal resolution satellite imageries to obtain annual LST. Therefore it will give more accuracy if able to use MODIS 8 day composite satellite images for huge areas due to its low spatial resolution.

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EVALUATION OF SOLAR POTENTIAL BY DOMESTIC BUILDING TYPOLOGY

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Abstract - Renewable energy is playing an ever important role in meeting energy requirements across the world. It exhibits favourable credentials such as an abundant and widely available resource base, inexhaustibility and environmental friendliness, which have contributed to its fast growth over the last two decades. Sri Lanka lies within the equatorial belt, a region where substantial solar energy resources exist throughout much of the year in adequate quantities for many applications. Due to the continuously increasing energy demand in the construction sector, there exists a potential for significant expansion of the use of this renewable energy within the region. This paper intends to demonstrate the effect of domestic building type on solar potential, by analysing solar potential in the real urban context of Colombo based on building type and characteristics. Accordingly, this paper studies real cases in Colombo's urban context by selecting five cases of real urban residential blocks. The buildings were analyzed based on form and dimensions and classified into characteristic buildings. The solar potential was calculated for the roofs of these characteristic buildings respectively. The results obtained showed obvious differences between the six different types of buildings, where the distribution of solar irradiation on roofs for each building type was vividly different based on the building form, owing to differences in roof area and building footprint.

Keywords: Solar potential, domestic buildings, urban context

I. INTRODUCTION

A topic of great importance in recent years is the study of solar potential in the urban environment. The fact that there exists an environmental and energy crisis is now a widely accepted fact. On-site energy production and utilisation have become commonly utilised strategies to minimise energy losses due to transformation and transmission, in order to curb this growing trend (Mohajeri et al., 2016). In this case, solar energy is considered to be a renewable energy resource of great potential which is available in abundance and can be conveniently utilised in urban spaces through building integrated photovoltaic (BIPV). This makes the study and examination of solar potential in the urban environment a crucial matter. Several studies have been carried out relating to solar potential and urban space. Attention has been swerving towards endeavouring to quantify and estimate the amount of global solar irradiation incident on building envelopes, allowing the assessment of active and passive solar heating technologies and methods (Mohajeri et al., 2016 , Montavon, M. ,2010, Montavon, M et al., 2004). The implementation potential of solar technologies on stand-alone buildings has therefore been extensively researched (Hachem, C et al., 2011, Urbanetz, J et al, 2011, Liu, G., 2014) A significant challenge is created due to the overshadowing effect caused by the surrounding urban environment, which have been proved by previous studies that have been carried out, which is prevalent not only in high-density built urban contexts, but in low and medium-density ones too (Lobaccaro, G et al., 2017). The main legal barriers that exist against the deployment of solar systems are firstly, the lack of regulations and policies; secondly, the lack of education and practical expertise of practitioners and designers; and finally, the lack of a domestic market. However, in the past years, there has been a considerable rise in the awareness in solar technology investment, and the number of large-scale solar energy projects has augmented, where the housing market is also seeing an increase in the deployment of solar systems. However, there exists a requirement in the Sri Lankan urban context to determine the effects of building form and typology on solar potential.

This study therefore aims to examine the effect of building typology on solar potential and to determine the optimised

domestic urban form in order to maximise incident rooftop solar irradiation, whilst also considering the surface area to volume ratio of the buildings as a measure of their efficiency. This can be used by architects and urban planners, in addition to municipalities and decision-makers, in order to implement planning regulations that could enhance solar accessibility and the solar potential of urban domestic buildings.

II. METHODOLOGY

In the actual urban environment, solar potential can be affected by parameters of urban density. However, since there are many different parameters, such as site coverage, plot ratio, building density, etc., these parameters also present mutual constraints on each other.

This paper surveys several urban blocks in Colombo and identifies prevalent building types within the individual blocks. These building types are then analysed within each block in order to quantify their dimensions and calculate the average dimensions of each building type. Four blocks were selected in Colombo from which six different building typologies were identified, and the characteristics of solar energy utilisation potential were simulated using the selected software.

A. Solar Irradiation Estimation

In order to measure the solar irradiation incident on the roofs of the buildings, it was initially essential to establish a method by which to run irradiation simulations on the constructed models. Assessing solar potential in urban contexts becomes difficult, since calculating solar radiation is dependent on time, location and conditions, where the shadow effects also need to be taken into consideration, which include the shadows cast on useable surfaces by buildings, vegetation, or structural elements.

For the purposes of this research, it was required to determine a suitable tool that could be used for solar irradiation evaluation. From the literature review, innumerable existing models were examined that allowed for the assessment of solar irradiation in urban contexts, some of which include Radiance, Daysim, and ArcGIS Solar Analyst. Radiance is a highly accurate ray-tracing software system, which applies the Perez diffuse radiation model (Perez, R et al, 1987 , Perez, R et al, 1990), and considers both specula and diffuse reflections from urban obstructions. Based on the way in which light physically behaves in a volumetric 3D model, it uses a refined light-backwards ray-tracing algorithm which can even be used in complicated curved geometries (Ward, G., 1994). This software has been authenticated many times, and successfully utilised in many applications regarding the assessment of solar potential on building roofs and façades for day lighting and electricity generation. Therefore, Radiance was chosen as the method to estimate solar irradiation, and was integrated as plug-in Rhino 5, which could be used via the Grasshopper interface and the Ladybug and Honeybee tools. These help to examine and calculate the environmental performance, where Ladybug imports standard Energy Plus weather files into Grasshopper. It then supports the preliminary stages of design and the decision-making process by supplying a range of 3D interactive graphics. There are four validated simulation engines which evaluate building energy consumption, thermal comfort, and day lighting, namely, Energy Plus, Radiance, Daysim, and Open Studio (Roudsari, M et al. 2013). Honeybee connects the visual programming environment of Grasshopper to these four simulation engines. In this way, the validated environmental datasets and simulation engines are dynamically coupled with the adaptable, component-based visual programming interface by these plug-ins. The suggested method for this research, therefore, was to make use of Rhino and the Grasshopper interface, coupled with the Ladybug and Honeybee tools, which would act as a hub in order to utilise Radiance and Open Studio to run radiation simulations.

B. Urban Context

Initially, a domestic building survey was carried out in the four selected zones in Colombo. These blocks were surveyed in order to determine characteristic residential building forms, and the dimensions of all buildings were examined in order to obtain average dimensions for each building type. Four main residential blocks in Colombo were chosen for the purposes of this research, and these are listed below in Table 1.

Table 1. Block Locations

Block Number	Block Location
Block 1	Ward Place 6°54′57.4″N 79°52′17.5″E
Block 2	Independence Avenue 6°54′35.4″N 79°51′47.9″E
Block 3	Palm Grove 6°54′35.4″N 79°51′47.9″E
Block 4	Pedris Road 6°54′14.0″N 79°51′26.3″E

Source: T Mendis

Aerial images of the four blocks are shown in Figures 1-4 below.

Source: Google Earth

Figure 2. Block 2 at Independence Avenue
Source: Google Earth

Figure 3. Block 3 at Palm Grove
Source: Google Earth

Figure 4. Block 4 at Pedris Road
Source: Google Earth

III. RESULTS

From the domestic building survey that was carried out in Colombo, six different basic domestic building types were identified, and the dimensions for these were analysed and recorded. From all of the data obtained, average dimensions were then acquired for each building type, which are shown in Table 2. These buildings were then modelled on Google SketchUp and are shown in Figure 5

Table 2. Building Dimensions

	Dimensions				
Building Type	Length (m)	Width (m)	Height (m)	X1 (m)	Y1 (m)
1	19	13	6	-	-
2	20	11	6	-	-
3	15	14	6	-	-
4	17	17	6	9	9
5	28	22	6	9	8
6	18	19	6	7	10

Source: T Mendis

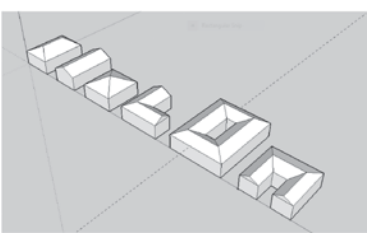
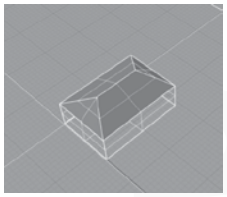
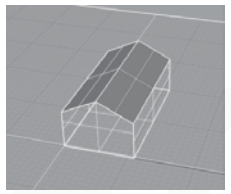
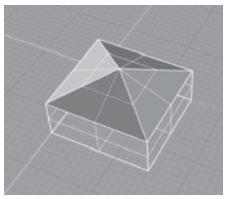
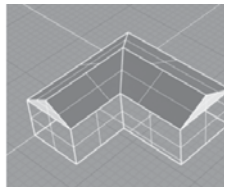
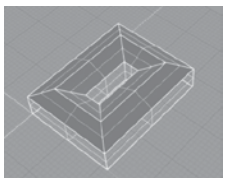
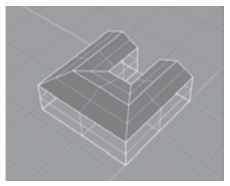


Figure 5. Characteristic Building Types
Source: Rhino 6

These blocks were then individually imported on to Rhino 6 in order to run a radiation analysis that would allow determining the solar irradiation incident upon the selected buildings. By making use of the Grasshopper plug-in coupled with the Ladybug and Honeybee tools it was possible to simulate and visualise the solar irradiation incident upon each building type. These results are shown below in Table 3.

Table 3. Simulation Visualisation

Building Type 1	Building Type 2
	
Building Type 3	**Building Type 4**
	
Building Type 5	**Building Type 6**
	

In order to determine the surface area-to-volume ratio of the buildings that would give an idea of their energy efficiency, the surface area of the envelopes the internal volumes of the buildings were calculated and are shown in Table 4.

Table 4. Surface Area to Volume Ratios

Building Type	Surface Area (m2)	Volume (m3)	S/V (m-1)
1	667.0	1820.0	0.37
2	648.3	1622.5	0.40
3	581.4	1505.0	0.39
4	669.1	1112.6	0.60
5	1433.1	4054.4	0.35
6	882.8	2076.3	0.43

The radiation results obtained from the simulation are shown below in Table 5.

Table 5. Radiation Results

Building Type	Total Irradiation (kWh)	Roof Area (m2)	Average Irradiation (kWh/m2)
1	637054	360	1770
2	435529	240	1815
3	605679	334	1813
4	472244	265	1782
5	1103409	622	1774
6	642609	350	1836

The results from the irradiation simulation and surface area to volume ratio calculation were compared side by side in order to determine the most energy efficient building type. It can be seen from the graph in Figure 6 below that building type 2 exhibits the lowest ratio of surface area to volume, indicating that it consists of lesser envelope area, minimising fabric heat gains with higher building volume. Furthermore, it is also capable of obtaining the most incident solar irradiation upon its roof surfaces.

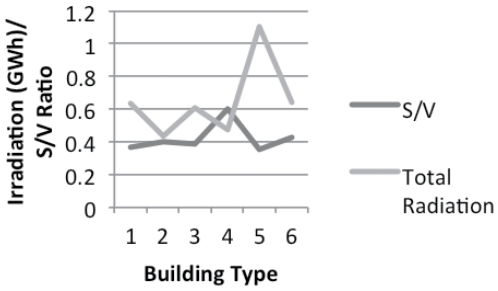


Figure 6. Total Irradiation vs Surface Area to Volume Ratio
Source: T Mendis

IV. DISCUSSION AND CONCLUSIONS

This research was conducted in order to identify prevalent domestic building typologies in Colombo, Sri Lanka and analyse them in terms of building efficiency and solar potential. Four residential blocks were selected in the city, which were surveyed in order to identify six main building typologies, from which average building dimensions were obtained. These buildings were then modelled on Google SketchUp and a radiation analysis was run on them on Rhino 6 by using the Grasshopper plug-in coupled with the Ladybug and Honeybee tools. The surface area of the building envelopes and building volumes were also calculated in order to obtain the surface area to volume ratio for each building type. The surface area to volume ratio and total irradiation incident upon the building roofs were then compared in order to determine the most energy efficiency building in terms of minimal heat gains and maximum PV potential.

From the results obtained it was apparent that building 5 was the optimal building form due to its low surface area to volume ratio, indicating that it has a lower building envelope area, thus minimising fabric heat gains, whilst also obtaining the highest amount of total irradiation upon its rooftop, which could be utilised for PV electricity generation in order to cut down on grid energy consumption by the building. It was also apparent that building type 4 was the least efficient as it had the lowest variance between its surface area to volume ratio and total irradiation.

The results from this research could be considered by architects, designers, and urban planners when creating large-scale city development projects in order to improve solar energy utilisation potential in the urban scale.

Limitations of this research include a lack of in depth analysis in order to consider for shading by surrounding objects and buildings in the urban context. Due to the high level of urban sprawl in Sri Lanka, neighbouring buildings could have a significant impact on the amount of solar irradiation incident upon low-rise residential buildings, and it is aimed to examine this issue in future research. Furthermore, this research only took into account residential buildings. Commercial and industrial buildings are other potential sources of solar utilisation for PV and similar research could be conducted based on these building forms.

Acknowledgement

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EVOLUTION OF THE SRI LANKAN SHOPHOUSE: RECONSIDERING SHOPHOUSES FOR URBAN AREAS

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Abstract - The very fact that shophouses and their proportions contribute to the growth of the evolution of tropical architecture is a phenomenal feature. Most of the shophouses in Ambalangoda and the down South have been destroyed due to street widening as people cannot afford to live in a house at such an edge of the street due to skyrocketed land prices, people prefer modern buildings with concrete and glass as they believe that owning a traditional dwelling as being a symbol of poverty these days. This fact could be justified as Hasan Fathy discovered the clay arch in Egypt pre-dating the Romans; he discovered that the normal village people instead wanted the glamour associated with materials such as marble and steel. People thought that using the traditional form would put them into the poverty stricken bracket. If these shophouses are completely destroyed, we would not have a gene pool. We need an area in which these shophouses thrive, posterity would be understood. Thus there is continuity from the past to the present. Although there are rules in the breach to protect these traditional buildings some of them are on the verge of being demolished. Although the shophouses have been` demolished there are sights of evolution of it into the contemporary world as these shophouses yield a sustainable way of building town dwellings with relation to the urban fabric.

Keywords: shophouses, traditional, sustainable

I. INTRODUCTION

"The beauty of the land captivates the visitor. For example, the landscape of Kandy in the hills of central Ceylon is delightful. The shimmering lake, formed by the damming of a small mountain stream reflects a constantly changing pattern of cumulous clouds and the blue sky". McCune (1947)

Sri Lanka has always been credited with a sense of natural beauty throughout its history, yet it wasn't this aspect of the island nation that brought the Portuguese in 1905 to Sri Lanka. The Portuguese who arrived in Sri Lanka were comprised of wealthy merchants who were driven to explore the island's valuable spice "cinnamon". "They settled on the shore to set up commercial strongholds, but soon got involved in local political conflicts and were drawn inland" Schrikker, (2007), although Portuguese were drawn inland they failed to get control of the centre of the island. As a result of this, the merchants conquered the Maritime Provinces and began implementing a new way of life. The introduced cash crops getting rid of local paddy cultivations, these cash crops include cinnamon, tea, rubber, all of which had a high commercial value in the world market. With these crops came the responsibility and need to buy and sell these products. Before the notion of shophouses were introduced there were places where business were carried out.

Figure 6. Total Irradiation vs Surface Area to Volume Ratio
Source: T Mendis

These goods had to be transported and several modes of transport existed back then. Traditional society mainly constituted of the inland water transportation which

included rivers and canals, for example the Hamilton canal between Colombo and Negombo and there were also the thoitiyas were the people who raft the boats across these canals. Another major means of transportation was on bullock carts. Within this changed services shophouses were places where the traders broke journey. With the setting up of these shophouses the system of trade became efficient and they became centres where people could buy and sell cash crops and other goods. The traders ended up residing in these shophouses. This shows the multifunctional nature of these shophouse buildings since this aspect came into being on account of the need to accommodate this new social paradigm. The streets began to develop with these shophouses acting as commercial centers, which in turn gave rise to the unbroken streetscapes.

Modernity and traditional dwellings

The century old shophouses alongside the streets express the old commercial interactions through their planning. But they are fast disappearing with only a few of these shophouses in existence in Sri Lanka at present. Increasing economic growth which raised the standards of living, people are yet going for a modernized building style bringing down the traditional forms such as these traditional colonial shophouses and with them a way of life. According to Tiamsoon Sirisrisak, a researcher on culture at Mahidole University "there is more than just the architecture to preserve in the community. If these old buildings are demolished, the people will go, so will the lifestyle and culture". Modernization has brought about sweeping which have impacted on the form of the shophouse.

Hasan Fathy in Egypt went back to the traditional house and he discovered that the arcuated form the dome and arch existed before the founding of Rome "It is curious that in one short tour I had seen standing proof of the prevalence of vaulting throughout Egyptian history, yet from what we had been taught in the School of Architecture, I might never have suspected that anyone before the Romans knew how to build an arch. Archaeologists confine their attention to broken pots and effaced inscriptions, their austere discipline being enlivened from time to time by the discovery of a hoard of gold" (Fathy2010).Hasan Fathy then started using these forms in the contemporary architecture of Egypt but he discovered that the normal citizen did not want to use the elements of the past instead people wanted the glamour associated with materials such as marble and steel. People thought that using the traditional form would put them into the poverty-stricken bracket. This is evident in Fathy's work where he documented his project with the traditional forms of Egypt under the title Architecture for the Poor but its more correct and original title was Construire avec le pepule(Building with the people)" (Ragette 2003). The notion of building for the poor projects a negative image of building cheaply for people who cannot afford better. The reason why the traditional forms are being brought down and now need to be preserved is because people think that they are too poor to change. The real reason for the disappearance of traditional dewellings is not just modernization but people accepting modernization as a higher standard of living.

Most of the shophouses in Sri Lanka have been demolished as they have been acquired by the merchant class who does not place a great store by traditional values since they enterprise quantity over quality. The Ena De Silva House is a case in point- the property was sold to Durdans Hospital, the management of which intended demolishing it to create a modern car park. Fortunately aesthetic conservatives and local architects dismantled the building brick by brick and reassembled it in Lungaga in order to preserve it for posterity. Geoffrey Bawa and Ulrik Plesner who discovered the proportions of the traditional dwellings and they figured out that the colonial scale when building is very pleasing "Colonial scale is somewhat huge. But the moment it is taken in Bawa's design it becomes comfortable" (GA houses 2010) this was mainly seen in this shophouses which is now seen in modern building types such as Lighthouse hotel. Bawa accomplished the continuity of the configuration of these shophouses into modernity. Bawa used these proportions in his contemporary architectural works, the people residing in the houses Bawa built were upper income bracket people who could appreciate the history and the culture of the land. Although the architecture of the shophouses continued into modernity through the hotels and the houses of the wealthy designed by Bawa, the poor middle class people who initially owned the traditional dwellings from which this contemporary architecture was derived, did not place great store on these dwellings because they thought that living in one of these traditional houses would automatically result in them being cast into a lower income group. This is similar to the observation made by Hassan Fathy in the Egyptian context.

If interventions by these wealthy entrepreneurs are not managed properly it can dilute the cultural significance of the colonial heritage of Sri Lanka. This is an area where

there is a profound lack of concern. More effort could be done by the government and cultural organizations in order to retain these historical buildings, one such way could be through live conservation. As the architectural value of the colonial streets have to be protected whilst these street shophouses are modified to accommodate the needs.

Preservation of the shophouse architecturally, functionally and socially in the landscape

"Heat polishes the new buildings and depresses the old, whose faces sag behind skimpy shrubs until they resemble old whores, dabbling their wrinkles with tissue paper stained cleaner-pink and bougainvillea- mauve"

The above statement attributed to Anderson in the book by (Savage 1992), reflects the present state of the colonial shophouses. In order to keep this building typology intact and to retain their vitality there has to be efforts put into preserve these remaining shophouse dwellings. These shop houses consists of elements were unique to Sri Lankan colonial architecture which could strengthen the resonance of our contemporary architectural tradition. Due the elements which make up the configuration of the shophouse there is need to preserve the remaining shophouses so that the origins of the modern day architectural features could be appreciated. Hence the preservation of shophouses ensures their architectural, functional and social attributes.

Architectural

There are certain elements in the configuration of these shophouses which mainly had their origins during the colonial period which in turn affected modern Sri Lankan architecture. "The balcony and roof overhang were supported on delicately carved timber columns and the balcony would be enclosed by fine timber screens or trellises" (Robson 2016), this reflects on the some of the standout elements of a colonial shophouse, these timber columns were brought into use by the Dutch "they were the first to employ…vocabulary of simplified Western Classical elements such as the squat Tuscan column (Lewcock, Sansoni, Sennanayake1998). "In the towns of a new way of living was introduced…ceilings everywhere replaced open roofs in the interiors, lighter furniture was introduced, and in the new double-storeyed buildings, central staircases in polished furniture woods of magnificent craftsmanship made their appearance" (Lewcock, Sansoni, Sennanayake1998), this shows the development in configuration of the shophouse during the British Colonial period. "The British introduced the fashion for louvered shutters and doors" (Lewcock, Sansoni, Sennanayake1998), all of these were seen in the morphology of the shophouse. There was a trend observed in the houses on the road from Colombo to Galle back when these shophouses dominated the streetscape " The roof often reached down low over the verandah to keep out sky radiation and driving rain" (Lewcock, Sansoni, Sennanayake1998) " Another important quality of the screen is that they form perforated walls, letting the air and the breeze, while at the same time reducing the glare of the sun"((Lewcock, Sansoni, Sennanayake1998), these architectural features prove that these shophouses were built with extreme concern of suiting the tropical climatic conditions of Sri Lanka. Thus through the preservation of these shophouses we would be ensuring their continuity into posterity, preserving thereby an important period in our island's history.

Functional

The function of the Portuguese houses also seem to correspond to that of the shophouses "the whole lower floor was used for storage and the rear for cooking. The upper floor was a piano mobile, with private rooms on the street side" (Lewcock, Sansoni, Sennanayake, 1998), this caters the need which started during the trade development during the colonial period and these multi- functions of these shophouses was a result of the social evolution that took place with time. The Dutch had big impact of the style of Sri Lankan architecture, as their planning form corresponds to the shophouses "a typical plan had a central doorway under a covered verandah or colonnade which led to a central square hallway" (Lewcock, Sansoni, Sennanayake, 1998). So preserving these functions help retain the activities of the colonial trade days

Social

"The specific character of the street has direct relationship with its particular activity pattern" (Rajapaksa2007). This portrays the interaction of people across a period of time and this creates a coexistence between the occupants and the architectural fabric towns. Further it enhances the social image of towns hence the shophouse needs to be preserve socially to build an identity of its own among the rest of the streetscape. These shophouses are pivotal for understanding the culture, the way of life of people during the colonial period as (Gould, Kolb 1964) states

"Primitive building, most simply, refers to that produced by societies defined as primitive by anthropologists. It refers largely to certain technological as well as economic levels of development, but also includes aspects of social organization".The folk tradition, on the other hand, is the direct and unselfconscious translation into physical form of a culture, its needs and values — as well as the desires, dreams, and passions of a people (Constantino, Doxiadis 1964).

II. METHODOLOGY

A total of five case studies have been done to showcase the evolution of the shophouse into contemporary times.
The case studies start off with the appreciation of the architecture of the colonial period shophouse in the original form, this is done by taking into account a study of three shophouses from the coastal towns in the south for appreciation of the original architecture form of the shophouse. Thus, the first three case studies present three original shophouses in the Southern part of Sri Lanka. Three case studies are done instead of one original shophouse to exhibit the architectural features because these shophouses are in the deteriorating state, i.e. one shophouse cannot exhibit all the features as they in the verge of being brought down.

The fourth case study focuses on how the shophouse has been put into new use (Live conversation) in contemporary terms with an example from the Galle Fort.

The evolution process is further highlighted as the final case study proves how a single entity developed into a generalized version into the contemporary townscapes with the case study of a Mahaweli Town in "Digana" which was done by Architect Nihal Perera and Ulrik Plesener.

The essay finally ends on the positive note of how these shophouses could be adapted into human scaled townscapes through the analysis of the shophouse with the new urbanism principles.

There is a template done for the first three case studies for a comparison giving a gist of the analysis done. The idea for the template was obtained from the book Precedence in Architecture; Second Edition by Roger Clarke and Michael Pause. In this book the authors have analyzed famous buildings in a template in terms of their structure, plan, section, natural light, additive and subtractive, geometry and balance, parti to name a few. The case studies have adopted a similar template form but with some modifications as there have being additions such as the special features of the shophouses in terms of ornamentation, planning, proportion etc…

III. RESULTS

Attached ahead are the three templates for the three case studies. Features that are unique to each shophouse is highlighted in a color, this shows how architectural elements contributed to street architecture of the colonists. Case studies four and five proves how the shophouses have evolved in contemporary times. The Galle Fort exhibits conservation efforts trying to restore the architecture of our colonial heritage. Whilst the fifth case study proves how the concept of the shophouse has being adopted for contemporary towns by architects.

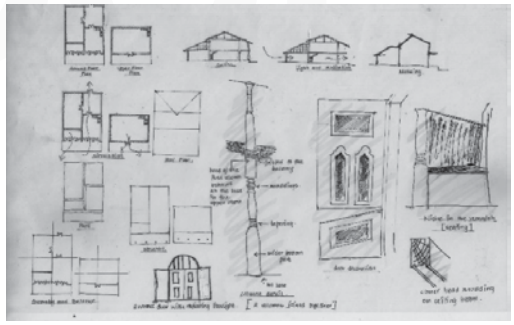

Figure 2- Template for Case study 1, Source- Author

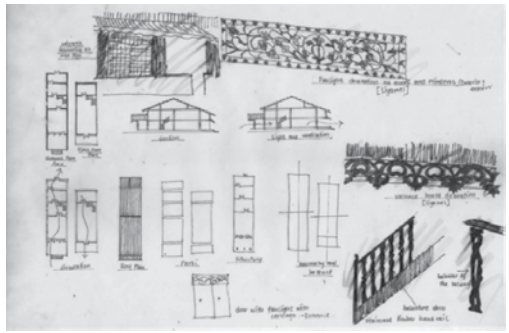

Figure 3- Template for Case study 2, Source- Author

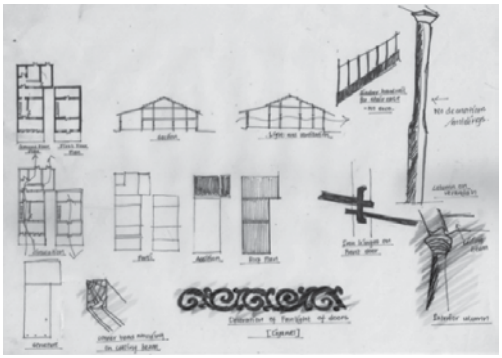

Figure 4- Template for Case study 2, Source- Author

III. DICUSSION

The first shophouse is currently not being occupied or used for any purpose. But it is a beautiful piece of work of the colonial builders showcasing the original form of shophouse that existed in Sri Lanka. This shophouse has a simple planning configuration consisting of a verandah, living area, storage/alternate shop, kitchen, upper floor solar lead by a ladder staircase opening to the balcony. The plan form and the sectional drawing of this shophouse adhere to the value of the golden ratio. There is the use of bright colors on the exterior and interior walls. On the verandah there is a pilakottae type seating that enhance the social interactions of people. Four sashed six timber doors stand at the entrance with two consisting of arched fanlights above them. The entrance doors are elegantly paneled. Some of the doors have massive hinges. Walls are chamfered to bare the windows. These mentioned features on these doors reflect on Dutch and British influence. One of the striking feature of this shophouse are its four columns on the verandah. These are continuous columns without bases from the ground floor till the roof consisting tapering and mouldings on their shafts. The interiors are kept free of columns to maximize the space. There is no ceiling for the ground floor, the upper floor solar covers the ground floor and underneath the solar there are dark blue beams with corner bead moldings spanning the interiors. This shophouse is sheltered by a double pitch gable roof (major part) and an over lapping hipped roof. As there is no ceiling above the roof is an exposed structure, due to the long span there are wooden trusses at regular intervals which transfer the load into the wall plate and the column below.

The second shophouse in Ambalangoda is currently the home of Mr Gunawardene and his family. The planning configuration is simple with the verandah, living, bedroom, dining (now a sleeping space), and storage, kitchen on the ground floor whilst the upper floor lead by a cement rendered ladder stairway consists of a solar, balcony and there is a garret / storage space with short walls taking one end of the roof. The plan is longer in depth so there are more windows to cater the ventilation problem. The handrails of the stairway and balcony display traditional Sinhala timber carvings. A significant aspect of this house is that there is a shop still in existent in the part of the verandah. The shading for the verandah displays a beautiful detail resembling that of the corbel stone. The walls are thick made up of coral stones with lime mortar. And since there are people residing in the shophouse changes such as for the wall colors has been done accordingly, blue has been used for the exterior and the interior walls. Three double sash timber doors with fanlights without much decorations lead to the interiors. However on the interior doors, the fanlights are decorated with the traditional Liyawal designs, this is not seen in the first shophouse. The windows are of two sashes and are of timber. The wall is elegantly chamfered to highlight the window for aesthetic purposes and this allows rain water to slope down easily. On the verandah there are three masonary columns and these columns resembles a fin, a part of the wall. There are three timber columns from the balcony supporting the roof. The roof is an exposed structure supported on a timber truss system. There are remains of the valence board in the Liya wal designs.

The third shophouse in Ambaangoda is currently not in any use. The planning configuration is simple with a verandah, living, bedroom, dining and a kitchen space which is a later construction. In this kitchen space there is a storage space already incorporate within it. And also is an additional storage area constructed which doesn't align with the full width of the plan. On the upper floor there are two rooms and the balcony. These prove that these were later additions. Also the plan form excluding the later kitchen construction adheres to the golden proportions. The walls appear to be degraded with time so no indication of the color is visible. However the structure of the walls are similar to the earlier two shophouses. There are three sleek timber columns with no ornamentation in the verandah and the balcony. The handrails of the cemented rendered ladder stairway and the handrails of the balcony displays no ornamentation. Five double sash timber doors painted in turquoise with ornamented fanlights of Liya wal designs vent into the interiors. The interior doors do not have any fanlights. There are huge iron latches and hinges on the doors. Windows are chamfered on to the walls and these

do not have fanlights. There are interior columns, which is unique with wider bases that supports the beams on the solar above. These beams display a corner bead molding and a molding at the centre. The roof is half round tiled (except for the later construction) exposed with a wooden truss system

In comparison to the case studies of the first three shophouses, the fourth shophouse has been put into live conservation. However only the ground floor is an original colonial construction whilst the upper is a new construction. This shophouse is being used as a lodge. The zoning is very simple adhering to the simplistic zoning functions.-verandah, living area, courtyard, bedroom, dining, and a rear kitchen and on the upper floor there are three bedrooms and the balcony. Since the shophouse functions as getaway three of the bedrooms have attached toilets. Since the zoning of the shophouses is flexible alterations could be done, as here the courtayrds are covered off and they are now used as a seating, sleeping space. Colonial features are visible in thickness of the walls on the ground floor as there is a deep niche created to store ornaments and also rubble texture on some of the walls (now used as a feature wall). This shophouse is mix of contemporary architecture with the colonial as traces of Geoffery Bawa's influences are seen as in the texture used on the doors and windows. Unlike in the earlier shophouses a row of doors doesn't stand at the entrance instead it is just one double sash textured timber door than opens into the interiors which are free of columns. There are no timber columns in the verandah .Instead two timber columns support the balcony. The handrail of the balcony is not decorated. Unlike the other shophouses this shophouse had a ceiling. When live conservation is taken into consideration the authenticity of ancient architecture such as in its form, elements and materials have to amalgamate with the new function and the contemporary use. This case study proves that a colonial shophouse could be put in to a new use. And a juxtaposition of the colonial elements with a modern day twist could resonate the vibes of the colonial shophouse in a new context. The functionalism of the shophouse might be distorted but there is a new life given to a decaying structure. This shophouse displays a contemporary use regarding a single entity on the verge of collapsing. But this one entity could become generalized in contemporary landscape so this creates way for the adaptation of the concept of the colonial shophouse into a contemporary designed streetscape which is depicted in the final case study.

Digana is the first new upstream Mahaweli town located along the Kandy-Mahinyanagana Highway. The final case study analyses the architectural elements of the shophouses in the Digana town which were designed by Architect Nihal Perera and Urlik Plesner and how these have influenced the townscape. Diagana is a townscape which has adopted the concept of the colonial shophouse. It is similar to the experience of walking through a bazaar. There are extensive verandahs for people to engage in social interactions. The roofs of these shophouses are extended and it is beautifully propped up on timber struts. The extension of the eave adds comfort for walking through the verandahs. There are four shophouses which form one unit. The ground floor was designed by the architects whilst the upper floors were designs of after thoughts of the inhabitants. Most of the initial designs have disappeared such the entrances were of roller doors. Towards the interior there some timber panel doors. There are wooden trellises inspired from the colonial period visible on the windows. There are only two massive columns bearing the weight of the structure. The roof is exposed with their wooden truss system. The bottom line is that the construction of these contemporary shophouse take pride from the past colonial counterparts as visible in these shophouses. This proves that the colonial shophouse is a viable commodity for the development of urban townscapes in Sri Lanka. Digana is one beautiful low key town niched on the outskirts of Kandy which exhibit a resonance of a colonial townscape with its two storey shophouses along the street. When the street elevation is observed, the majority of the façade is still intact with the shophouse features. However due to rapid modernization occurring, there are some modern buildings erected within the shophouse units. This distorts the original landscape of the town and these modern buildings look alienated. These modern constructions should be avoided and policy planning has to evolve in such a state that these old quarters of the town are conserved and are put into new use. Preservation is not just with regard to the building, preservation is a way of life. For example- preserving these parts of towns could highlight the culture and the way people thought back then. It is not just Digana which needs to be conserved, other towns should also be controlled by government organizations. As Sri Lanka does not boast a historical townscape with abundance except for the Galle Fort. There must be more towns that reflect the heritage of the island whether it is traditional or colonial. After all our architectural identity is morphed by all these periods of history. One could argue that the architecture evolves with the needs of people especially in urban areas and historic buildings need to be brought out to cater the

modern needs. But a good designer would always portray working with historic buildings as an opportunity rather than a restraint or a barrier as a contemporary building could be created in such a way that it brings a new layer in shaping the future heritage of a country. Preservation is a balance between protecting the vitality of history and accommodating changes so that it is sustainable for generations to come. So the whole is greater than the addition of the parts. In this manner these shophouses could be suitable for a robust urban environment.

The shophouses is a subtle example of a building form which could be used in these livable human scale towns. If shophouses are being used for these towns their viability in the modern world would not be lost. So there could be parts of Sri Lanka which boasts layers of towns which follow the new urbanism principles making way for a robust environment to prevail. The final section of this essay reflects on how the shophouses justify the nine new urbanism principles. The case studies done in this research justifies these nine principles. This would further prove that these shophouses should be retained in the townscapes of Sri Lanka.

New Urbanism is an approach of planning and designing urban areas based on principles which were used in the past. This includes going back to the concepts which were used in the history for creating livable environments. There are nine principles which are adopted for the design of towns under new urbanism. These principles are as follows- Walkability, Connectivity, Mixed Use and diversity, mixed housing, Quality Architecture and Urban design, Traditional neighborhood structure, increased density, Smart transportation, Sustainability.

The shophouses could be proved sustainable through its analysis with the new urbanism principles. The first two principles are walkability and connectivity. The shop fronts are narrow with verandahs and there are many shophouse units along the street so this implies that the people walking could cover more units per stroll comfortably. The long verandahs of the shophouse units in diagna signify this and also the verandahs of the shophouses of Ambalangoda (if the original rows of shophouses were present)would justify the walkability. The comfortable experience is enhanced as the walkway provides protection from the rain the sun. The rear lanes of these shophouses are kept free of motor traffic creating paths for people to walk on. These rear lanes are independent from the main street on the front as seen in the case studies especially in Digana were the back lanes constitute of the drain lines. However the network of dual lanes provides a sense of connectivity as their density is high. The third and fourth principles are mixed use and diversity and Mixed Housing. These two principles could be justified by the function of a shophouse as traditionally the shop owners lived on the upper quarters. This shows the mixed uses of the shophouses. For successful housing flexibility is key as the internal space arrangements with column free interiors (case studies 1, 2, 4, 5) provide optimum flexibility of spaces for activities of many purposes to take place. The fifth principles are Quality Architecture and Urban design. The shophouses uses the natural lighting and ventilation system effectively. This done by its inner courtyards and its linear form allows light and ventilation in from openings such as doors and windows. The use of local materials for the walls and floors brings a sense of coolness. The overhanging roof also prevents the direct sunlight from hitting the walls and the lime wash coating on the walls further cools the walls and the interiors through evaporation. These houses are naturally ventilated compared to modern houses which achieve comfort through air conditioning. This proves that the quality of the architecture of the shophouse is adaptable to the tropical urban environment of Sri Lanka. These features excluding the courtyards are visible in all of the case studies carried out. The sixth principle is a Traditional Neighborhood Structure. The shophouses in Sri Lanka are of the colonial period of our history. So these shophouses echoes a sense of colonial tradition in the modern streetscape. The seventh principle is increased density, with the walkways of these linear shophouses created for walking attracts people (more shophouses per unit stroll) and creates a very livable space. The eight principle is smart transport, with its walkable nature and the mixed use reduce the number of motors needed for transport. This is seen in Digana as the motor traffic is quite less compared to other towns without shophouses. The ninth principle is sustainability, the shophouses are built using traditional materials for all the shophouses, such as timber rather than modern construction materials. This creates naturally ventilated structures with carbon-free interiors which need low maintenance and are long lasting. The final principle is the Quality of life, these shophouses in the past catered a traditional way of life with a quality of its own. In terms of thermal comfort these simple structures have very livable interiors due to the massive thickness of their walls and these finished off with a lime wash coating bringing coolness inside through evaporation. With natural ventilation prevailing through their inner courtyards, balconies (present in case studies 1, 2, 3, 4) and verandahs (present in all case studies) these shophouses combat the high humidity levels extremely

well. The shophouses although small in scale could outclass modern interior which achieve these same comfort levels through.

IV. CONCLUSION

Interpreting the shophouse on the basis of the principles of new urbanism creates a platform for a much better culturally, socially, environmentally and economically sustainable urban towns and housing. These sustainable approaches help create human scaled spaces where the enjoyment of the pedestrian in the main goal. These shophouses can be used to create pedestrianized towns in Sri Lanka. The concept of the shophouses have evolved throughout our history and it has yielded many architectural aspects into the contemporary tropical way of building. Thus, to pave a way for a sustainable way of constructions the shophouses of the colonial times in Sri Lanka would serve as good precedent.

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IMPACT OF RECREATIONAL PARKS ON SOCIAL INTERACTION: A STUDY OF THE FACTORS RELATED TO INTERACTION AMONG VISITORS WITH SPECIAL REFERENCE TO SELECTED EXAMPLES IN COLOMBO DISTRICT

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Abstract – Recreational parks are considered as important public spaces in urban areas which enhance the quality of life by means of improving health conditions, social interaction and recreation among urban population. Several recreational parks have been established recently in Colombo District as a part of physical development implemented by the government after the end of civil war. Although these parks seem to be used frequently by the urban population, it is necessary to ensure that the objectives of these establishments are achieved.

This study aims at examinimg the social interaction among urban people who use these parks, which is one of the objectives and is expected to be improved. The primary objective of this study is to find out the impact of recreational parks on social interaction in relation to some important factors related to interaction among visitors of these parks. Identifying the factors that should be improved to enhance social interaction is the secondary objective of this study. The study was carried out with special reference to three (03) selected recreational parks located in Colombo District. A total of 150 individuals (50 from each park) from different age groups were selected as participants among the people who visit the selected parks. Stratified random sampling method was used to select the participants. Primary data were collected using a researcher made questionnaire regarding the factors related to interaction such as distance from residence to park, purpose of visiting, opportunity to improve interaction among own relations, opportunity to build up new relationships, opportunity for communication among visitors, and use of built spaces and landscape elements. Data were analysed descriptively. Social interaction among visitors was identified in different levels in relation to the factors considered. Further, some aspects related to the above factors were identified to be improved for enhancing social interaction.

Keywords: Recreational parks, Social Interaction, Colombo District

I. INTRODUCTION

It is evident that there were gathering spaces in Sri Lankan history which showed close relationships with nature. Today, due to rapid growth of population and hasty urbanization, the need of public spaces has been more emphasized with complex and stressful human life style. Becoming important urban public spaces, recreational parks have been drawn more attraction as one of significant elements in urban design that give breathe for busy urban lifestyle through improving interaction among urban population. Some recreational parks have been successful in improving social interaction while others have been failed in that task. Recreational parks with organized landscape are the best approach of urban planning rather than building design. Several public parks were designed in Colombo District as a part of physical development implemented by the government after the end of civil war. Those parks should help to enhance the interactions between urban communities as expected by establishing them. Therefore, it is important to find out whether this interaction actually takes place in these parks. The ways of people perceiving those places physically and psychologically with landscape elements should also be taken in to consideration. As urban population comprises different ethnic groups, cultures and sub cultures, it is important to ensure that these parks are able to enhance

the interaction among them. This assurance would also help to facilitate the inter-ethnic reconciliation.

The primary objective of this study is to find out the impact of recreational parks on social interaction in relation to some important factors related to interaction among visitors of these parks. The secondary objective is identifying the aspects related to above mentioned factors that should be improved to enhance social interaction within recreational parks.

II. BACKGROUND AND LITERATURE REVIEW

Excessive population has created irregular constructions and informal environment in the cities. It influences the social structure by forming loneliness, lack of interaction and improper communication among urban communities. To resolve this problem, most of urban designers have tried to find solutions by changing the spatial arrangements in cities. As a result, recreational parks emerged as urban gathering spaces which can contribute to create a new social structure in the cities.

Most of researchers define urban parks in relation to different aspects such as their roles, benefits, landscape characteristics, activities etc. Yuen (1996, p.955) has defined an urban park as "any public area of land set aside for aesthetic, educational, recreational or cultural use by the public amidst essentially urban surroundings". According to the Yuen's complex definition about urban park, it is the place that fulfils many social characteristics and human needs. Olmstead (1986) defined the park as a naturalized passive retreat which provides treatment to the people physically and psychologically.

Some of urban geographers have defined urban parks in terms of the landscape elements that contribute to enhance the quality of the place. Solecki (1994, p.93), emphasizes that landscape features serve many functions as providers of passive and active recreation, environmental benefits and wildlife habitats. This reflects the importance of landscape elements and outdoor characteristics of urban recreational parks.

Hesham et al. (2011) reveal that people choose to use or not to use urban parks not only because of the features, but also the condition of the environments and features maintained in the parks. For instance, the openness of the setting in parks attracts the people. "An open view helps the person to see and make sense of a scene, whereas a blocked view limits this ability by making a sense more coherent, the open view may increase the preference." (Nasar, 1997, p.68). Hesham et al. (2011) emphasize that the green areas designed using natural elements contribute to socialization of the members of the society.

Water bodies are important elements in urban parks. Alexander et al. (1977, p. 323) states that we came from water; our bodies are largely water; and water plays a fundamental role in our psychology. Further, he emphasizes that we need constant access to water, all around us; and we cannot have it without reverence for water in all its forms. But everywhere in cities water is out of reach. This implies the inevitable connection between water and human being. Further it shows that moving water can create active impression on the human mind. Therefore, people usually prefer to gather around water. Yee (2010, p.38) reviewing the condition of the Charleston Park states that lakes enhance water quality and reinstitute tidal flushing, lively promenade experience and multiple gathering places giving attractive places to the visitors for socializing and recreation.

Sculptures and monuments enhance the quality of the place in particular environments. In large urban parks, monuments provide the legibility to the people providing the sense of belonging. Building patterns in urban parks are also important. Alexander et al. (1977) implies that tall buildings have negative psychological aspect among the individuals. It can destroy the spatial quality and interaction in the space. Uslu and Gökçe (2010) review that landscape design and colours are parts of suitable spatial arrangements which encourage more social interaction.

Peters (2009) finds the impact of green areas including trees and shrubs on social togetherness. In addition, he implies that most of the people enjoy their outdoor activities in a green and relaxing environment. Pathways defined by trees provide more pleasant and encouraging walking. "The great deal of planting along a path reinforces its image: paths along water or parks tend to be more memorable" (Lynch, 1960, p.51)

The patterns of events that take place in a space differ according to the people's sense of space and the way of experiencing the place. Activities in urban recreational parks differ as per their characteristic features and the ways of perceiving the spaces by people. Kaplan and Kaplan (1989) emphasize that tree element, seating and

beautiful spaces in urban parks contribute to promote visiting, relaxing, and experiencing the place. Recreational activities depend on peoples' perception as well as other factors such as age, ethnicity, gender etc. Social interaction is a communal connection between communities during their day today activities in a particular place. Gehl (1987) implies that human activities and design elements promote people to spend more time in urban parks. Also, he finds that most of people choose to sit on edges. It reflects relationship between human activities and outdoor elements.

Konau (2016) defines thedetermining factors for use of the urban green spaces such as familiarity with site, frequency of visit and distance from home, age groups of visitors, landscape style preferences and environment factors. Uslu (2010) determines the factors such as socio-demographic characteristics, the perception of research population about their living environments, the perception of the research population about neighborhood relations, places where the research population meet with their neighbors, factors that the research population find important for social interaction, communication of the research population with other people.

III. METHODOLOGY

Three recently established recreational parks in Colombo District were used as case studies namely Diyatha Uyana, Bellanvilla Park and Nawala wetland Park (Vally Park). A total of 150 individuals (50 from each park) from different age groups were used as participants among the people who visit these parks. Stratified random sampling method was used to select the participants. Primary data were collected using researcher made questionnaire regarding the factors related to interaction as mentioned below.

1. Distance from residence to park
2. Purpose of visiting
3. Opportunity to improve interaction between own relations
4. Opportunity to build up new relationships
5. Opportunity for communication among visitors
6. Use of built spaces and landscape elements.

Collected data were analysed descriptively.

IV. RESULTS AND DISCUSSION

The data which were collected through researcher made questionnaires were summarized using graphs.

A. Distance from residence to park

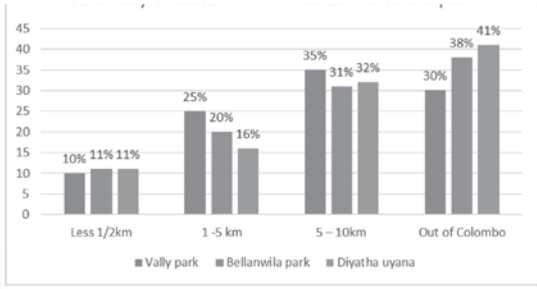

Figure 1. Summary of distance from residence to park

According to the survey results, most of the visitors come from areas beyond 5km away from the park. (Vally- 65%, Bellanvila- 69%, Diyatha- 73%) A minimum number of people who live in nearby area (less than 1/2km) tend use the parks. (Vally- 10%, Bellanvila- 11%, Diyatha- 11%)

B. Purpose of visiting

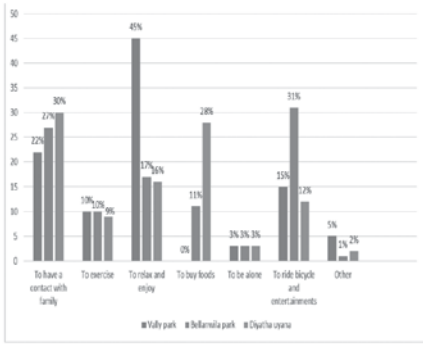

Figure 2. Summary of purpose of visiting

It was evident that the purpose of visiting parks depends on personal preferences as well as on the intended purposes of the parks. Considerable amount of visitors expressed that they want to spend their time with family and others who come with them. (Vally- 22%, Bellanvila- 27%, Diyatha- 30%) Each park has used different tricks to attract people. For instance, there is an attractive bicycle track around the lake at Bellanvila park to provide facility of riding bicycles. (31%) Most of visitors use Vally Park to relax and enjoy. (45%)

C. Opportunity to build up relationships

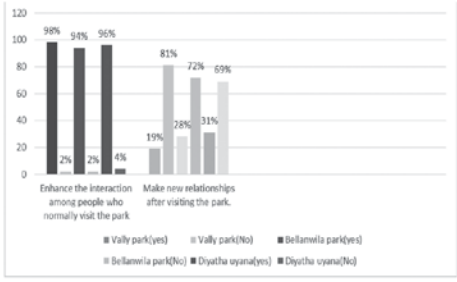

Figure 3. Summary of Opportunity to build up relationships

The survey questionnaire was prepared to get information about the relationship between own relations as well as other visitors. It was evident that there was an improvement of interaction between own relations in all three parks as illustrated in the graph. (Vally- 98%, Bellanvila- 94%, Diyatha- 96%) There are fewer propensities to make new relationships with other visitors. (Vally- 19%, Bellanvila- 28%, Diyatha- 31%)

D. Opportunity for communication among visitors

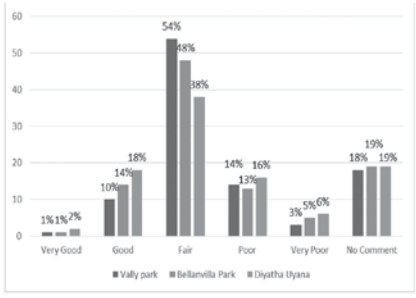

Figure 4. Summary of Opportunity for communication among visitors

High percentage of visitors has fair communication between other visitors. (Vally- 54%, Bellanvila- 48%, Diyatha- 38%) It is significant that the percentages of visitors who have 'very good' (Vally- 1%, Bellanvila- 1%, Diyatha- 2%) and 'good' (Vally- 10%, Bellanvila- 14%, Diyatha- 18%) communication were low for all three cases.

E. Use of built spaces and landscape elements

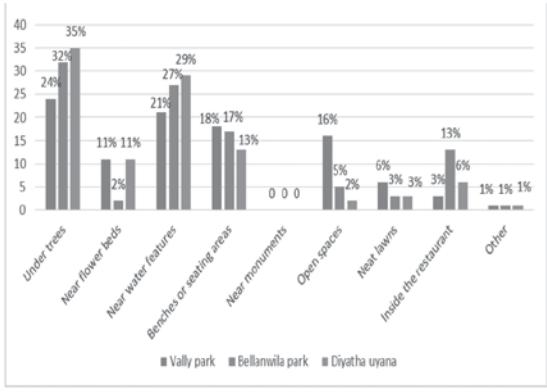

Figure 5. Summary of Use of built spaces and landscape elements

According to the study, most of the visitors preferred to spend their time under trees, (Vally- 24%, Bellanvila- 32%, Diyatha- 35%) near waterfronts (Vally- 21%, Bellanvila- 27%, Diyatha- 29%) and at seating areas.(Vally- 18%, Bellanvila- 17%, Diyatha- 13%)

V. CONCLUSION

According to the results received for selected three examples, the percentage of neighbouring people who visit recreational parks is low. It has adversely affected interaction takes place among different social groups. By analysing the purposes of visiting parks, it can be seen that most of the visitors come to spend time leisurely or enjoy with their families, relatives and friends. The opportunities for entertainment which can cause improving social interaction are less other than exceptional case in Bellanvila Park which has a bicycle track.

The results reveals that people do not tend much to build up new relationships while using parks rather than trying to enhance interaction among own relations who visit the parks with them. Having less percentage of 'very good' and 'good' communication among visitors, people show their attempt to maintain their own private space within the public space.

It also shows that people tend to use outdoor spaces than indoor built spaces and gather around natural elements like trees, water bodies, etc. Due to lack of trees which provide good shading, social interaction has been

decreased as minimum number of people visits the parks during midday.

According to entire results discussed above, it can be concluded that the impact of recreational parks on social interaction is evident in different ways and at different levels.

Introducing new ways of attracting neighbouring people can be suggested for all three parks to enhance interaction between different social groups. Introduction of different ways of entertainment can attract more visitors and facilitate improving interaction among visitors other than intra-family interaction. Adding more natural elements, trees with large canopies can attract more people during the day time enhancing social interaction taken place.

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APPLICATION OF GIS IN CONSTRUCTION MANAGEMENT

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Abstract - Geographic Information System (GIS) has been used in many fields of Science including engineering. GIS is a Computer based tool which is used to solve engineering problems related to spatial data. The potential importance of GIS to construction management in the construction industry has not been realized completely. GIS technologies have the potential to solve space related problems of construction management involving, integration of information, urban planning, project site selection, soil studies, hydrology and environmental studies. It was found that the construction industry in Sri Lanka is reluctant to apply the GIS in the construction projects. Therefore, this study was aimed to analyse the implementation issues of the application of GIS in the field of quantity surveying as a part of construction management in engineering. Interviews were conducted to gather data from the senior quantity surveyors in the fields of construction and project management. The sample was 40 and the selection method was purposive sampling specially based on the direct involvement in the project under the capacity of decision making. The study was done by using only the primary data and the analysis was done by developing a comprehensive content analysis. It was found that there are key issues in the implementation of GIS including the unawareness and the overlapping with other specific techniques. The respondents have proposed the possible ways of implementing GIS to the construction management for enhancing the productivity of the projects specially by doing a proper cost benefit analysis.

Keywords: Geographical Information System (GIS), Construction Management, Custom Application, Project Management

I. INTRODUCTION

Geographic information system (GIS) can be stated as a system designed to store, retrieve, manage, display, and analyse all types of geographic and spatial data. Basically, it is a computer-based tool which used to input, storage, management, retrieval and output of information. The GIS information connects to the attributes of geographical locations. In GIS basically shows what is located at a specific location geographically. GIS has various definitions and meanings in different aspects. GIS is a combination of both hardware and software used in working with the spatial information. GIS can answer for following questions,

- What exists or what is there at a given location?
- Where something does has occurred?
- What has changed of a specific point in some period of time?
- What kinds of spatial patterns do exist?

Most commonly GIS has defined as a specific software package used in handling and dealing with the spatial information. Geographical information can be identified as a the information about a name of a place, a street address, state or province, zip code information and coordinates of longitudes and latitudes. GIS enables, examining and analysing geographical information in different levels of detail or from different aspects. Also, it able in customizing the display of the maps and analyses in order for different purposes for different audiences for presenting. For Government Purposes the requirement of GIS can be vary and almost seventy percent of the information that are used include geographical reference. By using a GIS application it is capable of opening digital maps on computer and create a new spatial information that can be added to a map and also create printed maps

and customised according to the user needs and execute spatial analysis. Geographical data that are used in GIS are raster and vector data. The location of certain features are considered in relation to another feature on land in below applications such as assessing the property records, zoning, tracking the permits, management of natural resources, management of transportation and infrastructure, planning the economic development and the public health and safety (Anbazhagan, 2003). By relating the features the GIS system allows the user to visualize the relationships in between.

GIS can be used in different professions in construction industry. For Architects to design 3D maps and to solve query data about the elements geographically to make the design and to perform an analysis about the design. Mainly most of the Mechanical, Electrical, Plumbing (MEP) designers this GIS tool helps to design the 3D concept of the design and its exact locations. For Engineers the GIS designs and databases will help to enhance the accuracy to locate the exact locations of the geographical locations of the elements (Hemal, 2000). For Quantity Surveyors, to take off quantities, preparation of Bills of Quantities, compare GIS quantities with site quantities GIS is a handy tool. For Surveyors to demarcate land areas and to calculate cut and fill soil volumes of a particular land area the GIS technology is used.

A. Literature Review

The Construction Industry comprises of number of complex set of activities that has a huge number of tasks and cost that has involved in construction projects is a huge concern. The role of Quantity Surveyors and project management techniques used heavily effect to the success of project is very much important and sometimes they may confused on what to do next or what is the best step that has to be taken (Kolagotla, 2009). GIS has the ability to integrate miscellaneous data sets, databases and different applications in order to support and enhance the decision making among the professional in project (Chang, 2006). Many believed that the cost and time can be controlled in construction but doesn't realise that through efficient and effective cost estimation, planning, scheduling and control it can be done (Bansal and Pal, 2006). GIS can be used in construction industry for various types' tasks. The estimates prepared without detailed engineering data considered as less accurate. Therefore, GIS provides a database to store, access and manipulate data which can be used for accurate cost estimation (Bansal, 2011). GIS has the ability to recognize points, lines and areas of spatial objects. There are analytical functions that can perform such as, overlay operations, neighborhood functions, and connectivity functions which are proximity and network operations (Sebt et al., 2008). The application of GIS in construction sector has in Taking off quantities, Real time updating of Construction progress, Transport, Watershed Analysis, Environment Impact Assessment, Remote Sensing, Urban Development, Target Site Selection, Landfill Site Selection, Mineral mapping, Pollution Monitoring, Natural Hazard Assessment, Resource Management.

GIS can replace the manual methods of quantity takeoffs and to assess the materials layout design (Bansal and Pal, 2006). Due to the complexity and large varieties of activities the integration between the Project Management and GIS is a key part of the solution. By this enables the person to visualize the construction progress with the time (Kolagotla, 2009). Recently an automated site layout system was developed for construction materials. It was consisted of a new tool to help the managers to determine the most suitable and economical areas to locate construction materials. Using GIS the geographical location details are linked about the graphical features of the stores and shops. Then based on particular project's estimating quantities and final detailed design the most suitable store is selected. There will be few attributes in concern that will help in deciding the most appropriate supplier and the attributes will be weighted as per the importance (Cheng MY, 2001). As a summary the application in GIS for construction industry and construction management is identified in various aspects. The applications are researched in different professions by realizing the application that can be implemented to increase the efficiency and effectiveness by time saving to achieve the project outcome.

II. METHODOLOGY AND EXPERIMENTAL DESIGN

This research is mainly conducted through primary data collected via interviews and this is a mix of Qualitative and Quantitative data. The main objective was to find out the awareness, types of construction GIS can be applicable, ongoing construction projects using GIS, advantages and effective output that can be achieved by using a standard GIS and steps that need to be implemented in order to increase the GIS usage in Sri Lankan construction sector. The interviews were conducted from the professionals in the construction sector whom possess a vast knowledge and experience in the field. A set of questions were asked from them with given appropriate answers and based

on them the interviews were conducted. The questions were answered with their opinions and experience in the construction projects they have worked and involved in. The interviews were conducted over 30 professionals from chartered Quantity surveyors, Engineers, Architects, Surveyors and Project managers about their role and how their views and opinions about the current usage of GIS technology and how they can be used and steps to be taken to increase the usage.

III. DATA COLLECTION AND RESULTS

As per the data collected through conducting the interviews from different personnel whom are experienced in field of construction the data was analysed. The interviews were conducted in aid of a questionnaire and answering to those questions and elaborating their perspectives and views on those questions were recorded. The data was collected through 40 different professionals whom have currently involved in construction sector as professionals. As a whole, the GIS usage and implementation in construction sector has a low involvement. Mostly since the surveyors that has more knowledge in GIS uses it for demarcating and locating different kinds of activities. The involvement in mega building projects also has some involvement and for small projects GIS is not used commonly. In pre contract stage GIS can be used for finalise a detailed 3D design including the heights and accurate locations. For Post contract stage GIS can be used to locate the actual location of the building services or any other element to carry out the practical construction without creating a dispute accurately. Mainly for infrastructure projects such as irrigation projects including piping projects and waste water projects, Telecommunication projects and Electrical projects by Ceylon Electricity Board the usage of GIS in order to locate and to identify the elements. Mainly the National Water Supply and Drainage Board (NWSDB) use GIS to identify the locations where the valves, pipes are located from their latitudes and longitudes and path it runs through for maintenance purposes.

The GIS database will be prepared if only the request of the client in most of the construction projects. If the client has a GIS database it will be updated by contractor and handing over is done in modern projects. It contains the manholes, junctions, valves and other elements data feeding to the GIS database. For large scale projects which covers a large area a GIS database is mostly useful. GIS can be used for road constructions. Mainly that is used in expressway networks to implement structure locations, camera networks and structure health monitoring. Another point that discovered was that the GIS design for infrastructure projects is a very much useful way to visualise the entire premises in a 3D aspect. If the designer is far away from the site location he or she can visualise the location and decide what steps need to be taken and the condition of the site. Mainly in foreign projects without visiting to the practical site the decisions can be made if the GIS design is available. Moreover, the costs for the trial pits in order to decide the exact locating the services laying underground such as water pipes, sewerage lines, electrical cables and telecommunication lines can be easily identified with the accurate location due to the outdated data in surveying department.

Figure 1. Awareness of Professionals about GIS usage in construction sector

Due to the lacking of planning and uncertainty about the activities needed to be carried out different types of disputes arises and causes delay to the project. Mainly the consultants and contractors in mass construction has enough knowledge on GIS but due to the cost and not common usage is the issue. Considering about the Colombo Municipal Council (CMC) the involvement or construction sector is high. But other districts the involvement is much lower which needs upgrading the involvement at least up to the level of CMC.

IV. DISCUSSION AND CONCLUSION

The data collected from different professional whom involved in construction industry has different perspectives. According to their experiences the results of this research has collected. It is clear that the GIS information in a project can be used to visualise and also

for the future constructions that will be carried on that particular location area. Therefore, if there is a method and procedure that have to be adopted in order to make the GIS design. Therefore, if one contractor has design the GIS design it can be used in future projects too. The contractor and his team can finalise the design as well as planning actual activities that has be carried out without uncertainty, without delay in an cost efficient manner. Also the necessity of preparing GIS design and database has to be identified. In the developed foreign countries using GIS databases to identify the soil layers and services such as electrical lines, sewerage lines, water pipe lines that runs underneath the soil. This leads to many advantages for both contractor and to the development as a country to maintain its standards. If the preparation of GIS database about the particular project is essential in every project and entered into the bidding document it also will be an initiative step to implement the usage of GIS for construction sector. As an example if there is a clause to prepare the GIS database and submit it to relevant authorities such as Ceylon Electricity Board, National Water Supply and Drainage Board (NWSDB), Urban Development Authority, Road Development Authority, and Relevant Municipal Council to enter the GIS details about the particular project that the contractor has carried out including its soil details and all other details. Therefore a government policy has to be establish and implemented about the creation of a GIS database to a particular project. Another step that can be take is to insert a definite clause as a general condition to bidding documents. If so, the importance and necessity of a GIS database to the project will be made and sent to the relevant authorities to update their database. From implementing that there will be many advantages. Such as, allowing the public to access to those databases for their construction works will ease their activities that has to be carried out and in planning them. As an example, if a person wants construct a boundary wall he or she has to be aware about the services running beneath the soil and in some other times he or she needs to get water line the easiest route can be identified easily through the GIS database that has already with the National Water Supply and Drainage Board (NWSDB).

In the constructions of services or buildings nowadays find out the real geographical locations of the elements by using a separate activity since the available surveying data in survey department is outdated which arises so much of unnecessary costs of machinery and tools, costs for labour and time prolongation. Therefore, if this GIS databases implementation will be there the contractor or the person who is going to do the construction can get the awareness about his site premises and also the neighbourhood site premises since the access to neighbourhood will cause disputes and most of the times it is impossible to carry out trail pits to see what is underneath their soil.

Moreover, in the construction activities such as piling works most of the times that has the vulnerability of causing cracks or any other damages to the neighbourhood around services or other constructions can be reduced and avoided by this GIS database information that will be available in relevant authorities. Another step to formalise this can be used is a unique software or database separately for each authority. IF so, the uniformity and reliability will be there. As an example for CEB the GIS design database about electrical lines runs through has to be submitted by the contractor at the end of the project and for NWSDB the water lines and drainage lines designs and a database has to be submitted by the licensed surveyor in that particular project. If a licensed surveyor is not available in the project hiring a licensed surveyor from surveying department. There has to be a standard one version of GIS to be used throughout the country. By that the easiness to work with it can be achieved since everyone will be able to use it and easily manipulate. In purchasing that software some discounts can be allowed to the contractors to increase the initiative of them in using this in their projects. The awareness and implementation advantages of the GIS design and the database is not much in the construction sector and can conduct CPDs at relevant authorities and other organisations involved in construction sector and share information through leaflets and other communication media. It is a requirement for the government as well as a country to uplift the standards that is not available in the country to move forward.

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PERFORMANCE ASSESSMENT AND WHOLE LIFE COST COMPARISON OF SELECTED SUSTAINABLE BUILDING COMPONENTS OF ABC GREEN UNIVERSITY

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Abstract - The ABC Green University is constructed with the support of high technical methods and skilful labour. After analysing the built drawing and the final accounts, it was found that there are number of variations in the elementals and their costs, especially the cost of sustainable construction elements is comparatively higher. It is proved that the whole life cost of the sustainable construction increases due to the high maintenance cost and the replacement cost. Sustainable building design and construction is the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout the life cycle of a building. In this research, it was aimed to conduct a performance assessment and a whole life cost analysis on sustainable construction elements of the ABC green University. The methodology adopted for the process is the case study method and the primary data was accumulated through interviews from the technical persons who have been involved in this project. Apart from that questionnaires were distributed among the expertise on the sustainable construction and the whole life cost procedures. Data analysis was done through a content analysis and descriptive data analysis. The findings exemplify that the cost of sustainable construction is higher in the short run and the cost can be covered in the long run. Though, proper cost benefit analysis should be done to each case before applying the sustainable construction methods. Further, it is recommended that the sustainable constructions should represent the real concept itself. Detailed performance assessment and a whole life cost calculation can be used to identify suitable alternative materials to reduce the cost.

Keywords: Performance Assessment, Whole Life Cost, Sustainable Building, Green University

I. INTRODUCTION

Background - In the concept stage of a construction project, the clients consider whether their investment for the project will be profitable at the end. The clients usually place high priority on cost of procurement and construction when deciding to commence the project. But most of the time the future costs of the building are ignored. If there will be high future costs comparing to the initial cost, it will affect the client's cash flow expectations negatively.

The main intention of the Whole life costing is to conduct a proper monitory assessment of assets over their life cycle considering cost factors such as, capital, operational, maintenance, repair, upgrading, and also cost of disposal. With better whole life cost analysis, sustainability of the building can be compared with the whole life cost and identify suitable remedies to increase the sustainability of the building cost efficiently.

When considering the construction industry, the application of whole life cost concept is barely identifiable. The main reasons for this is the lack of awareness regarding the concept of whole life cost among the industry professionals, unavailability of reliable data, and lack of expertise knowledge about identifying and estimating future costs.

The main objective of the research is to conduct a whole life cost analysis of selected building components of project X and to propose a solution for maintaining a data base for whole life costing purpose. , The analysis reveals

the importance of the use of energy efficient material for the building and possible alterations of the concept in order to make it popular in the industry.

Following building is selected for the quantitative and qualitative analysis of the whole life cost concept because the building is constructed after addressing all the parameters of the concept.

According to the literature review whole life costing which is also known as the life cycle costing was originally designed for investment purposes in the US Department of Defense. Whole life costing has many interpretations. As examples, According to Emblemsvåg (2003) Life Cycle Costing is; "the total costs that are incurred, or may be incurred, in all stages of the products life cycle". Dell 'Isola and Kirk (2003) clarified Life Cycle Costing as an economic assessment of an item, system or facility over its lifespan, expressed in terms of equivalent cost using baselines identical to those used for initial costs. Dhillon (1989) defines LCC as; "the sum of all costs incurred during the life time of an item, i.e. the total of investment- and operational costs". LCC is therefore based on an integrated approach with respect to the investment and operational costs.

The project x is constructed with the support of the high technical methods and the skillful labors from China, according to the built drawings and the final accounts there are number of variations in the elementals and its cost, especially the sustainable construction elements' cost is very high, and it is proved the Whole Life Cost of the sustainable construction will increase due to the high maintenance cost and the replacement cost.

Research Questions (research/sub-problems).

The following are the identified research questions:

I. Does the Contractor conduct a deep analysis on the Whole Life Cost?
II. Will it be possible to face technical and economic issues by a local contractor?
III. Are the contractors aware about the alternative sustainable materials in Sri Lanka?

Purpose of the Study/ Objective.

The Overall objective of the study was to find out the reasons for increasing WLC of the sustainable construction element in the project and suggest the suitable remedy to reduce the maintenance and the replacement cost of the Project:

Impact of the Maintenance and Replacement cost on the WLC of Sustainable components.

Impact of Technical and Economic factors on WLC.

To identify the suitable alternative Materials available to reduce the WLC.

II. LITERATURE REVIEW

Benefits of the whole life costing of sustainable(green) building has examined in this research based on the qualitative research methodology. With regard to this, gathering answers for the questioners from the expertise professionals has been conducted and simultaneously details from the literature study will also be adopted. According to the literature study, the main focus has been the Economic benefits of whole life costing, Qualitative benefits of whole life costing, Sustainability benefits of whole life costing, Process-related benefits of whole life costing and the disadvantages of whole life costing separately. But in this research, each of these criterions will be considered related to sustainable (green) building project. The findings of the questionnaire revealed that the issues regarding the implementation of whole life costing for building are as following,

Insufficiency of resources and competent personnel - Even though the implementation of whole life costing is possible in Sri Lankan construction industry the main limitation of it is there are no enough resources and personals who are competent enough to carry out the procedure.

Initially cost is relatively high - When considering the whole life cost the first in line consideration is the initial cost which is also known as capital cost (CAPEX). Initial cost of sustainable (green building) which is simply the construction cost is very high when comparing to a normal building construction cost. As an example, a sustainable building should be consisted of water management system and an air quality system. The initial installing cost of these systems is considerably high in comparison to other systems in a building.

Maintenance cost is relatively high - A sustainable building should be maintained in an efficient manner to have the

desired outcome (energy saving etc.). So that the operation cost which is also known as the OPEX is relatively high in a sustainable building.

Other than these main limitations of implementation of sustainable building there are issues such as the persons who are related to construction industry has a lack of interest with regards to sustainable construction concept. Because of these issues most of the employers are not intended in their project merging with the sustainable construction (green) concept. (Joost Lansink (2013), The Benefits of Applying life cycle costing method)

French architect Jean Francois Roger mention in his research that "whole Life Costing as common design methodology for building projects in Europe is one of them" This research mainly focused on how WLC is used to make investment decisions considering the environmental impacts. In this research it is attempted to find the alternative design approaches, and material selection which minimize the whole life cost and the environmental impact. In our research we compared whole life cost of different sustainable building construction solutions to choose the most productive alternative with in the sustainable material. (Jean Francois Roger France, Architect, MA (AA School London), Lecturer at the St Luc School of Architecture Brussels, Architect Council of Europe (ACE- CAE) Convener for the EEC in the Taskforce 4 WLC in Construction)

K. Hunter, J. Kelly and G. Trufil have conducted a research regarding whole life cost of a sustainable building design. This research was based on finding the micro economic issues regarding sustainable construction by analyzing a whole life cost of sustainable design. Also, the difficulties faced when adopting the sustainable practices through the life span of a project were identified. We in our research did not focus to solve the micro economic problems in the industry. We only focused on providing solutions for sustainable construction by using WLC and also advice the client on choosing a better alternative evaluating the result for a single construction project. (K. Hunter, J. Kelly and G. Trufil School of the Built and Natural Environment, Glasgow Caledonian University, Sustainability Centre Glasgow, Drummond House, 1 Hill Street, Glasgow, G3 6RN

A research regarding whole life cost concept towards building sustainability is another valuable research relevant to our research area. This research was regarding the difficulties faced in the implementation of whole life cost method due to unreliable data, price fluctuation and economic changes. According to the findings of this research, it is important to adapt the sustainable construction, which increases the value for the money for material and method used for the construction, rather than selecting non-sustainable construction alternative which helps to lower the tender price due to low initial cost. Also, they have found that the use of renewable energy technology will result in increasing the value of invested money. In our research we compared with in the sustainable alternatives use in different buildings to find the best solution and discuss about the employer's lack of knowledge regarding the evaluation of the results find through a whole life cost method. (Ing Liang Wong Glasgow Caledonian University, Conference Paper · February 2010)

III. METHODOLOGY

The research will mainly attempt to discuss the importance of the WLC calculation for the selection of an alternative material for the sustainable construction components. The Primary data which was required for this research is the most important part of the study. The primary data was collected via direct, indirect oral interviews with the technical persons who were participated in the project, mailed questionnaires from the expertise on the sustainable construction and the WLC procedure.

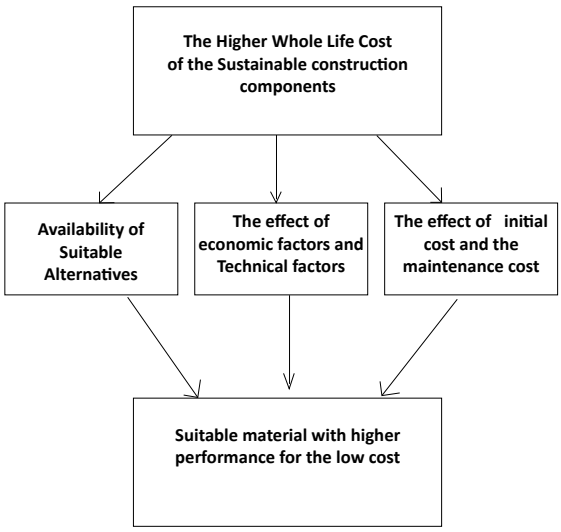

Figure 1 conceptual frame work
Source: Research objectives

There are some written material about the importance of WLC analysis, so the secondary Data research approach will be a collection of data through Journals and Articles which consist of related literature reviews of studies on importance of WLC analysis in the construction industry. Detailed whole life cost calculation will be used to identify the cost for the sustainable components which are used in the project X. The suitable alternative materials identified through the collected data from the primary and secondary approach and the Whole Life Comparison cost did for the alternative and identified the most suitable way to reduce the maintenance and replacement cost for the sustainable construction elements in the selected project. Data should be analyzed after preparing the whole life cost of each proposal and by comparing performance assessment the most suitable alternative material and the procedure proposed to the Contractor and the Employer.

IV. ANALYSIS

Sustainability is a universal concept. It is about consuming natural resources, the kind of legacy the current generation leaves for the future generations. At Present sustainability concepts are being applied to majority of industries globally and locally. With high tendency of scarcity of people thinking about remedies for utilize natural resources efficiently.

As all other industries, construction industry also tries to adopt sustainable concepts for their building work. Considering the Sri Lankan approach regarding the sustainable concept is important. For that it is important to consider social, economic, cultural, and cost factors. A developing country like Sri Lanka should pay more attention to the cost factor.

The case study was conducted on the Sustainable Construction's Materials used in the project X. The collected data from the project were analyzed with the questionnaire answers (Qualitative) collected from the expertise on this field. The main objective of the research is based on the effective study of the contractor regarding the WLC of the sustainable components. It seemed through the construction documents the contractor didn't do any deep study regarding the selection of the components. The selection process only depends on the quality and the price based on the quotations.

The comparison of the Initial contract price and the contract price of the project shows a huge variation of the prices. The main factor for this variation is the sustainable construction. The contractor had to spend more money for the maintenance purpose than the anticipated amount during the construction and the defects liability period. The expertise people mention that the Lack of proficiency of the contractor is the main reason for this issue. The contractor statement mention that the reason is the Unavailability of resources.

The Technical factors were considered by the contractor on the performance assessments are aesthetics, Durability, cleaning Thermal properties, Acoustic properties. The contractor stated that due to the Unavailability of resources the performance assessment was not conducted in the expected level.

The WLC calculation and the performance assessment were again compared with the available alternatives in the local and the global market to give more emphasis for the findings and the recommendations. The findings of the research reveal that the main reasons for the research problem are Lack of proficiency, Unavailability of resources, Negative attitudes, Reluctance to move with new trends, economical factors and the performance factors. Based on that the recommendation was made to the Project X and for the Construction industry of Sri Lanka.

V. CONCLUSION AND RECOMMENDATION

If construction industries are actively engaging with sustainable concepts, they should thoroughly analyze the life cycle costing and the payback period of total cost. Then it will depict how worth it is and how nicely it manages the building's energy, water, air quality and site towards the betterment of organization. If buildings are integrating BIM to this process, all cost calculations can be done before the construction and that analysis will greatly support the decision-making process of the organization. Accordingly, it helps to implement sustainable building concepts along with sustainable building certifications.

According to the facts obtained through the literature review, most of the organization including sample organization, select sustainable building elements for their construction, not considering the whole life cost. If construction industry has sperate professionals for whole life cost estimation the accuracy of the whole life cost will be very high. Then most of the investors plan their budget with the help of a whole life cost estimator to minimize

their project cost. By that analysis building owners can get a basic idea about where and when to their monitory commitments to maintain, repair, and modify. Further, it is recommended that the government should encourage the law grade contractors to use sustainable elements after rational whole life cost analysis. It will cause to encourage sustainable material supplier and the prices of materials will be low. A whole life cost concept for sustainable buildings is a new concept for Sri Lanka therefore well-maintained records regarding costs for the maintenance and the repairs will be important. It will be important to analyze the way that investors should make their monetary commitments to maintenance and repairing of the building.

Implementing the green concept for buildings is practically possible for all building types. But due to the insufficiency of resources and competent personnel, this has become a sort of discussing matter. When it comes to the sustainable building concept, with the rating parameters we have to go for sustainable energy system, air quality system and water management system. So, in this scenario, the initial cost is relatively high. That means to cover this initial cost, the payback period is much higher. Hence, all these comprehensive procedures are hesitant to take the step forward to move with the sustainable concept.

So, if we go for sustainability considering global environmental constrains it is worthless. Most of modern thinkers, think like in this regard. But according to our opinion, government should encourage investors to invest their money on sustainable construction because if we don't even start to make sustainable buildings we won't be able to compete with the global construction industry in the near future. Because globally there is higher market for the sustainable construction. Even if we have built sustainable building before achieving national development goals, when we achieve those goals we can maintain our national development with those type of construction which are globally accepted. Also, if we think beyond the cost constrains we can find out that the sustainability will cause to increase the popularity of tradename of the organization. More nature lovers will be attracted to the organization and it will be a long term benefit.

The contractor of the project is from China and also the technical people and other labors involved with the project are Chinese. The main limitation occurred during the case study was regarding the communication and the document clarification.

The research was conducted regarding a performance assessment and a Whole Life Cost analysis on sustainable construction elements of ABC green University. The data was collected via case study method and interviews of technical people who involve in the project and expertise people in construction industry related to WLC and sustainable construction. Through those data collecting methods, maintenance and replacement cost of WLC regarding sustainable components, economic and technical factors that affect to the WLC, identification of alternative materials for reduce WLC were the objectives. By analyzing those objectives, the lack of knowledge regarding WLS methods and procedures of stakeholders in the industry, the necessity of WLC in the preliminary stage of the construction project has been identified and finally, the benefits of sustainable construction with proper analysis of WLC for construction project as a country has been identified.

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IMPACT OF DECISION MAKING ON THE CREDIBILITY OF BILL OF QUANTITIES (BOQ)

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Abstract - There is a strong statement of the society that the estimated cost in Bill of Quantities is very less than the actual cost incurred. Further, it means that there is a significant gap between the estimated cost and the actual cost which cannot be accepted. The argument is that the trustfulness of the clients on the BOQ has been understated and the BOQ is prepared for the documentation purposes. Therefore, this study was aimed to find the reasons for the gap arisen between the estimated value of BOQ and the actual value incurred. Data collection method was done through interviews by taking a sample of 50 people who have been involved in preparing and using the BOQ in the construction field. The main dimensions were focused on the role of a quantity surveyor in this regard, types of procurement strategies, defects of cost estimating methods and the parameters of cost estimations. One of the main findings was that the clients have added extra cost to the estimated cost which has not been specified at the point of BOQ preparation. Some of the quantity surveyors believe that the rate adjustments should be more practical by addressing them to the modern complex market. Further, it seems that the accountability of both quantity surveyors and the clients should be enhanced to avoid the misinterpretation of the said statement regarding the BOQ. Then the credibility on the BOQ can be enhanced up to the expected level.

Keywords: BOQ, Credibility, Decision Making

I. INTRODUCTION

According to Seeley and Winfield (1999) Bills of quantities (BOQ) is a document which consists of schedule of items of work that has to be done under the contract with quantities entered for each item which is prepared under the Standard Method of Measurement of Building Works. Currently we are using SMM7. According to Ramus and Birchall (2003) BOQ's are completed by a Quantity Surveyor on behalf of the Client with the use of detailed drawings and specifications which are drawn up

by an Architect. Also according to them the BOQ's, the drawings and the specifications are then sent to the contractors to decide price for the project. Then the contractors allocate a unit price for each item in the BOQ and when all items are totalled the result is the total cost of the bills for that particular project and thus the tenderer's price (Turner 1995).

The ups and downs of the bills of amounts have been calculated on for a long time and have created firmly held and varying perspectives. According to Davis, P.R., Peter,E.D.,Baccarini,D.(2009) the arguments against the use of the BOQ is that it can only be used to price the materials, labour of a project at a given specific time accurately. Outside of materials and labour, there are added costs of preliminaries which consist of insurances, site mobilization, and items of plant etc. These costs according to Davis et.al. (2009) are priced on the percentage of the total material and labour costs. Phung and Ming (1997) state the uncertainty of the ability to price items such as preliminaries accurately as a con of the bill of quantities. According to Brewer (1998), the rules on which a bill of quantities is, does not allow items to be measured accurately, thus creating an uncertainty in the bill of quantities.

According to Duncan Cartlidge (2009) : "during the recent past the bill of quantities has been much maligned as out-dated and unnecessary in the modern procurement environment. Indeed it is undeniable that on the face of it the number of contracts based on a bill of quantities has

declined sharply over the past 20 years or so". Usefulness of the BOQ when obtaining bids and as a post contract cost control tool have been documented and has been researched before but the decision making credibility of the BOQ has not been researched before in building project procurement. In this study we attempt to study the credibility and usefulness of the BOQ.

II. LITERATURE REVIEW

According to FIDIC (International Federation of Consulting Engineers) Bills of Quantities (BOQ) comprise a list of items of work which are briefly described. The Bills also provide a measure of the extent of work and this allows the work to be priced. The work included in the item is defined in detail by the rules in the Method of Measurement. The shortened item descriptions are allowing the relevant rules of method to be identified. The measurements may be single item or number. Unites may be length (leaner meter, square meter and cubic meter) time (hours, weeks) or weight. The Bills of Quantities may serve a number of functions as: The bill of quantities may help to analyse number of factors such as price breakdown without contractual status but giving information to selection from renderers'. The revised contract price can be fixed with tender price. When actual quantities of works done are measured the tender price can be received by measure and pay basis. The measure and pay basis is the form of checking the contract, the schedule rates can used to measure variation of the work. This is basis to pay the interim payment for the value of the work done.

MIllican states that (1996 cited in Bandi, 2012) BOQ is a document which used over 300 years as a one format safe and BOQ is most important document in construction industry govern by traditional procurement methods. Seeley (1997 cited in Davis et al.2009) started that if the work carried out without BOQs it leads to variations, risk in estimating and more difficult to come agreement in both parties. But now there is a doubt about the credibility of the BOQ. Difference of the estimated cost and actual cost affects the credibility of BOQ as well as profession of the quantity surveyor. Not only others , one aspect of a situation implement data and information. It can be very difficult to detect and prevent as well have inadequate understandings which bias our research. Data and information selected may not be relevant to the decision for which the information is required. Information for one decision-makers I time to be used in decision making. To identify some of the qualities requires of information which is useful in decision making.

Brook (2008) said "the BOQ has two primary uses. One is at the pre-contract stage where it assists the contractors in the formulation of their tenders. The other is at the post-contract stage where the BOQ assists contractors and quantity surveyors in the valuing of progress payment and variations among others. For more than 40 years, a lot of work had been done to examine the suitability of the BOQ in these two key phases of construction". Also Love et. al. (2006) mentioned "the use of traditional procurement is heavily reliant on the design documentation being completed and a detailed -BOQ being produced so that cost certainty can be provided to a client prior to construction commencing".

Yueshui, L.I. , Jinhai, F.A.N, (2006) said ' current construction market environment remains imperfect, so the process control must be strengthened during valuation with bills of quantities' . The paper presents an emergency computer aided valuation appraisal technique for verifying design and quantifying the material cost components contained within BOQs. This technique has the potential of closely verifying the accuracy of presented BOQs, Opeyeolu, T.L. , Samuel, B.A.(2014)British Journal of Applied Science and technology 4(27),3956. According to Gunathilaka, A.A.U.S, Indunil, L.D., Senevirathna, P, (2013) It is necessary to illustrate that if there is any error in BOQ, that would directly affect the base of the construction projects. As a result all the stakeholders involved in a project have an extremely higher concern on those three expects, as having an error free BOQ is vitally important. Errors can occur during preparation stage and pricing stage of the

BOQ. According to Srinath Perera, et al (2009)" in traditional procurement where traditional bills of quantities are used, there are deviations between the budgeted cost in the BOQ and final account figures.

III. RESEARCH METHODOLOGY

This study was carried out primarily through the use of secondary data. Data were obtained from past bills of quantities of building projects recently completed in different areas in Sri Lanka. The data related to the estimated cost and the actual cost after the completion of the different project types are investigated. The aim of the research was to evaluate the impact of decision making on the credibility of Bill of Quantity (BOQ). Collection of data was done by providing a questionnaire to the Industry Experts who have been involved in preparing and using the BOQ in the construction field.

The questions which are used for the survey are based on the type of construction which is done by the client. It may be building construction, road and highway construction, irrigation construction, bridge construction, steel construction or water supply and drainage construction. To determine the preparation of BOQ for the construction has done or not also focused. To include the purpose of the BOQ, the reasons are also determined.

Accordingto the construction industry the BOQ is used for many reasons such as to get general idea about construction, obtaining bank loans and getting funds, to measure construction works for tendering purposes, evaluation of progress, engineer's estimate etc. Checking the variance between actual cost and estimated cost also aimed in this survey. And focus on the solutions of the variance such as unforeseen site conditions, market price fluctuation, design changes etc. are included. The data analysis was carried using frequency table and getting percentage of the purpose of use of BOQ. Two further analyses were carried out by the percentage of getting variation between estimated cost and actual cost and the reasons for the mentioned variations. The analyzed data will be represented in a pie chart.

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IV. ANALYSIS

In this we compare and contrast the results which we have obtained through this research.

Fig 1. Presents the BOQ data for the project we have studied. An investigation of percentage difference between the tender sum and the final account figures give us an implication of the budgetary credibility of the BOQ. Through the research we have found that the percentage difference between the budgeted cost and the final account ranges between the budgeted cost and the final account ranges between 5% and that is the range which has been stated as the acceptable accuracy range between the quantity surveyor's estimate and the accepted tender by Morrison(1984).

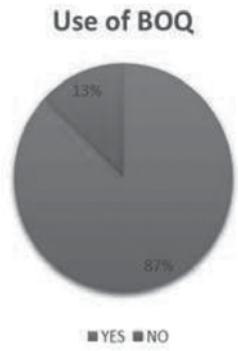


Figure.1 Use of BOQ

According to Cooke and Williams(2009), one of the risks and the most serious effects for the client is the failure to keep within the cost estimate. We have observed that some of the reasons for these fluctuations between the sums were different site conditions, design change, weather conditions. The site which has been chosen for the construction might not be suitable for the specific building

work so might need to go beyond the budget and make it suitable for the project, the employer might change his decision and may want something else entirely, when that happens we may need to change everything in order to cater to his need. The design changes will also make the project estimated amount to go up. And we might get unforeseen weather conditions and we may be not prepared for it and the damage which it has caused might not be enough to be compensated by the contingency sum. In that case the project actual cost would get higher than the estimated sum.

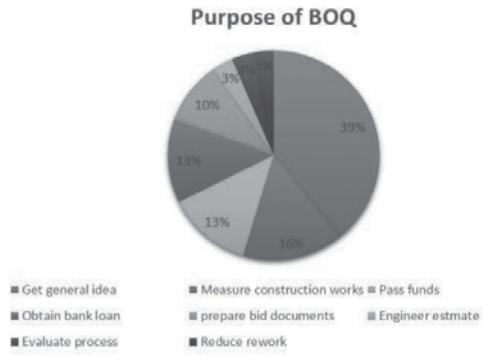
Some of the other reasons for the gap between the two sums are the unpredictability of some work in the tendering stages. (De watering, cofferdaming cost, underground excavation and underground rock excavation etc..) And these unknown factors may be stated in different ways by different people but however the estimate for them should be within 10%, if it has been done properly. Market price fluctuations, tendering process unexpected wastage lack of supervision might also cause for the gap between the sums. Practical constraints due to change of material price, lack of materials, material cost variations when project implementing labour costs and overhead costs can be varied, transportation and machinery charges may increase, the taxes may go up and the project scope may change and power failures can happen. Because of all these reasons the gap between the estimated cost and the actual cost can go up. From the graph below you can see how the variation has happened.

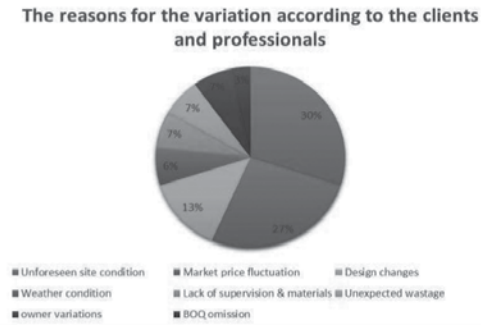
Mostly the variations have happened due to unforeseen site conditions and secondly due to market price fluctuations and thirdly due to design changes. Further analyses were carried out to state the budgetary reliability of the BOQ and we have analyzed how the Clients were hoping to use the BOQ. In the graph above we can observe how the Client was planning to use the BOQ and for what purposes they have used it. They have used it to get a general idea about the cost which would be needed to obtain bank loans which would be needed to gain financials which would be needing for the project, to prepare bid documents, to make the engineers estimate and to reduce rework. Mostly they have used this to get a general idea about the project and how much it would cost and secondly, they have used the BOQ to measure construction works. Fig 2.

Figure 3 suggests that where clients are interested in cost certainty, quantity surveyors and project managers need to qualify the price they give to clients with an indication of confidence limits. This is very essential because the deviations are observed with an indication of confidence limits. This is very essential because the deviations are observed as a result of risk factors that are inherent in construction.

V. CONCLUSION

This paper has examined the fiscal reliability of Bill of Quantity (BOQ) using secondary data from completed building and other works. We have employed the survey method with the help of a series of questions that have been given to industry experts. The problem that we have faced was the gap between the estimated cost and the actual cost and the reason behind it. By doing this survey we were able to determine the reason behind it. While doing the research we have found out that almost every single reason behind the gap was not the quantity surveyors fault but they were due to the unforeseen site conditions and market price fluctuations. BOQ still exists as a budgeting tool even though the common awareness of the defects. Even though there are deviations it acts as a useful tool in the overrun.





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REVIEW OF THE BUILDING SCHEDULE OF RATES (BSR) FOR WORK NORMS

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Abstract - The Building Schedule of Rates (BSR) for standard work norms should be reviewed due to some technical problems raised in the current construction industry. It was found that there are some work norms that have not been recognized in the BSR. The role of a quantity surveyor has been widely recognized through the BOQ preparation. Therefore, the trust on the duty of the quantity surveyor is understated due to the rates which are not allocated in the BSR. As the methodology, an expert analysis was done to find the new variables for work norms which should be included in the BSR. Around 30 professional quantity surveyors have been interviewed to get the opinion regarding the missing variables. Most of the respondents said that the BSR rates should be changed according to the changes available in the market. The given rates are somewhat old, and the new items have not been identified. Specially, the modern technology introduces new materials and methods for the building works which have been developed after the development of the existing BSR rates. According to their opinions, some of the rates for items can be identified indirectly using some of the rates given in BSR. But, to get the real picture, the BSR standard should be updated.

Keywords: Review, BSR, Work Norms

I. INTRODUCTION

Construction industry plays a major role In Sri Lankan economy. The construction sector was continuously growing at high rate during the previous years. Materials, plant and labour components are the main inputs to the construction sector. Planning, organizing, directing and controlling of material, plant and labour components are the main factors to a successful project. To assist these functions, the standard norms were developed time to time. Today, the development of the modern technology, work norms to the construction industry are to be updated. In Sri Lanka, standard work norms are available and it is called Building Schedule of Rates (BSR). It is very helpful in estimating different parameters.

The Building Schedule of Rates (BSR) is developed, mainly based on work standards generally accepted for building construction work with eight hour labour input. The rates are build- up, based on pricing and engineering estimate for the construction maintenance or addition or improvement to a building. The Rates include Overhead and Profit Margin as per their own norms, but general 15%.

BSR analysed a specific rate for many building works. In the construction site, the rates are analyse by examined the materials consumption and labour involvements in two different selected sites and all the data were recorded on daily basis according to the construction events. The experimental data were analysed by statistical techniques and compare with the BSR rates available up to date. But some of the rates are old and they are not updated to the current market price.

The BSR is directly incorporated for the preparation of BOQ. Because of the improper rate allocation, there will be a major deviation between actual cost and the BOQ price. And this, directly affects to the cost of the project. Therefore the reliance on the duty of quantity surveyor is understated due to the improper rates allocation as per given in BSR.

The main objective of this research is to find out the reasons for not identify a specific rate for the work norms mentioned before.

II. LITERATURE REVIEW

The Building Schedule of Rates (BSR) for building work norms should be reviewed due to some technical problems raised with the rates which are not allocated in the BSR. According to Cambridge English Dictionary, review defined as, "to think or talk about something again, in order to make changes to it or to make a decision about it". So this research is aimed to find out the reasons for not analyse a specific rate in the BSR, for current building works.

According to SMM7(2017), "The Building Schedule of Rate is prepared based on work standards generally accepted for building construction work with 8 hour labour input. The item description of the BSR is recruited with a view to directly incorporated in to a BOQ, Which in turn will be used as a bidding document for measure and payable contracts along with specifications, drawing etc." BSR rates are built-up, based on pricing and engineering estimate for the construction maintenance or addition or improvement to a building. BSR analysed a specific rate for many building works. But today, the development of modern technology, work norms are to be updated. The BSR is directly incorporated to the preparation of BOQ. Because of not analyse a specific rate to the current building works, quantity surveyors use various methods to calculate the rate. There will be a major deviation between actual cost and the BOQ price because of the improper rate allocation. And this is directly affects to the cost of the project. Therefore the reliance on the duty of quantity surveyor is understated. This is a major issue in current construction industry.

According to Construction Law, Chapter 1, section 1, "Construction work norms is defined as an aggregate of norms and regulations binding on all persons participating in construction that regulate construction and the operation of structures as well as explain construction terminology".

This research is mainly focused on the current building works which haven't a specific rate in BSR. Specially, the modern technology introduces new materials and methods for the building materials which have been developed after the development of the existing BSR rates. So the BSR should be updated for the current market.

According to Bhutan Schedule of Rate (BSR-2017), "The Bhutan Schedule of Rates are prepared and published primarily as a tool to assist in the estimation of project cost. Due to difficulty in obtaining comprehensive and accurate rates from base towns and associated complexity in their analysis, the BSR reflects only suggestive averages and not accurate current market rates. Materials and labour rates also fluctuate frequently, and by the time of the publication of this book, many rates would have already changed". So by this evident that there are various reasons for not identifies a specific rate for the new materials. And according to the author, the Bhutan Schedule of Rates reflects only suggestive averages and they are not accurate current market rates. In Sri Lankan construction industry, standard work norms are available and it called Building Schedule of Rates (BSR). But it also not updated for the current market price.

According to Work norm analysis for medium scale building project by U.K.D.L.T Udawatta, department of civil engineering, University of Moratuwa (2010) found that the actual material consumption is relatively high comparing to the standard BSR value which were previously developed. It is evident that there is a major deviation between actual cost and the BOQ price. It also directly affect to the total cost of the construction project. The new variables of the modern market should be validated and recognized by the BSR. If not, it directly affects to the preparation of BOQ.

According to, Causes of construction delay traditional contract (2002) by Abdulla M., Hussien T, Many projects experienced extensive delays and thereby exceed initial time and cost estimate. There are many factors affect to delay a project such as ;Financing and payments, labour productivity, slow decision making, improper planning etc . By referring the financing and payment factor of this research can get some additional information to this study. If the cost of the tender is too high, the client has to delay or re-design the project moreover cost of the BOQ and the real cost of the project has a major deviation, then they have to delay or re-design the project. BSR rates may affect to the cost of the tender. During the tender stage, the construction companies in the private sector use rates which are relative to them. Because of not having a standard method to analyse the rates for certain building works, the total cost of the project may deviated.

III. METHODOLOGY

Structured interviews were conducted as the mode of data collection technique to gather data for the study concerned. The interview was conducted with a randomly

selected, around 30 professional quantity surveyors, involved in current construction industry from different parts of the country in Sri Lanka.

BSR analysed a specific rate for many building works, but it is not updated for the new items, arrived after the development of the modern technology. When studying the BSR, we found out that there are some building works that haven't a specific rate in BSR. From that building works, we do our research based on the aluminium ceilings The collection of data was done by preparing a list of simple questions based on one selected building work; aluminium ceilings. First off, the first question was raise for the interviewers to get to know about, whether this building work (mentioned before) have a specific rate in the BSR or not. And the rest of the answers are depending on the answer give to this question. Various methods are use in construction sector to analyse a rate for the works that haven't a specific rate in the BSR. This interview helps to get a clear idea about these methods. Because of not analyse a specific rate for the current work norms in the BSR, quantity surveyors use various methods to analyse the rates. The next question consider about the impact to the preparation of BOQ by using various methods to allocate the rate. Because of the improper rate allocation, there will be a major deviation between actual cost and the BOQ price. The role of the quantity surveyor has been widely recognized through the BOQ preparation. So due to the improper rate allocation, the trust on the duty of quantity surveyor is questionable, because the BSR is directly incorporated for the preparation of BOQ.

This study is aimed to find out the reasons for not analyse a specific rate for the new variables by conducting interviews with the professional quantity surveyors involved in current building construction industry. To overcome this issue, the findings of this research are really helpful.

After examined the professional quantity surveyors, the data analysis were carried by using a grid table, and compared each and every answer with other. The analysed data will be represented by using a pie chart. Finally an overall conclusion made from the information gathered through the interview.

IV. ANALYSIS

According to the questionnaire and the referred details, there is no rate analyse for Aluminium ceilings in the BSR, published by the Building Department But in modern construction field use aluminium ceilings. Most of the professionals said that there are various methods use to analyse a rate for the aluminium ceilings in modern construction. Most of the professional quantity surveyors are analysed rates by using previously completed projects. Some of them use specialised quotations from sub contractors and also use current market rates for analyse a rate for the aluminium ceilings. They use various methods for analyse the rate for aluminium ceilings because it doesn't have a specific rate in BSR.

According to the questionnaire, it is evident that there are lot of reasons for not identify a specific rate in BSR to this work. According to their answers, timbers, asbestos ceilings were used in many years back, at that time aluminium ceilings were not available in the local market so they didn't have much knowledge about aluminium ceilings those days when preparing the BSR. Some respondents said that there are many types of aluminium ceilings available in market, so rates are depend on the type of the material(ex: powder coated, anodize etc) , type of finish, hanging type and hanging material. Some said that techniques, methodologies are changing time to time so it's difficult to analyse a special rate for this type of materials. Manufacturing, installation process are very complex in this type of materials so need skilled labours for this type of work. So they cannot identify an accurate price because of the complexity of the process. BSR rate analysed only for the basic items, for new items they should depend on this basic items and analyse a new rate. And also client requirements are changing day to day so cannot fix for the norms. Quality and nature vary from project to project.

Next query consider that, if it may be a problem to price the BOQ when there isn't a specific rate analyse for this material. Some respondents said that it may be a problem and some said no.According to the professionals who said that it may be a problem, the clients' requirements day to day change and it cannot fix for the norms specially materials and selected materials usage and required executions can't judge based on the requirements and design teams, design norms should vary. To making norms and collecting details not simple. When pricing BOQ needs additional time to develop all because studying details, collecting details, analysing are not easy. If there is a variation or an extra work in construction field, it may be a problem when analysing a special rate. Some respondents said that tender prices are vary because different contractors give different tender prices so they have to make construction descriptions, need to give approximate specifications and accurate price details, so the process is complex. If they

don't price the work correctly they may either loose the job at tendering, or if the tender awarded, they won't be able to have any profit. Some experts answer was that it doesn't mainly become a problem as they use specialized supplier rates to price these items. But if they don't send the quotations on time or fail to provide full price list, they will face difficulties. Furthermore when they fully depend on that external party they don't have a bench mark rate to evaluate the supplier rates. And also the aluminium works are not always is a work of sub-contractors.

According to the respondents, for the most commonly use brands and specifications, a standard rate analysis can be provided in the BSR. This standard rate analysis can be sued as a bench mark rate and adjust accordingly with the relevant brands and specifications. Some respondents said that changing the BSR rates is not a solution for this problem because the market rate and requirements are varying time to time. When finding the solutions for this matter using the questionnaire, most of them said that BSR must be updated according to the current market rate, new modern technology or an equal quotation must be specified. Some professionals said that to give a price proposal for the building department, as a solution or they can develop pricing system with some hard work, such as collect all the details in manufacturing process and the installation and develop a detailed breakdown for the work with the market rates. Most accurate norms can be build up using historical data which was used in similar work in previous projects or can maintain update database of commonly used aluminium ceiling types from different suppliers. Some said that they can do a work study and build up a workable rate. So, many professional quantity surveyors gave various solutions for this matter. The analysed data is represented by the pie chart below; Figure.1

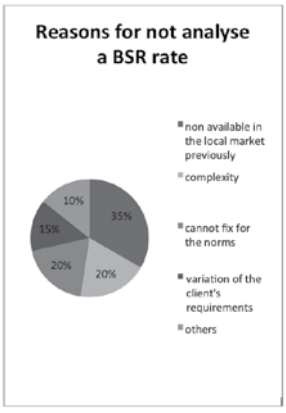

Figure.1 Reasons for not analyse a BSR rate

V. CONCLUSION

The Building Schedule of Rates (BSR) published by the Building Department, Sri Lanka for building work norms should be re-evaluated due to many technical problems which were raise in real world calculations. There are many variables in building works that have not been recognized in the BSR published by the building department. The BSR is directly incorporated for the preparation of BOQ. So because of the improper rate allocation, there will be a major deviation between actual cost and the BOQ price. This will directly affect to the cost of the project. Therefore the reliance on the duty of QS is understated due to the improper rate allocation as per given in the BSR.

The main objective of this research is to find out the reasons for not identifies a specific rate for this special works. So, structured interviews were conducted as the mode of data collection to gather data for the study concern. The interview was conducted with randomly selected professional Quantity Surveyors involved in current construction industry.

Considering the answers of the professional quantity surveyors, it is clear that there hasn't a specific rate analyse for the aluminium ceilings in the BSR published by the building department, but in the modern technology aluminium ceilings are using for the constructions. But there hasn't a specific rate analyse for aluminium ceilings so to get an accurate price rate for this item, they use various types of methods. Most of them use rate from previous completed projects and current market rates to give an accurate rate for the aluminium ceilings. From this research it is evident that there are various reasons for not identify a specific rate for the above item. Most of the respondents said that the market rate is change from time to time and the requirements of clients are vary from project to project. So it's difficult to get a specific rate for the special works and cannot fix for the norms. Especially materials and selected material usage and required execution can't judge. It will base on the requirements and the design teams design norms should vary. And when publishing the BSR, aluminium ceilings were not in the local market.

Most of the respondents said that because of not having a specific rate for this material, it will be a problem when pricing the BOQ. According to the professionals, to making norms and collecting details are not simple. When pricing the BOQ, needs additional time to develop all. Studying details, collecting details, analysing is not easy.

When available of norms, can save time within pricing BOQ but without all time people additional involvement make additional cost. So it may be a problem when there's not having a specific rate for this works when pricing the BOQ. Some obtain quotations from sub contractors and analyse a rate for this material. They said that it's not a problem when pricing the BOQ.

This research only considers about the Aluminium ceilings as the work, but the modern technology introduces many more new building works. So, each of the work needs to analyse a specific rate when preparing the BOQ. If not it directly affects to the quantity surveyors duty, so the reliance on the duty of the quantity surveyor is understated due to this matter. When considering the most of the respondents' answers, conclusion can be made that the BSR should be update at least once a year and the updated BSR should have to use in the current construction industry.

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SMM7 based Standard Building Schedule Rates (SriLanka) Abdulla M and Hussien T, (2002) Causes of construction delay traditional contract.

SEA LEVEL PREDICTION MODEL FOR COLOMBO COASTAL AREA USING MATLAB SOFTWARE

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Abstract - Sea level rise can be explained as an increase in the volume of water in the oceans of the world. But the rates of rise over local areas are variable. There are several reasons for the rise of the sea level; mainly thermal expansion of the sea and melting of ice caps. Sea level has significant impact on construction industry near coastal areas in the world. It affects Sri Lankan coastal areas also, especially in the Colombo coastal area. So, it is necessary to do an analysis on the tide gauge data collected from 2006-2018 in the Colombo coastal area, and build a model to predict the sea level to minimize the impact from rising sea level for future construction projects. The tide gauge data collected can be displayed as a frequency distribution with time as the x axis and Sea Level as the y axis. Missing values will be filled with linear interpolation. Then the wave type distribution will be decomposed until a residual can be gained from it using Empirical Mode Decomposition (EMD) method. After that the residual will be selected from the Intrinsic Mode Functions (IMFs) that has been created from the EMD process. The selected residual will be then curve fitted using a polynomial interpolation technique of a higher degree. Then the fitted curve extrapolated to a given time domain, following which the prediction results can be given. Analysis of the sample data of 8 months of Tide gauge data resulted in an unreliable prediction result but it was closer to the current prediction levels of the Intergovernmental Panel on Climate Change.

Keywords: Sea level rise, Prediction, Tide Gauge data, Intrinsic Mode Functions, Residual, Curve fitting, Polynomial interpolation

I. INTRODUCTION

A sea level rise can be explained as an increase in the volume of water in the oceans of the world. But the rate of rise over local areas are variable. There are several reasons for the rise of the sea level and they are

i. Thermal expansion of the sea (Mainly)
ii. Melting of Ice caps
iii.Freshwater content flowing to the sea
iv. Salinity
v. Density

Etc…

Rising sea level makes a significant impact for construction sites near coastal areas since the construction in these sites does not stop for few years but instead of that the people continuously construct and upgrade components in these sites for centuries. Main impacts can be categorized as follows…

i. exacerbated inundation and flooding of low-lying coastal areas
ii. increased coastal erosion
iii.effects on coastal ecosystems such as salt marsh, mangroves and coral reefs
iv. salt water intrusion into estuaries and aquifers
v. changes in sediment deposition along river channels

the research focuses on finding a sea level prediction model for the Coastal area around Colombo and analysing the impact caused by the sea level rise for the construction sites.

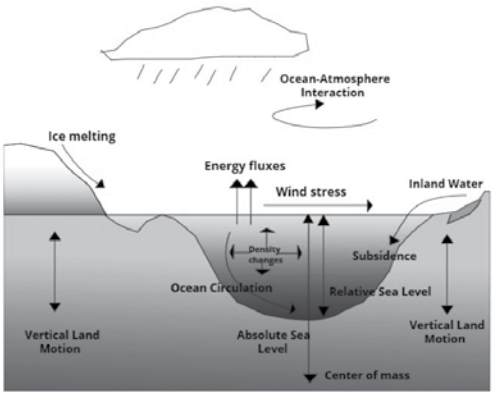

Figure 1. Process that influence Regional Sea level

The research type is analytical research which uses the Tide Gauge data for the analysis and prediction of the sea level. The Colombo tide station tide gauge data collected over decades were stored IOC Sea Level Monitoring Facility website. The data collected can be displayed as a frequency distribution with time as the x axis and Sea Level as the y axis. But there may be missing values. These missing values will be filled with linear interpolation. Then frequency distribution or the wave type distribution will be decomposed until a residual can be gain from it using Empirical Mode Decomposition(EMD) method. After that the residual will be selected from the Intrinsic Mode Functions(IMFs) that has been created from the EMD process. The selected residual will be curve fitted using a polynomial interpolation technique of a higher degree. Then the fitted curve will be extrapolated to a given time domain. Then the prediction results can be given.

The Research hypothesis is the Sea Level near Colombo shore line rises impacting the construction sites within 200 years.

Scope and the delimitations of the study:

i. Data Collection for a Sea Level prediction there must be sea level data collected for more than 19 years. But there were only 12 years of raw data in Colombo tide gauge (pressure gauge). Also from that data only 3 years of refined raw data were collected for processing. This raw sea level data must be refined again for wind wave errors.

ii. For the Data collection only, the pressure gauge sensor data were taken as recommended by the National Aquatic Resources Research and Development Agency (NARA) staff.

iii. Full physical understanding of the Ocean is lacking.

iv. For the processing part need high powered computers which are networked since lots of data are involved in the process.

II. LITERATURE REVIEW

A. Sea Level Change:

Sea level changes anytime over the sea are a composite of a Global Mean Sea Level change and regional procedures. Generally ocean level speaks to the mean height of the ocean sea surface as estimated either as for Earth's centre point of mass (absolute sea level) or, then again, with respect to the crust or ocean bottom (relative sea level). Figure 1 describes the above schematically. Procedures prompting changes in sea level are connected on the global scale to changes in the aggregate mass (freshwater content) as well as volume (warm content) of the seas, but at the same time it is related with geometric distortions of the ocean bottom. On regional scales, sea level can be influenced by changes in the Atmosphere and Oceanic circulation (from this point forward referred to as powerful changes) and by solid Earth processes, i.e., huge scale deformations of ocean basins and varieties in Earth's gravity field in addition to nearby ground movement impacts (henceforth referred to as static changes). (Stammer et al., 2013).

B. Current Rate of Sea Level Rise:

The time mean rate of Global Mean Sea Level rise during the 21st century is very likely to exceed the rate of 2.0 [1.7 to 2.3] mm yr–1 observed during 1971–2010 (Boretti, 2011, 2012b, 2012a, 2012c, 2013a, 2013b. 2013c; Boretti and Watson, 2012; Parker, 2013a, 2013b, 2013c). It is very likely that the mean rate of global averaged sea level rise was 1.7 [1.5 to 1.9] mm/yr between 1901 and 2010 and 3.2 [2.8 to 3.6] mm/yr between 1993 and 2010 (IPCC, 2014).

C. Empirical Mode Decomposition(EMD):

It is a method of breaking down a signal while staying within the given time domain. This method is useful for analysing most often non-linear and no-stationary natural signals such as sea level. EMD filters out functions which form a whole and almost orthogonal basis for the authentic signal. Completeness is primarily based at the method of the EMD; the manner it is decomposed implies completeness. The functions, referred as Intrinsic Mode features (IMFs), are therefore enough to describe

the signal, even though they may be now not necessarily orthogonal. The way that the functions into which a signal is decomposed are all in the time-domain and of the same length from the first signal considers differing frequencies in time to be protected. (Lambert et al., 2018).

III. METHODOLOGY AND EXPERIMENTAL DESIGN

A. Algorithm or the Model:

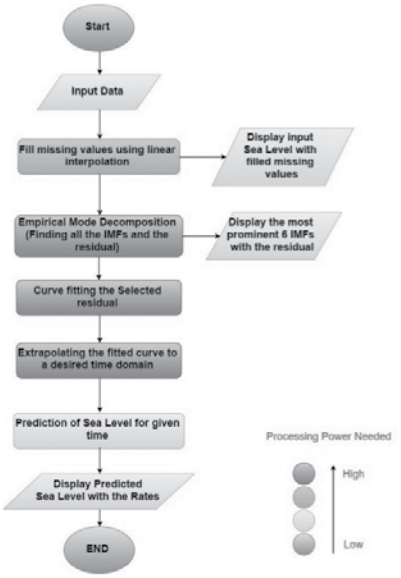

Figure 1. Process that influence Regional Sea level

B. Input Data:

12 years of data were selected from the IOC Sea Level Monitoring facility website from 2006-2017. But from those 12 years, 3 years of data were selected since they were collected continuously without corruption. Collected data were saved as Data Sheets in a .xlsx format book and named as "sea-level.xlsx". while collecting missing data entries at the start and end of sheets were removed. This "sea-level.xlsx" file was set as the input data file for the Model or the program created.

C.Filling the Missing values:

There were missing values inside the Data Sheets. Those entries should be filled for continuous arrangement of data. Linear interpolation was adapted for filling the existing gaps. There the missing values and the 0 valued entries were converted to NaN (Not a Number) values. After that those values were called and filled with linear interpolation. Significant amount of processing power is needed for this process.

D. Displaying the Input Sea Level with filled missing values:

Then a graph will be shown to examine the continuousness of the sea level data with time as the x axis and the sea level as the y axis.

E.Empirical Mode Decomposition (Finding all the IMFs and residual):

1) The EMD will decompose a frequency distribution or a signal into its segment IMFs.

2) An IMF is a function that:
   i. has just a one extreme between zero intersections, and
   ii.has a mean value of zero.

3) The filtering Process

The filtering process is the thing that EMD uses to fragment the signal into IMFs.

For a signal X(t), let m1 be the mean of its upper and lower envelopes as decided from a cubic-spline interpolation of local maxima and minima. The locality is controlled by an arbitrary parameter; the processing time and the viability of the EMD depends extraordinarily on such a parameter.

i. The first segment h1 is processed:

$$h_1 = X(t) - m_1$$

ii. In the second filtering process, h1 is dealt with the data, and m11 is the mean of h1's upper and lower envelopes:

$$h_{11} = h_1 - m_{11}$$

iii. This filtering system is repeated k times, until the point when h1k is an IMF, that is:

$$h_{1(k-1)} - m_{1k} = h_{1k}$$

iv. Then it is assigned as c1=h1k, the main IMF part from the data, which contains the most limited time frame segment of the signal. We isolate it from whatever is left of the information: X(t)- $c_1 = r_1$The strategy is repeated on rj: r_1-$c_2 = r_2$, ... ,rn-$_1$ - cn = rn

v. The result is an arrangement of functions; the quantity of functions in the set relies upon the original signal.

4) Following image shows the IMFs and the residual that resulted from the EMD processing of Sea Level Data.

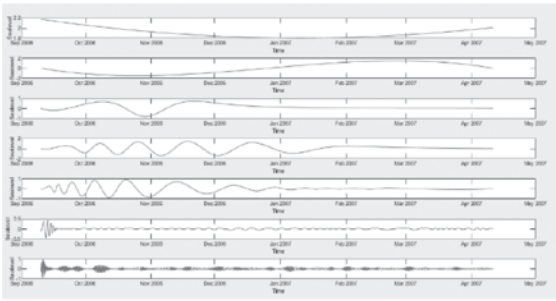

Figure 4 : Example for IMFs and the residual

Each IMF shows different segments or components of the signal, giving an excellent breakdown or decomposition of the original signal. The residual can be identified as the trend of the signal. Very High amount of processing power is needed for this process.

F. Curve fitting the selected residual:

The residual or the last IMF is selected from the group of IMFs created by the EMD process of the model. Then fitting the residual curve with 95% confidence level. The curve fitting is done according to a higher desired polynomial degree (3 or 4 depends on the existing residual curve). Significant amount of processing power is needed for this process.

G. Extrapolating the fitted curve to a desired time-domain:

The fitted curve is used for the extrapolation of the residual or the trend of the past Sea level to a desired time domain with 95% confidence interval. Significant amount of processing power is needed for this process.

H. Prediction of Sea level for a given time:

By analysing the extrapolated data of the residual, we can get the di sea level rising rate can be calculated.

I.Displaying the predicted Sea level with the rate:

The predicted or extrapolated sea level and the sea level rising rate will be displayed.

IV. DATA COLLECTION

Tide gauge data from the Colombo Tide station was collected from following source :IndianOceanSea-LevelMonitoringfacility<http://www.ioc-sealevelmonitoring.org/station.php?code=colo>.From 2006/09/10 to 2010/02/27; about 3 years of data were selected for the processing part. The following diagram shows the schematic of the pressure gauge established at the Colombo station.

Pressure tide gauges measure the water pressure over the sensor. Regardless of whether pneumatic, strain gauges or quartz crystals, they don't require a stilling well. They should be immersed sufficiently so they stay submerged during equinox low tides. Set on the seabed, they measure the ambient pressure, which reflects the height of the water column and the atmospheric pressure at the surface. It is valuable to know atmospheric pressure and the water density to decide water depths.

Let's consider the pressure sensor located and set on the seabed.

i. H : depth of the measurement location (average immersion of the sensor)
ii. h (t) : the change in sea level, a function of time t and the zero mean h(t) = 0
iii. p (t) : the pressure measured by the sensor
iv. pa (t) : the atmospheric pressure at sea level,
vi. ρ : the average density of the sea water (a function of temperature, salinity, the effect of the pressure being neglected for immersions less than a few hundred meters) on the height H h (t),
vii. G: the acceleration of gravity

The pressure given by the sensor is equal to the sum of the atmospheric pressure and the hydrostatic pressure,

$$p(t) = p_a(t) + \bar{\rho}g[H + h(t)]$$

The height of water above the bottom sensor is:

$$H + h(t) = \frac{[p_a(t) - p(t)]}{\bar{\rho}g}$$

p(t) - pa (t) is measured directly by some systems, this differential pressure equal to the hydrostatic pressure of the water column. But this means that atmospheric pressure measurement must be available at the differential sensor through an air intake, which is not feasible when the unit is submerged far from the shore. Moreover, in some applications, especially in the field of physical oceanography, the pressure p(t) is the useful information. Thus, to determine changes in sea level h(t) at sea based on pressure on the seabed p(t) three variables must be known:

i. g
ii. pa (t)
iii. (ρ)

About the acceleration of gravity g, it varies with latitude L according to the formula (in m/s^2)

$g = 9.7803185 (1 + 0.005302357 \sin^2 L – 0.0000059 \sin^2 2L)$ m/s^2

V. DATA ANALYSIS

1) For the data analysis from the 3 years of continuous dataset 8 months of sample sea level data were selected to do the analysis.

2) The selected data were subjected to fill missing values process. There the linear interpolation is used to interpolate the missing values.

3) Then the fully continuous data set is subjected to Empirical Mode Decomposition method so that it can simplify the complex signal until it gives the valuable residual or the trend.

4) This Trend is subjected to curve fitting by using polynomial interpolation technique.

5) Then the prediction is done from 2007-04-11 to 2008-04-11.

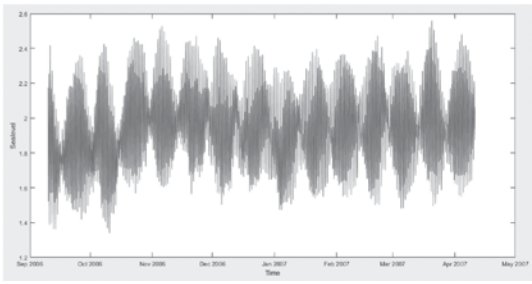

Figure 8. 8 months of Sea Level data with filled missing values

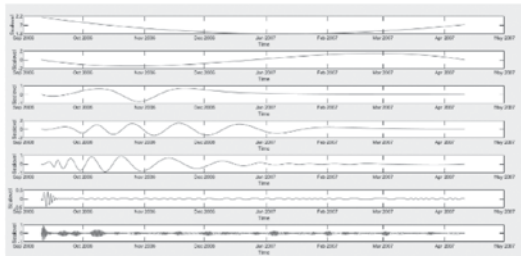

Figure 5 : Example for IMFs and the residual

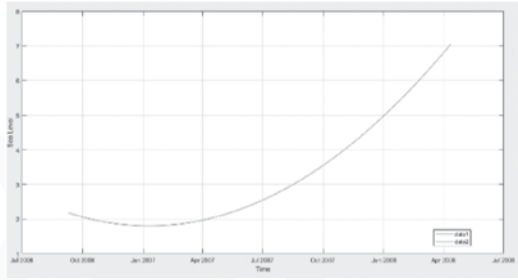

Figure 6: Predicted Sea Level data(Data 2), Collected data(Data1)

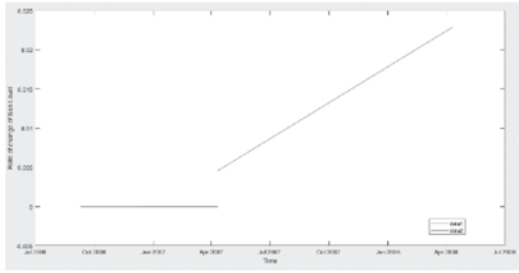

Figure 7: Predicted Sea Level Rate (Data 2), Collected Sea level Rate(Data1)

By taking the differentiation of the resulting residual values the rate of change of Sea Level vs Time was calculated.

VI. RESULTS

If the environmental conditions (such as Sea surface temperature, Salinity, Global warming) were continued as of 2007-04-10 to 2008-04-11 the following result can be gain.

Table 1: Result Comparison

No.	Property	Result	
1.	Date	2007-04-10 2359h (current data)	2008-4-11 0000h (predicted data)
2.	Sea level	2.010 m	7.0337 m
3.	Rate of Change of Sea level	3.48864e-06m year-1	0.02287 m year-1
4.	Rate of change of change of Sea level	1.4610e-11m year-2	2.505e-05m year-2

Here the accuracy of the results increases with the Increase of the Volume of data collected.

VII. DISCUSSION

1) Limitations:

i Need Higher computer power or parallel computing techniques to provide a reliable result.
ii. Require higher data volume to provide a reliable result.

2)Applications:

Can be used for predicting much larger Sea level data sets to predict sea levels for over 100 with the prevalence of current environment conditions.

VIII. CONCLUSION

Even the prediction results are unreliable with low data volume, it is closer to the current predicted rate of sea level rise by Intergovernmental Panel on Climate Change. It is [2.8 to 3.6] mm/yr between 1993 and 2010 (IPCC, 2014). Prediction result of this research gives 2.287 cm/year rate of change of sea level. This rate of change sea level also changing with the time showing that the sea level rise has been accelerated.

In the near future there will be results such as

i. exacerbated inundation and flooding of low-lying coastal areas
ii. increased coastal erosion
iii. effects on coastal ecosystems such as salt marsh, mangroves and coral reefs
iv. salt water intrusion into estuaries and aquifers
v. changes in sediment deposition along river channels

What can the present government do to protect the Colombo coastal area from above future scenarios.

i.Armor shoreline with seawalls and dykes
ii.Elevate Construction site Finished Floor level near to shoreline
iii.Elevate Buildings and Structures near to the shoreline
iv.Allow selective incursions to protect key areas
v.Add sand and plant mangroves in a gradual retreat
vi.Manage relocation

Acknowledgement

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VOLUME ESTIMATION FOR HIGHWAY CURVES USING END-AREA RULE

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Abstract - The volume calculation of road sub surface materials in highways is important in project cost estimation prior to the construction, and in investigations after the construction. Usually it is done with the linear measurements and a level line as the field measurements, and the end-area-rule is the most widely used equation in the calculation. This theory provides the volume between two consecutive sections which should be parallel to each other. Curve shape is often neglected in most of the construction projects due to the difficulty of conducting an advanced control network survey. Therefore, calculated material volume of a road bend might drastically deviate from the original material volume. This study was carried out to develop a physical model to determine the volume between two cross sections which are not parallel. Initially the scope of the study was limited to a circular curve with uniform variation of cross section. The volumes between two cross sections for different angles were measured using the mathematical and physical models in order find the correlation between them. It was found that the end-area-rule is valid for circular curves and the developed physical model provides an acceptable estimation of volume. The outcome of the research would assist construction professionals to identify the error of the previously used method and to overcome the predicament.

Keywords: Circular curves, volume calculation, end-area-rule

I. INTRODUCTION

The road construction projects become very important development activity for a country as it is directly related to the economy through factors such as transport, tourism and security. Volume calculation of road sub surface materials is the most complex event in the cost estimation as it is varying according to the terrain. This volume estimation is required to estimate the cost of the total project at the planning stage and also used in investigations on factors such as material usage and workmanship conducted after the construction.

Calculating the volume with cross sections is the most widely used and the most convenient method used in the analysis since it can be conducted with linear measurements and a level line run through the centre line and along cross sections which are perpendicular to the road centre line. The cross sections are usually generated from these measurements and the sectional areas measured from these sections are used to calculate the volume. The equation called end-area-rule is usually used to calculate the volume between two such cross sections which are at a known distance apart. This theory has been derived for two parallel sections with a linear variation of sectional area over the distance between them. Even though the rule is valid under these conditions, it is widely used for skewed sections in volume calculation of road materials. This negligence of parallelism of sections occurs due to the curves in highways leads to errors in the volume calculation. The angle between the sections can not be measured with linear measurements and it can be determined by conducting an advanced control survey.

This study was conducted to analyse the effect of skew angle between the cross sections on the volume calculation when end area rule is used for such situation. The actual area calculated using a mathematical model using integration for curve with defined shape. A physical model was developed to measure the volume for sections with varying angles of cross sections. The result was correlated to determine the relationship between these models and also used to determine the modification for the end area rule to be applied when it is used for curved highways.

II. LITERATURE REVIEW

The material volume is one of the most important objectives in horizontal optimization, so most researches firstly focused on the measuring material volume to control the cost. End area rule is the most commonly used technique in volume calculation for road construction projects. It is used to find the volume between two parallel sections assuming the sections vary linearly. The volume is estimated by multiplying the average area by the distance between the sections.

There are various researches have been done regarding the volume estimation. As stated by Easa (1992), existing method of average volume is only an approximation and it is only applicable for level terrains. An exact method is not available for fluctuating profiles as the end area rule assumes a linear variation. The model introduced by Easa was based on triple integration, assuming that the ground cross slope is constant between stations. The application results indicate that the volume of the average-volume method is deviating greatly from the exact volume and that the mathematical model is also reasonably accurate when the grounds cross slope changes moderately.

According to Easa (2003), the traditional model for estimating earthwork volumes of curved roadways (flat horizontal curves) is suitable only for level terrains. For moderately fluctuating terrains, a mathematical model has been developed. This model, however, assumes that the longitudinal ground profile between successive stations is linear and the ground cross slope is constant. The mathematical model is not accurate for greatly fluctuating profiles, such as those in hilly and mountainous terrains.
Cheng (2005) conducted a study to solve the inaccuracy problem caused by average end-area method and prismoidal method used for the calculation of roadway earthwork volume. Further it was presented in a complete 3-dimensional algorithm of roadway earthwork volume as well as its executable computer program. The algorithm benefits from the re-triangulation technique of constrained Delaunay triangulation (CDT), which can yield a true volume value theoretically.

Cheng and Jiang (2013) reconfirmed the feasibility of average-end-area method for earthwork volume and the analysis of difference of accuracy between 3D method and average-end-area method. It shows that the critical value of interval distance between two consecutive cross sections is 30m for average-end-area method. It is also concluded that the 3D method could be easily used in practice with the CAD software. Meanwhile, average-end-area method with less than the critical interval distance between two consecutive cross sections can guarantee the earthwork calculation accuracy.

Hu (et. al., 2015) proposed that assessment of slope excavation can be performed with laser scanned data together with the quality control indices such as average gradient, slope toe elevation, over break and under break, cross-sectional quality assessment and holistic quality assessment methods. An algorithm was also presented to calculate the excavated volume with laser-scanned data. It is also stated that time consumption can also be deducted from 70% by using laser scanning technology for excavation quality assessment than traditional method. Khalil (2015) stated that the average end area method is tedious and time consuming. Volume of terrains that do not have regular geometric structure can be obtained more accurately by using 3D models of surfaces with respect to developing technology such as GIS. The gridding method and point distribution are important factors in modelling earth surfaces used for volume estimation. The results show that for gentle slope surface, Triangular Irregular Network (TIN) and all interpolation techniques gave results very close to the exact except Kriging and Trend interpolation. Kriging interpolation gave the best results for steep slope terrain.

The above studies demonstrate that the end area rule can be use for the volume estimation together with proper adjustments in order to achieve higher accuracy for curved roads.

III. METHODOLOGY

C. Mathematical Model

Initially a circular curve was selected in order to develop the physical model and compare the volume measured by different methods. A circular section of radius R with uniform width was considered as in Figure 1 and the variation of thicknesses were selected such that they vary linearly along the outer and inner edges. This factor assured the major assumption of end area rule that is the variation of sectional areas to be linear. Then a small section at α angle with small dα was considered as per the figure. The heights of corners were calculated by interpolation and the linear integration was used to calculate the volume of the section mathematically.

Following notations were used in the mathematical model.

R	-	Radius of the curve
W	-	Width of the section
θ	-	Angle of the curve
α	-	distance to the considered small section
dα	-	small angle
hi	-	corner height of the section
h'	-	height of the small section at outer edge
h"	-	height of the small section at inner edge

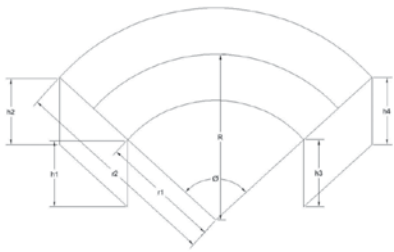

Figure 1. The mathematical model

The heights h' and h" calculated using linear interpolation considering the linear variation along the edges.

$$h' = h_1 + \left(\frac{h_4 - h_1}{\theta}\right)\alpha$$

$$h'' = h_2 + \left(\frac{h_3 - h_2}{\theta}\right)\alpha$$

The volume calculated by integration = ∫dv

$$= \int_0^\theta \left(\frac{h' + h''}{2}\right) WR.d\alpha$$

$$= \int_0^\theta \left[\frac{h_1 + \left(\frac{h_4 - h_1}{\theta}\right)\alpha + h_2 + \left(\frac{h_3 - h_2}{\theta}\right)\alpha}{2}\right] wR.d\alpha$$

$$= \int_0^\theta [\left(\frac{h_1 + h_2}{2}\right) WR + \frac{\alpha}{\theta}(h_4 - h_1 + h_3 - h_2)]WR.d\alpha$$

$$= \left(\frac{h_1 + h_2}{2}\right) WR \int_0^\theta d\alpha + \frac{WR}{2}\int_0^\theta (h_4 - h_1 + h_3 - h_2)\alpha.d\alpha$$

$$= \left(\frac{h_1 + h_2}{2}\right) WR\theta + \frac{WR}{2\theta}(h_4 - h_1 + h_3 - h_2)\left[\frac{\theta^2}{2}\right]$$

$$= \frac{WR\theta}{2}\left[h_1 + h_2 + \left(\frac{h_4 - h_1 + h_3 - h_2}{2}\right)\right]$$

$$= \frac{WR\theta}{4}[h_4 + h_1 + h_3 + h_2]$$

$$= \frac{h_1 WR\theta}{4} + \frac{h_2 WR\theta}{4} + \frac{h_3 WR\theta}{4} + \frac{h_4 WR\theta}{4}$$

$$= \left(\frac{h_1 + h_2}{2}\right)\frac{WR\theta}{2} + \left(\frac{h_3 + h_4}{2}\right)\frac{WR\theta}{2}$$

Since; $A_1 = \left(\frac{h_1 + h_2}{2}\right)W$ & $A_2 = \left(\frac{h_3 + h_4}{2}\right)W$

$$= \left(\frac{A_1 + A_2}{2}\right)R\theta$$

= Average area x Distance between the sections

D. Physical Model

The physical model is developed by carving a circular groove with constant width and a thickness varying linearly along each edge. The radial lines at various angles were marked and a stop board was used to limit the volume at different angles. The height of the groove at each radial line was measured and ensured that they vary linearly. The space was filled by sand sieved from number 200 sieve with a fluviation height less than 1 cm and the this volume of sand is measured with a measuring cylinder. This procedure was repeated for different angles by changing the stop board.

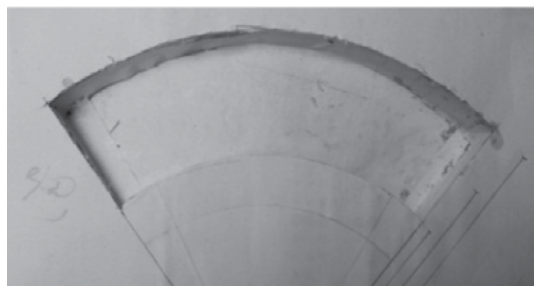

Figure 2. The physical model

E.Correlation of Volumes

A calibration was needed for the physical model in order to calculate the actual volume from the sand volume used to fill the space. Cubical grooves with known dimensions were carved in the same base as the physical model and those spaces were filled with the sand in the same procedure. These volumes were measured with the measuring cylinder and they were compared with corresponding actual volumes calculated by dimensions to find the correlation between the actual volume and the sand volume.

IV. RESULTS

F. Correlation of Volumes

The sand volumes of cubical grooves and the volumes calculated by dimensions were given in Table 1.

Table 1. Sand volumes in calibration

Dimensions /cm	Volume (cm3)	Sand volume/ ml
3.5 x 3.5 x 2.5	30.625	34.0
3.5 x 3.5 x 3.5	42.875	48.0
3.5 x 3.5 x 4.5	55.125	62.0
2.5 x 2.5 x2.5	15.625	17.5
2.5 x 2.5 x 3.5	21.875	24.5
2.5 x 2.5 x 4.5	28.125	31.0

As per the Figure 3 it is found that the variation of sand volume and the actual volume is linear and the correlation factor is 0.893 where sand volume is taken in millilitres while actual volume is in cubic centimetres.

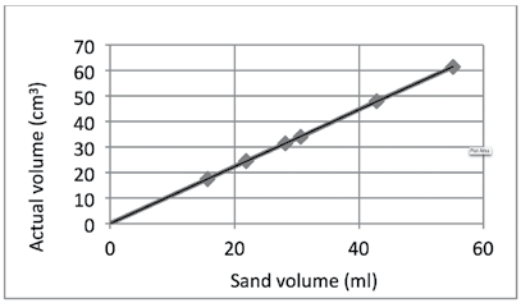

Figure 3. The variation of sand volume with actual volume

G. Volume Measurements

The measurements obtained to calculate the volumes for physical model and the mathematical model are given in Table 2. The skew angle was controlled by stop board and the sand volume was measured to obtain the volume of physical model and heights of corners were measured for the volume of mathematical model. The initial corner heights (h1 and h2) were 2.2 cm and 1.2 cm and the radius and width were 20 cm and 10 cm respectively.

Table 2. Measurements for volume calculation

Skew Angle	Corner heights (mm)	Sand volume/ ml
00o	2.2, 1.2	-
15o	2.6, 1.8	142.0
30o	2.9, 2.4	318.0
45o	3.3, 3.0	533.0
60o	3.6, 3.6	775.0
75o	4.0, 4.2	1065.0

The calculated volumes for both physical and mathematical models are given in the Table 3 and their variations were illustrated in Figure 4.

Table 3. Calculated volumes for different methods

Skew Angle	Calculated Volume / (cm3)	
	Physical Model	Mathematical Model
15o	127.63	126.81
30o	284.71	283.97
45o	476.15	475.97
60o	693.79	692.08
75o	949.02	951.05

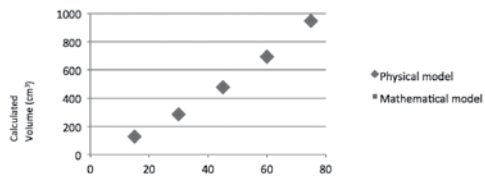

Figure 4. The variation of calculated volumes

V.CONCLUSION & DISCUSSION

The study confirmed that the end area rule can be directly applied to circular curves neglecting the criterion that the sectional areas should be parallel. The physical model developed by this study can be used to estimate the volume between two cross sections by considering the end area rule. It is recommended to extend this research towards a curve with non circular profile.

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COMPARATIVE STUDY ON METHODS FOR 3D MODELLING WITH TRADITIONAL SURVEYING TECHNIQUE AND TOTAL STATION TECHNIQUE

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Abstract - Three-dimensional modelling of the natural surface of the Earth is very important in understanding the irregularities of the Earth surface. It is a vital tool in planning large development projects such as designing of high ways, airports, hydropower plants, reservoirs; building sites etc. Two technical approaches are being used for the above task in conventional land surveying. The first step is to carry out horizontal surveying and producing a survey plan which depicts the horizontal projection of the area of interest. The second step is to carry out levelling in order to obtain heights with reference to datum over evenly spread grid points covering the required area. With the introduction of Electro-Magnetic Distance Measurements, a new equipment known as total station is available for land surveyors to capture three dimensional coordinates of points on the ground. This new technology is comparatively much faster than the conventional two-fold technique of collection of horizontal coordinates through surveying and obtaining heights through levelling. This research paper evaluates accuracies of conventional surveying and levelling methodology and the modern Electro-Magnetic Distance Measurements. It also compares the precision of the output of the conventional surveying contour plan and the digital terrain model empirically and statistically in order to evaluate pros and cons of conventional and modern surveying techniques. For this evaluation, a total station and an automatic level was used to survey the study area, employing both methods and analysing data from each method empirically, statistically and comparing the outcome of aforesaid methods. After the analyses of data it was revealed that both techniques are comparatively equal in precision but the total station is far more efficient than the conventional surveying and levelling method. The final outcome of the study is that the total station is more suitable for an engineering survey done for general purposes.

Keywords: Digital Terrain Model, Evaluation of accuracy of contour plans, Three-dimensional modelling

I. INTRODUCTION

This research paper assesses conventional and modern method of data collection required for three-dimensional modelling of the surface of the planet earth. It is useful in finding out the lay out of the terrain which is an essential prerequisite for large scale construction works and large-scale development projects such as air ports, sea ports, high ways, and lot more other types of construction projects. This methodology of three-dimensional modelling commonly known as engineering surveys carried out prior to any large-scale construction or development project. It is defined by the American Society of Civil Engineers (ASCE) "as those activities involved in the planning and execution of surveys for the development, design, construction, operation and maintenance of civil and other engineered projects" (The American Society of Civil Engineers (ASCE), 1987). Engineering survey is the point of beginning of any large construction project. If the engineering survey is delayed the whole project may get delayed or worse the whole project may get cancelled before the construction even starts. Therefore, it is important that the Engineering survey or the three-dimensional modelling of the terrain is done as fast as possible.

The traditional way of executing engineering survey is a twofold method. Those two methods are horizontal survey done using the theodolite traverse or the total-station traverse and then measuring the spot heights using running level lines using levelling instrument.

The conventional way of executing engineering survey is a twofold method. Those two methods are horizontal survey done using the theodolite traverse or the total-station traverse and then measuring the spot heights using running level lines using levelling instrument. The associated problem with this method is that it takes long time to complete. This type of survey is associated with blunders and systematic errors such as booking errors and computational errors. But with the introduction of the GNSS (Global Navigation Satellite System) and the modern total-station it is possible to observe three dimensional coordinates of the points in one step. This research paper discusses the usability of the modern total station as a tool of collecting three dimensional coordinates of the points on the earth surface by using the in-built method called TOPO which is available in most of the modern total stations. Horizontal coordinates obtained through modern total stations are very accurate of and widely used by land surveyors. But surveyors are somewhat reluctant to use total station to collect heights. This research assesses the height accuracy of the total station and the automatic level. It evaluates the possibility of using total station as a tool for collecting coordinates of points for three-dimensional modelling.

II. EXPERIMENTAL DESIGN

The experiment was design in way that both total station and the level instrument are being used to measure the same land plot to collect data on same points in the same day to minimize the effect of the other external factors such as temperature, humidity weather and time.

III. METHODOLOGY

In order to compere the height accuracy an automatic level and a total station was selected. The sokkia CX-101 Total Station and the sokkia B-30 Automatic levelling instrument was selected to carry out the data collection. All instruments and accessories used are shown in the following table.

Table 1. The Equipment Used in Field Work

No	Equipment	Amount	Type
1	Total Station with accessories	1	Sokkia CX-101
2	Prism Poles with prism	1	Sokkia
3	Automatic Level	1	Sokkia B30
4	Levelling Staves	2	~
5	Foot Plates	2	~
6	Tri Pod (Wooden)	1	~
7	Tri Pods (Aluminium)	1	~
8	50M Steel Tapes	2	~
9	Gig Umbrella	1	~
10	Hammer	1	~

IV. PRACTICAL PROCEDURE

A plot of land with moderate slope was selected. The approximate size of the selected area was about 2500 m2 with vertical height variation of about 6 m. A 40 m by 54 m rectangular grid on the land was set out using the total station and prism pole by marking the four corners of the gird. A 50 m steel tape is used to set out pickets in 10-meter interval on the ground and marked on the ground with help of a marker pen. A prospection diagram is prepared to show pickets and numbered those points consecutively from 1 to 90. The south west corner of the grid was assigned coordinates as 1000N, 1000E. Coordinates of all grid points were computed as the gird distance between points are known related to the south-east corner. A level line was running from each grid corner to the next grid corner and obtained heights of the pickets in between them. After words level lines were ran to obtain heights of all points marked on ground. Three-dimensional coordinates of all 90 points were computed and added to a table.

Then the total station was setup and carried out the temporary adjustment to eliminate systematic errors of the instrument. Afterwards three-dimensional coordinates of all marked points were obtained using the TOPO mode of the total station. Heights of all points were tabulated in new column of the same table to complete practical procedure.

V. RESULT

After collection of data two contour plans were created to depict the terrain model collected through each instrument. The contour plans were created with the same contour interval of 0.1 m because most of the general-purpose engineering surveys only required to output a contour in 0.5 m to 1.0 m contour intervals. If there is no visible difference between two maps at 0.1 m contour interval there is not going to be a difference 0.5 m or 1.0 m contour interval maps.

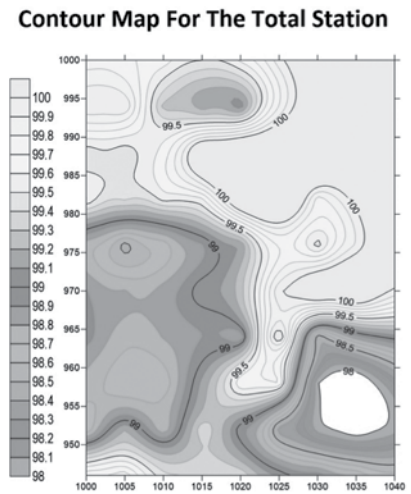


Figure 9. Contour Map for The Total Station

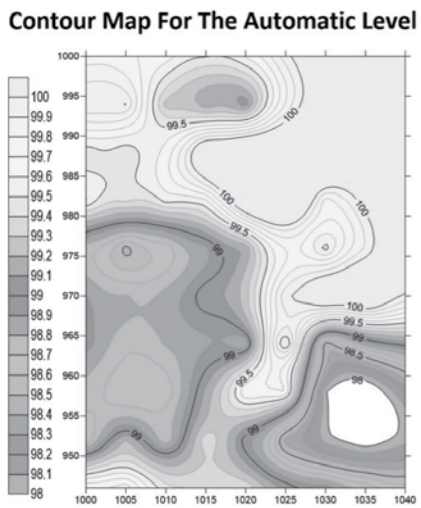


Figure 10. Contour Map for The Automatic Level

When comparing two contour plans there is not much difference between those two contour plans even at 0.1 m contour interval.

For further clarification two 3D models were created using same set of data.

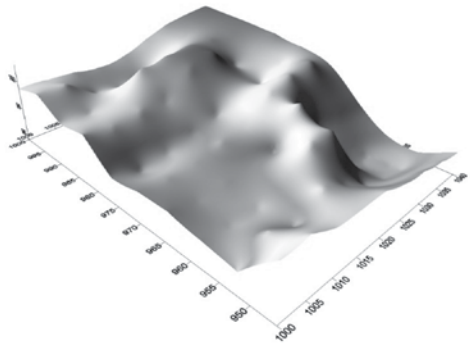


Figure 11. 3D model of the data collected by levelling instrument

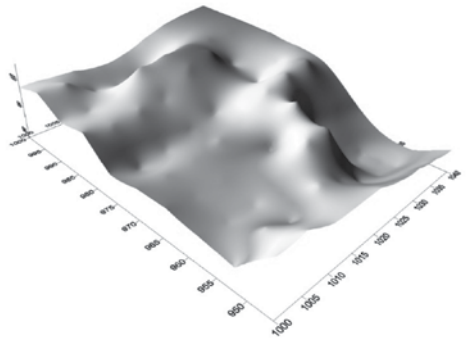
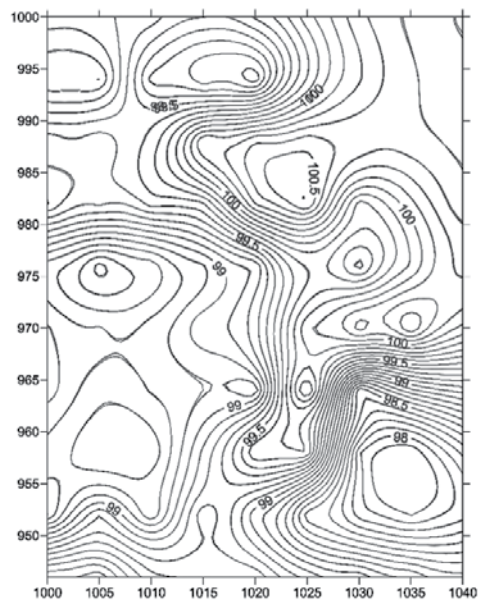


Figure 12. 3D model of the data collected by the Total Station

It is evident that the terrain is not depicted much differently in both 3D models so the quality of data collected from both instruments are nearly the same.



Blue-Total Station
Red - Automatic Level

Figure 13. Over lapped contour plans

VI. DISCUSSION

From this research, it was proved that the difference between two contour plans produced for the study area of 50 m by 50 m at contour intervals 1 m and 0.5 m does not have a significant difference. when overlapping contour plans the difference about each contour is about the 1 cm to 5 cm at maximum.

Reasons for above discrepancy as follows. When the total station is in operation the standard prism pole was used to collect height data. At the time of using the prism pole the pole should hold very steady and vertically so the height of the pole is the actual height of the target that entered to the total station. But when using the automatic level, the level staffs are mech easy to keep level and much more accurate. Disadvantage of automatic level is that reading is limited to maximum of 40 m. Level staff are impossible read at more than 40 m so at that situations level line to be ran in order to measure the height to a point that is far than 40 m. There for it is required a close circuit level line to be measured to ensure the accuracy of the heights obtained through level.

That is the reason why when running long level line, optimal distance between the level instrument and the level staff should near 30m. But for the total station there is no such short distance limit because it is possible bisect the prism from a distance at 500 m easily. But it is not possible to read about 500 m to get height using the total station because in the total station there is a drop of height accuracy of the total station with distance. It was tested and accuracy was found to be less than 1 cm in distance range between 0 to 50 m when using the prism pole to measure the height. But when the distance is ranged between 50 m to 100 m the height accuracy drop is about 1 cm to 3 cm. So, it is suitable measure heights when distance is up to 100 m. The total station measure heights much longer than the level instruments with adequate accuracy.

In using total station there are no booking errors and computational errors as recording of data and computation is carried out by the microprocessor of the instrument. This is an advantage of using total station as it minimises human blunders and errors in computing. So, simply the total station is much faster at collecting data and it is much efficient method of data collection.

VII. CONCLUSION

This research proves that the modern total station is an efficient tool in collecting three dimensional coordinates for three-dimensional modelling or an engineering surveying. But still the most accurate tool for getting height data is the level instrument. Typical engineering surveying the total station is the best instrument because the speed at which the data can be collected with the instrument is comparatively very high so the work can be completed very fast.

In any large-scale engineering or development project the first step is to complete engineering survey to generate a realistic over view of the terrain. Therefore, it is necessary to get work done faster as possible hence it was proved that the total station is the best instrument for any typical engineering survey with an average accuracy.

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AN ANALYSIS OF LAND USE SUITABILITY OF A SELECTED ZONE IN WATTALA LOCAL AREA PLAN

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Abstract - The Development Plan of an area is a main legal document that is prepared for development of that area, integrating Social, Economic, Physical and Environmental aspects with the views of stakeholders in addition to general public and Local Authority. Zoning is one of the tools used to control land use change on plots and it is defined based on existing potentials and possible impacts due to the rapid urbanization with the agglomeration of various economic activities which may take place in the area in future. This study area is confined to Handala Grama Niladhari Division which is identified as "Moderate Residential Zone" in Wattala Development Plan that encompasses Wattala Urban Council area which is still in draft level. Through this development plan, it is expected to create a sustainable development with the prime objective of uplifting the living standards of people living in the area by improving efficient environment for the residing people and preparation of strategies.

Aim of this study is to carry out suitability analysis of existing land uses in the selected area, to find out incompatible land uses and why it has taken place in an area within the development plan. Finally, this research analyses to what extent this Development Plan is effective for harnessing existing potentials and how far it can regulate the land use activities. This study reveals that 79% of the area is used for Residential or Commercial activities. 19 % of the area is consisted with water and marshy lands. 12.5% of the area has been neglected as barren or Waste lands. It is highlighted that development plan prepared for such a rapidly developing area is still being at draft level and is hindering the effectiveness of the enforcement of new planning regulation.

Keywords: Development Plan, Zoning, Land use, planning Regulation

I. INTRODUCTION

Sri Lanka is a developing country with annual increase in population at a highly considerable rate (Sampath Pathikada, 2012), especially in the urban areas. Systematic town planning could ideally be the deciding factor of what a town should be like before it is built to fulfil the needs of its people. While some local areas show the urban characteristics, some urban directly show the developing characteristics like rural characteristics. Therefore, we are not able to define a clear margin for rural areas and urban areas. The urban areas could be defined according to the following common factors.

- Administrative boundaries (Municipal Council, Urban Council)
- Declare areas under the Urban Development Authority (UDA)
- Population Density
- Land Use Pattern (Commercial, Industrial uses, primary residential and mixed residential)
- Available Infrastructure (Water, Electricity, Road, Sewerage…etc.

Based on the above control parameters or any other means, urban development is the improvement of existing facilities to achieve the maximum benefits to upgrade living standards of residents.

Analysing land use pattern is important to spatial planners. As a professional in surveying, who are engaging with land

sub divisions process and allied works like various maps preparing, understanding how \ land use changes become evident with the physical development and the fact that land use changes are the everlasting process that may lead to more and more land fragmentation are more important for efficiency of the planning process. Understanding planning requirements according to the national, regional and especially local area planning will be helpful to expedite cumbersome planning approval process and minimize gap between planning professionals and survey professionals.

For this study, Wattala UDA area in Gampaha district has been selected as a case study area. Due to the population distribution and agglomeration of economic activities of the area, there is a huge demand on lands for residential, industrial and commercial purposes. UDA is regulating existing development for minimizing those incompatible land uses while improving quality of life of the residents and efficiency of the environment. It is important to analyse the human impact on land use changes in an area since this phenomenon is happening in whole urban areas in the country, affecting locally, within immediate regions and ultimately to the whole country.

This research mainly analyses the gap between present possible land use changes taking place in the area and expected land use changes according to the "Development Plan" which is being implemented. Thus, an analysis is carried out to find to what extent this Development Plan is effective for harnessing existing potentials and how far to regulate the land use activities in the area. In Wattala UDA area there are 46 Grama Niladhari divisions which enforce different regulations according to the existing development plan, promoting compatible land use activities while discouraging and/or prohibiting incompatible land uses such as residential, commercial, industrial uses, primary residential, mixed development, tourism, industrial etc.

This research focuses on "one selected zone" in Wattala area, existing land uses in that area in consequence with the prevailing development. Then it analyses the present land use changes within the zone and the driving forces for the land use changes taken place within the selected zone. In order to analyse changes in land uses pattern, below factors will be studied as main driving factors of human activities.

01) Population Density
02) Existing Road Network
03) Main Industries
04) Institutions (Schools/Courts/Government Offices)
05) Geography
06) Infill Migration

According to the livelihood engaged, expected quality of the life and image of the city, people tend to select an area to build their own houses. People those who can't afford such a land, are settled within the urban fringe either marshy land or low laying areas only for accessing infrastructure facilities (Land use data, 2012). When this process happens continuously, area can be subjected to natural disasters like flash floods and sanitary issues that lead to health issues within the community who are living in those areas. Highly sensitive wetlands like Muturajawela which is situated close-proximity of the area will get affected by illegal constructions. This negative impact can affect the endangered species in those areas. As a result some native organisms face a threat of extinction. This situation will directly affect the Environmental Sustainability.

I. LITERATURE REVIEW

A. Applying Zoning Regulations Internationally

Zoning for sustainability- this research tells how communities comply with zoning regulations to achieve their goals in sustainable manner and how to understand zoning plan regulated by the development plan. The study approach is in four phases. In the first phase a sample of the zoning plan is selected to evaluate. In the second phase, items that may be present in a zoning plan are identified to implement sustainability principles. The third phase determines if the regulatory items identified are presented in our sample of zoning plan and measures the extent to which sustainability has been included in zoning. The final phase reviews selected regulatory items which are considered to be important and which appear only rarely in the zoning plan. (Zoning for Sustainability, 2014) "Effectiveness of the Development Control System for the city of Colombo, Sri Lanka" -In this research paper, researcher analyses the regulations that specify the standards related to lot sizes, width of the access, parking requirements, reservations for open space and building densities. They are divided into nine land use zones, such as, primary residential, mixed Residential, commercial, General industrial, special industrial, Public and Semi-public, parks, play grounds and open space and agricultural

and Deferred Zones. Researcher says if development control is to be effective the standards stipulated in the regulations must be in accordance with the social, economic and environmental context of the particular city concerned. (Effectiveness of the Development Control System for the City of Colombo, Sri Lanka, 1987)

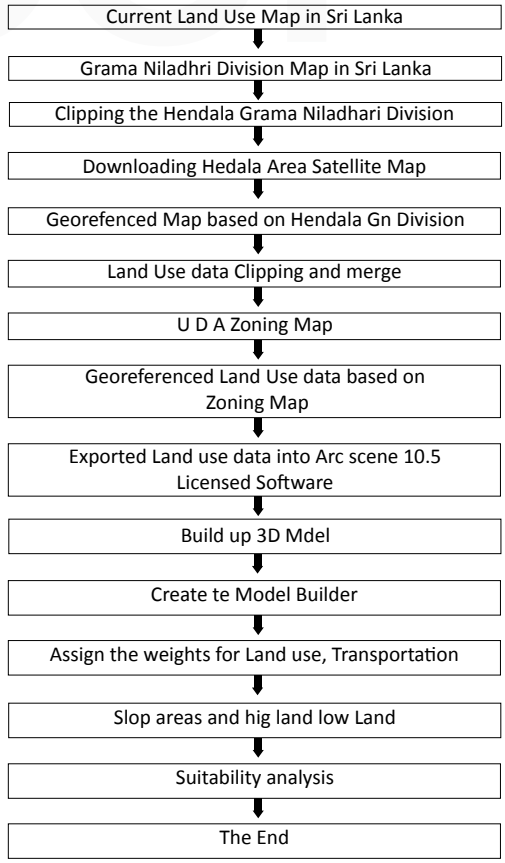
B. What are the good practices in Zoning?

Zoning and urban planning -In this research researcher declares the good planning practices in zoning. Many economies require the obtaining of a construction permit. This has been done to ensure the intended building located in the appropriate zone (industrial, commercial, residential) according to the city's zoning requirements. Some city authorities have completed the process efficiently and effectively by making zoning maps of cities accessible to builders, and then they can include the information in the building permit applications. In other economies the permits-issuing authority checks the zoning compliance after receiving the building permit applications. (Zoning and urban planning, 2015) and this research declares the sustainable principals, such as, encourage the higher density development, encourage mixed use, encourage local food production, protect ecosystem and natural functions, encourage transportation alternatives, preserve/ create a sense of place, increase housing diversity and affordability. (Zoning for Sustainability, 2014)

C. Identify land use changes

"Monitoring Land Use Change in Rural Sri Lanka from Sequential Aerial Photography" -Researcher uses number of methods to illustrate changing patterns of Urban Land Use. The researcher uses black and white panchromatic photography supplemented by Field checks. Preliminary air photointerpretation stereoscopic pairs of photographs were used to improve the accuracy of interpretation and assessment of agricultural land and water and resources. In 1956 air photos (scale 1: 40,000) and in 1982 air photos (Scale 1: 20,000) were used in this research. (monitoring land use change in rural Sri Lanka from sequential aerial photography, 1983) In "Spatial and Temporal Changes of the Green Cover of Colombo City in Sri Lanka from 1956 to 2010"- Satellite images were not available for research during the years from 1956 to 1982. Therefore, Aerial Photographs of 1: 20,000 scale were used during that period. High Resolution IKONS images (4m spatial resolution) were used from 2001 to 2010. They were georeferenced two IKONS images, and they were digitized by "on screen Digitizing" method using Arc GIS 9.3 software. The rate of green cover change was estimated by calculating the green cover change during each period and then dividing it by number of years consisted in that particular period. (Spatial and Temporal Changes of the Green Cover of Colombo City in Sri Lanka from 1956 to 2010, 2016) "Detection of Land Use Changes through GIS Functionality a Case Study in Randenigala and Kotmale Sub catchments" - Research used workstation Arc/Info version 7.12 as the GIS software. In addition, TIN module and Grid module of Arc/Info software were used to delineate catchment boundaries, and used map generalized procedure. However, it is not realistic due to the errors uncontended in process and time taken for such a process which was very high. In research digital land use map of 1956 and land use map of 1992 were reclassified into a unified legend. (Detection of Land Use Changes Through GIS Functionality: A Case Study in Randenigala and Kotmale Sub catchments, 2000)

II. METHODOLOGY FLOW



III. DATA COLLECTION

A. Primary data collection

The primary data collection was done by the questionnaires as well as by personal observations and interviewing the Executive persons, and the Data was generated by one Divisional Secretariat in Wattala. In this area there are 46 Grama Niladhari Divisions. Data was collected from those sample households through referring to past 10 years Documents.

B. Secondary data collection

The secondary Data was collected from the published and unpublished sources in Urban Development Authority and Survey Department. Published Sources are available at the Survey Department. Land use information and the zoning regulations related to the Hendala area ware obtained by Urban Development Authority, District office, Gampaha. Unpublished information is in the Wattala Zoning Map.

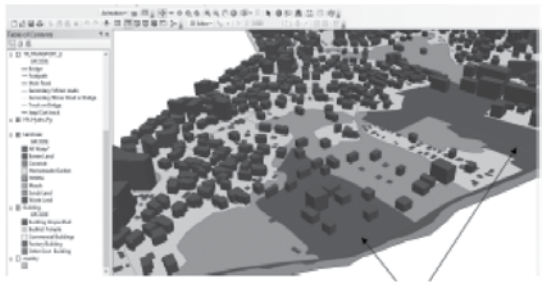
IV. DATA ANALYSING

Data analysis was done using the GIS 10.5 Licensed Software. Current land use map prepared by Survey Department, few satellite images taken in past 10 years of the Area and shape file of Hendala Grama Niladhari Division were used for analysis. Using clip function, the GN Division Map was extracted. Thereafter satellite Maps were Georeferenced based on the said Hendala GN Division Map. Land use Data were merged and clipped based on the GN Division Map. Zoning map prepared by UDA was used for georeferenced land use data and past satellite maps were georeferenced based on the Zoning map in the Area. It enables to identify what zoning regulations apply to this area (moderate Density Residential Zone).

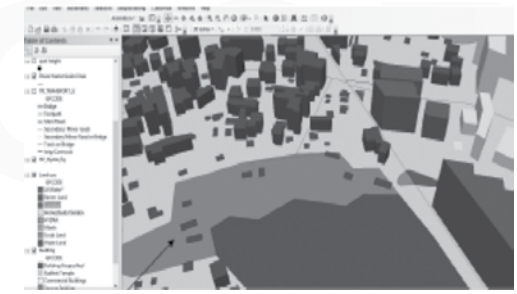
V. RESULT AND DISCUSSION

All the details are exported to the Arc Scene 10.5 and formed 3D model. The possible changes in area, present land use changes taking place in the area and expected land use changes according to the development plan can be identified through this analysis. Finally Suitability analysis was done using ArcGIS Licensed software. Possible changes of land use area.

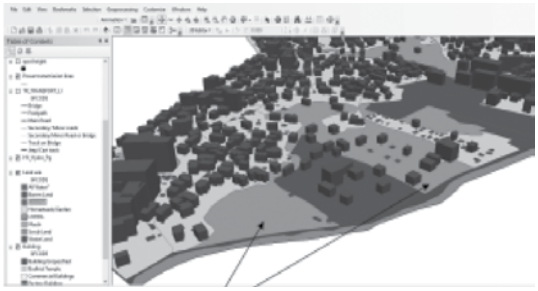
Barren land



Scrub land

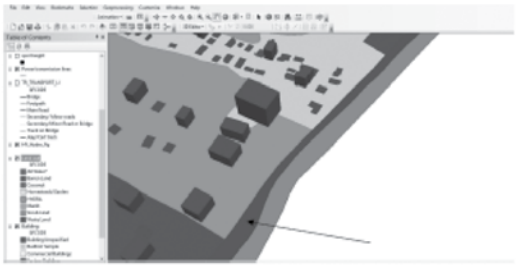


Marshy Land

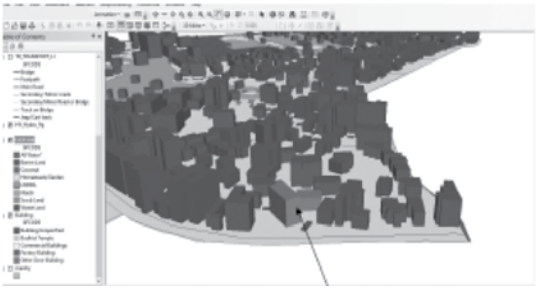


Garden Area

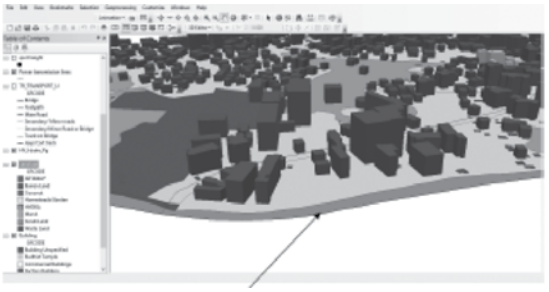
Waste Land



Other Government Buildings

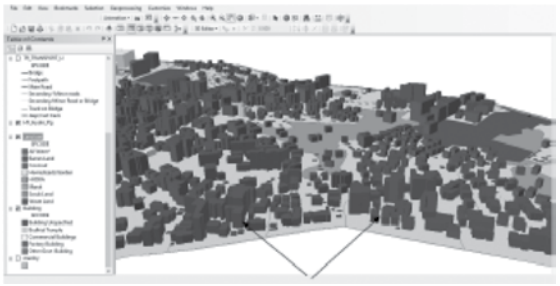


Water Areas

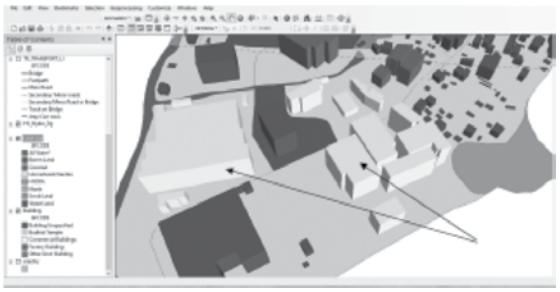


Model Builder

Commercial Buildings



Factory Building



Weighted allocated for suitability analysis

Raster	Influence	field	Scalevalue
Transport	40%	0 - 50m	7
		50 -100m	9
		100 - 200m	5
		200 - 555m	3
Slope	10%	0.001106- 1m	8
		2 - 8.75846m	8
Land use	40%	HOMSA	7
		All Water	1
		Marsh Land	Restricted
		Barren Land	8
		Hydro Area	Restricted
		Waste Land	3
		Coconut Land	3
		Scrub Land	6

Suitability for Slope Area

Suitability for Transport

Suitability of Topography

Suitability analysis for Hendala Area

In this division have many kind of land uses, such as, garden areas, all water areas, marshy land, barren land, waste land, coconut land and scrub land.

Garden area – 79.0960%
All water area- 9.6011%
Marshy land- 9.6011%
Barren Land-7.8739%
Waste Land- 0.33745%
Coconut land- 0.0218%
Scrub land- 0.8053%
hydra – 1.727%

VI. CONCLUSION

When considering the suitability analysis, we can review this zone how to regulate so far. This zone is allocated for 'Moderate density residential zone'. Hendala Grama Niladharie division is in this zone. This division has many kind of land uses, such as, garden areas, all water areas, marshy land, barren land, waste land, coconut land and scrub land.

In this situation we can identify how to regulate the zoning plan in the area. Since the community participation is a major event of the planning process, suggestion and proposals of the people of the area have been considered by the planning team in the preparation of the development plan of Wattala city and development objectives have been decided as follows.

Improve the Efficiency of the city

- Establishment of a systematic vehicle management System.
- Separation of mismatching usages of one another through zoning
- Improving the efficiency of Roads
- Improving the junctions of cities
  Creating a suitable living environment for the residing people
- Introduce the tube water system to the area.
- Establish infrastructure facilities necessary for the development of residencies
- Encourage developers for the development of houses
- Introduce a systematic waste management system
- Introduce a systematic sewer system
- Encourage fishery and tourism industries
- Establish basic post structural facilities for low-income people
- Introduce community development programs by the social development committees for the up liftmen of the social status of the people.
- Develop environmental facilities.

Preparation of strategies

The following strategies have been identified for the implementation of the development plan of the Wattala city systematically and efficiently.

- Implementation of zoning plan
- Implementation of planning and building regulations
- Implementation of identified active projects
- Strengthening the implementation process

According to the suitability analysis shown in the figure (36) 72.4063% can be used for residential area, 81.5070% area can be protected by natural disasters. Furthermore 12.24324% is not good for use residential purposes or any other construction purposes. Therefore these facts prove that the planners' selection of this area as 'Moderate Density residential areas' is correct decision.

Acknowledgement

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A REVIEW: PROBLEMS IN REFURBISHMENT PROJECTS

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Abstract - Globally, the existing buildings take a significant portion of total stock. Due to the cyclical nature, the performance of a building is getting retarded when it is exposed to usage. Thus, in order to prolong the life of a building, refurbishment has become a popular concept. New construction and refurbishment process has salient differences. Even though there are some problems common to both new construction and refurbishment, the impact is different in refurbishment projects such as; difficulty in achieving cost, time and quality targets. Suitable approaches should be adopted in managing refurbishment projects. Sometimes, the same approaches used in new construction may not be always suitable for managing refurbishment projects due to certain differences. Thus, prior to determining approaches, it is necessary to identify the problems associated with refurbishment projects. Therefore, this study aims to identify problems present in refurbishment projects considering the two main stages of procurement and construction.

To achieve the aim, a comprehensive literature review was conducted by accompanying books, journals, articles, conference proceedings and other reliable resources. The literature findings manifest that the most important problems associated with refurbishment projects are inaccurate and incomplete information during design stage, determining client needs, restricted access, and unavailability of space on project for storage of materials, potentially reduced security and increased risk to health and/or safety from construction.

Keywords: refurbishment projects,problems,procurement phase,construction phase

I. INTRODUCTION

According to Clough, G.Sears, and Sears (2000), the `nature of the construction industry is complex and heterogeneous. Subsequently, Hillebrandt (2000) stated that the construction industry has become a key sector of the economy of all countries. The term 'construction' canbe defined as all the activities whichrelated to physical infrastructure, civil engineering work, building work, maintenance and repair of existing works (Wells, 1984). Lawrence and Werna (2009) stated that equal extreme attention should be paid not only on new constructions; but also on the renovation and maintenance of existing structures. In addition, the authors stated that almost 50% of the total construction output is accounted for renovation and maintenance works where greater share of employment is also engaged than in new constructions. Thus, it is important to consider this refurbishment sector to develop the aggregate construction industry.

According to Mansfield (2002), the life of a building is in a cyclical nature with a sequence of discrete work parcels like maintenance, repair, replacement, refurbishment and redevelopment. Further, the author explained that, if it is unable to do regular maintenance of a property, it accelerates the decline in investment returns until refurbishment or redevelopments are implemented.

Wang (as cited in Arain, 2005) defined refurbishment as "a generic term including rehabilitations, modernization, renovations, alterations, improvements, additions, repairs, renewals, retrofitting: the term does not include domestic

maintenance work such as cleaning and emergency maintenance" (p.31). Even if, there is a wide range of constituents under refurbishment, it is difficult to identify the absolute boundaries of this physical process (Mansfield, 2002). Thus, the research identified the refurbishment as building work consists of any reconstruction, renovation, upgrading, restoration, renewal, conservation, rearrangement, alteration and conversion, expansion excluding new building or regular repair and maintenance works.

According to Ali, Kamaruzzaman, and Salleh (2009), once the existing buildings are getting old, maintenance and refurbishment works are done in order to prolong the life of those buildings. Further, the authors indicated that those refurbishment works have become an alternative when either the building reaches to the end of the service life or fails to perform the required function expected. In addition to that, Construction Industry Research and Information Association (CIRIA, 1994) stated that even the buildings with good working conditions, also subjected to refurbishments due to the requirement of owners to accommodate new technologies or to change the role of business operation. Thus, it is apparent that there are various reasons attributable to the refurbishment decision.

Refurbishment projects are considered to be more uncertain than other construction projects (Boothroyd & Emmett, 1996; CIRIA, 1994: Flanagan & Norman, 1985). Moreover, they are complex and less predictable projects within the construction industry (Egbu, 1994; Rahmat, 1997; Rahmat& Ali, 2010). According to Arain (2005), there are some highly changing variables and unpredictable factors that affect the construction process of a project those are result form different sources such as performance of construction parties, environmental conditions, involvement of other parties, contractual relations and resource availability.

According to Rahmat and Ali (2010), most of the activities in the construction industry are more centered on new construction and many refurbishment managers tend to use same approaches used in new constructions for refurbishments. Further to them, those approaches may not always suitable for the management of refurbishment projects.

Then the author explained some of the common barriers in refurbishment projects in design stage. Ali (2010) highlighted that limited information as a major reason to make difficulties for designers to complete the task successfully. Apart from that, Arain (2005) identified problems in construction stage. Further to the author, most of the problems may cause delay and extreme costs.

In order to minimize such adverse impacts to the cost, time and quality targets, suitable approaches should be adopted. Beforehand, it is required to identify the problems that are inherent which disturb the proper management. Thus, in this study it focuses the problems that are present in refurbishment projects due to the inherent characteristics of refurbishment concept.

II. RESEARCH METHODOLOGY

A comprehensive literature review was carried out to achieve the aim of this research study. Accordingly, data related on refurbishment projects were gathered referring books, journal articles, web sites, conference proceedings, and other related resources.

III. LITERATURE REVIEW

A. Nature of the refurbishment project

Refurbishmentsare one of the riskiest, complex, uncertain and less predictable projects in construction industry (Egbu, Barbara, & Victor, 1996; Rahmat, 1997; Rayers& Mansfield, 2001). Further, CIIRIA (1994) reinforced that refurbishment projects are more labour intensive than a new build.

When considering the refurbishment projects as a whole, Carbon Trust (2008) stated that one prominent difference that can be apparent between refurbishment and new build is the scale of the project. Further the same authors stated that new buildings tend to capture the imagination while existing are not. Moreover, the refurbishment projects are not focused on inspired or innovative solutions as new buildings which set ambitious targets. According to CIRIA (1994), one of the main characteristics that can be distinguished from a refurbishment project is the existing asset which is continuing throughout the duration of the project. Furthermore, in refurbishments the activities may involve completely refurbished, remodeled or redesigned to fulfill a new purpose which has a little relation to the previous function.

According to Babangida (2014) nature of the refurbishment demands a proper attention from managers and other

professionals on management more than usually paid on new build. Interestingly, Arain (2005) expounded that refurbishment projects demand more time and cost than initially estimated.

B. Reasons for refurbishment

It is important to identify the reasons for the decision to refurbish rather than selecting other alternative options. Arain (2005) stated that decision to refurbishing a particular building is taken relying on limited information available. Figure 1 shows the performance of a building throughout its life span.

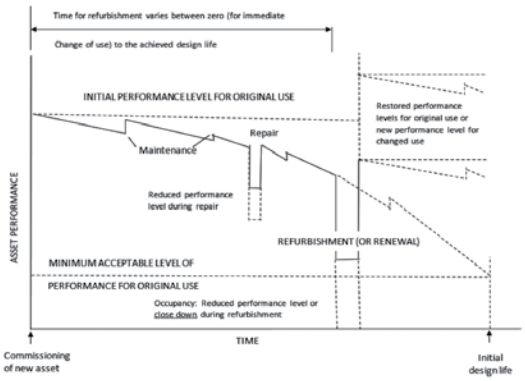

Figure 14:Performance of a building throughout the life time
Source: (CIRIA, 1994)

According to the figure, it clearly illustrates the deterioration in the performance of a building when it is getting old. CIRIA (1994) stated that this deterioration can be reduced using routine maintenance and repairs. Also, author mentioned that major refurbishment will be needed when the performance is reducing further or to zero which leads to complete shut-down of the building.

Arain (2005) stated that decision to refurbish should impose once the building attained to its end of the service life. Author explained that end of the service life means building is no longer capable to be fit for the purpose. According to Babangida (2014) buildings are being physically deteriorated over time and while subjecting to different forms of obsolescence. Thomson, Van der Flier and Nieboer (2015) explained obsolescence as the process of declining the performance of buidlings. The stage of obsolescence is important to get the decision whether to refurbish or completely redevelop (Kangwa&Olubodun, 2004).

Williams (1986) described six forms of building obsolescence as follows.

- Physical Obsolescence which occurs relating to changes in building fabric
- Functional Obsolescence which occurs with the spatial arrangements and required performance of the buildings
- Statutory Obsolescence which occurs due to technical and financial difficulties to meet the statutory requirements
- Economic Obsolescence which occurs due to the demand for building attributes like type and demand for productions and services related to it
- Location Obsolescence which occurs due to loosing location importnace with changes in market interests
- Communication Obsolescence which occurs due to conflicts of interests arising with the usage of buildings

C. Project life cycle

Generally, all types of projects are gone through similar steps of work (Hughes, 2003). According to Holden (2015), there are eight main stages such as briefing, designing, constructing, operating and using building projects. Also, author has detailed the tasks and outputs which are intended to be changed or overlapped at each phase according to the project requirements. Kerzner (2009) presents five key stages as grouped in PMBOK guide; project initiation, planning, execution, monitoring and control and closure. Accroding to Kulkarni, Bargstadt and Huckfeldt (as cited in Prabhakar, 2008) above stages can be grouped in to main three stages. Those are namely procurement phase, execution/construction phase and operation and handover phase. According to the author procurement phase includes from inception to begining of work, execution includes the implementation and final stage includes significant compleiton and handover after the defect liability period. These stages can be used as a base to manage refurbishment projects while identifying problems encountered. Further, this facilitates identifying responsible party and thereby applying suitable approaches to minimize those problems in each stage. In this study mainly considered problems in first two stages which have higher impact on successful completion.

D. Problems in Procurement stage

- **Lack of accurate and complete information during design stage**

According to Ali (2010), lack of information and lack of quality in available information has become a major obstacle in completing tasks during initial stages. Further to him, uncertainty in refurbishment projects becomes the main reason for that obstacle. Ascertaining information regarding existing building condition is much more difficult task (Ali, 2009). Ali (2014) explained that lack of information such as operating facilities, space limitations and maintain existing design makes the design process more complex. When considering the services installation, most of the time (i.e. electrical wiring and piping) they have been embedded in ceilings and walls (Ali, 2009). Ali (2014) mentioned it is difficult to design an existing structure rather than a new build. Moreover, designers may be less interested and tend to limit their creativity on designing refurbishment projects.

- **Determining client's needs**

Barrett and Stantley (1999) mentioned that the design brief is prepared by gathering client's needs and this is updated throughout the construction project. This is much more important because inability of providing adequate brief always makes additional works, for example design variations (Shen, Li, Chung, & Hui, 2004). According to Mitropoulos and Howell (2002), this condition limits design options and lateron it leads to iteration and rework in design process. Ultimately, as a result, cost and time would vary from the originally expected (Rahmat, 1997). Thus, it is clear that client's contribution is a key factor as if his preferences are uncertain in design process and it is likely to change those requirements later in the construction stage (Ali, 2009).

- **Determining the appropriate level of involvement of various parties at the different stages of the design process**

According to Ali, Rahmat, and Hassan (2008), determining appropriate level of involvement of each parties is a main problems presence in refurbishment projects. Further to authors, determining right involvment highly affects the performance of design which required to be within the estimated cost and time parameters. Traditionally, there are two main professionals involve namely; the architect and the contractor (Arain, 2005). Undoubtedly, gathering information on refurbishment projects is mostly depends on the competency and endeavor of designer's (CIRIA, 1994). Ali and Rahmat (2009) opined that the coordination in the design process helps to handle the uncertainty in efficient flow of information. Also stated that, more the coordination is, speed and accuracy will be increased. Coordination methods could be used to improve project performance such as cost, safety and reduction in variations and claims (Mitropoulos & Tatum, 2000).

- **Selecting suitable contract type**

Contract documents are much more critical as a source of information (Arain, 2005). Misinterpretation of actual requirement of project may happens due to poor contract documentation (Arain, Assaf, & Low, 2004). According to Arain (2005), it is preferred to use re-measurement contracts in refurbishment projects mostly where contractor quotes unit rates based on approximate quantities included in the tender document by the architect due to the inherent uncertainty. Moreover, author suggested not to use lump sum contracts when the projects have high risk factor.

- **The percentage of services work to contract value**

The services make greater problems in the accuracy of the designs and obviously affect the smooth running in construction process. According to Ali (2009), once the proportion of services work is increased, more problems likely to be encountered in servies designs. Also, author explained, the difficulty in obtaining design information when the services were concealed either in wall or ceiling. According to author, inn such circumstances, it is necessary to get the help of other designers such as structural engineers, architects to confirm the accuracy. As per McKim, Tarek, and Attalla (2000), inaccurate services drawings make the site condition unforeseen and unpredictable. If more information on services discovered in construction stage, it would make problems which lead to change the design which is initially accepted (Ali, 2009).

- **The percentage of provisional sum to project contract value**

According to Rahmat (1997), the provisional sum is an amount allocated for works that are unable to find sufficient information and value correctly only at the construction stage. According to Ali (2010), gathering most of the information of the existing building is difficult. As a result, greater proportion of provisional sums and contingency will require to be allowed in tender documents. This will lead to higher number of variations orders and exceed the target cost of the project (Rahmat, 1997). Barnes (as cited in Quah, 1998) stated that even though it is allocated

provision of the contract to provide such provisional sum, the determination of the amount to be included is difficult due to uncertain characteristics present in refurbishment project. According to the study of Rahmat (1997), it has founded the percentage of provisional sum also seems to be depend on the procurement system. Consequently, the author reported that it is lower in design and build projects than in traditional procurement system. Further to him, the involvement of estimators also in the construction phase is useful as the cost tend to vary frequently.

- **The percentage of structural work to project contract value**

According to Rahmat (1997) it necessary to do structural survey prior to design the refurbishment projects specially in historical buildings. Also stated that this increases the project cost and it would be difficult task with occupancy of the building. Moreover, if the project involves high proportion of structural work, it would be needed to use heavy plants which in turn reduce the space for material storage and make difficulties in access of sites.

- **Statutory requirements**

Ali (2009) stated that it is required to obtain necessary approvals prior to commence the designing phase of a construction project. According to Holm (2000), legislation requirements in construction industry is complex in nature. CIRIA(1994) reported that out of refurbishment types, certain projects such as change in use, alteration facades, historical buildings are vital to subject statutory requirements. When obtaining approvals from authroities, massive amount of time is wasting while making a adverse delay in refurbishment projects (Mitropoulos & Howell, 2002).

- **Degradation of undamaged materials over time**

According to Fisk (as cited in Arain, 2005), scope of the refurbishment project is determined at the inception stage. Consequently, Arain (2005) stated that there is a possibility of further deterioration occur between the period of initial survey and the start of construction. This extension may due to financial problems or delays in designs (Daoud, 1997). According to Mansfield (2002) there is no fixed period of time to start the refurbishment due to various factors. Babangida (2014) noted that in some incidents, the extent of refurbishment works to be undertaken is determined by the extent of deterioration of the building. Later replacement of degradations and discovery leads to variations which need extra time and cost (Babangida, 2014).

E. Problems in Construction phase

- **Restricted access, circulation routes and site boundary**

The uncertainty, restriction on space and access to the work site are major problems in refurbishment projects than new build (Ali,2009; CIRIA,1994). CIRIA (1994) stated that delivery of material, disposal of waste has to be done in small batches and this is uneconomical. According to Ali (2009) designers have to pay special attention on access during the design development and also the way of transferring tools, equipment, materials and the like. Also, the author mentioned that this is difficult to be handled in case of high rise building as the options are likely to be limited to lifts and stairs. Sometimes, advices from structural engineer is necessary in handling, lifting heavy equipments and and demolition of parts of the buildings (Ali,2009). Apart from that, occupants may add restrictions to access for some parts of the building and then space would be reduced for the labour movements (Rahmat, 1997).Additionally,if the refurbishment projects are in a high traffic area, it may be required to deliver the required materials and other tools in the early hours of the morning (CIRIA,1994).

- **Availability of space for storage of materials**

Along with the restricted access, limited space for storage of materials also can be considered as a problem in refurbishment projects. Hardy (as cited in Rahmat, 1997) highlighted lack of space become a reason for uncertainty and complexity. Rahmat (1997) explained that due to limited space available, small hand tools should be used and requires more supervision when using heavy plant and equipment. Besides, author identified that it is essential prerequisite to maintain a proper site layout and employing an experienced contractor to handle such difficulties appear in refurbishment projects.

- **Potentially reduced security**

According to CIRIA (1994), maintaining security is crucial mostly in occupied refurbishment projects as strangers have the easy access to the premises while executing the refurbishment. Thus, extra precautions have to be taken to ensure securitybecause most of the important documents, equipment and machineriesare kept at the site. Also, it

is required to provide warnings, security measures to decrease crimes, theft, and anti-social behaviour CIRIA (1994).

- **Noise, vibration, fumes and dirt**

According to CIRIA (1994), noise, vibration, fumes and dirt are four characteristics that should be carefully handle in refurbishment projects than new build. Thus, there is an extreme necessity to do proper planning and good communication on selecting equipment and relevant techniques to be followed in construction. Furthermore, if it is more harmful to continue occupying in building, building works should be stopped acquiring a huge loss.

- **Increased risk to health and/or safety from construction**

According to Hughes and Ferrett (2007) safety is the most important investment of construction projects.Authors identified health and safety as the health, physical and metal well-being of people around the workplace including economic motives. Accoridng to CIRIA (1994), the responsibility regarding safety in refurbishment projects is higher than in new build. Also, author explained that the professional and client involved in project have legal responsibility on their duties and their personnel. Further stated that, the presence of client's personnel makes complicate safety problems, enquiries in the progress. According to Ikpe, Potts, Proverbs, and Oloke (2006), accidents in construction sites may become a reason for death, dissability or illness of workers. Also author mentioned that fatal accidents and major injuries increase the cost of the construction.

CIRIA (1994) identified special risks in refurbishment projects namely;

- Many serious accidents occur during demolition work
- Dangerous in partly demolished buildings
- Hazardous roof working within the premises when occupiers present
- Difficulty in disposing material waste and keeping the site clear and secure
- Use of scaffolding and hoisting equipment

Additionally, according to Barnard (1998) some of the major dangers noticed in sites are falling workers or falling an object over a worker from height, falling into excavations, collapsing, and movement of vehicles in the same routes which pedestrians use.

IV. CONCLUSION

Refurbishment projects are unique in nature. Comparing to new construction the most critical aspect is the existing asset. It should be more careful when dealing with those as the necessity of acquiring right, existing data first. This becomes the first and foremost question that arises which contributes to more other problems. Also, it is important to identify other problems that interfere the management as the ultimate intention of refurbishment project is the successful completion within the targeted cost, time and quality. Thus, this study presents the most significant problems that is frequently present in refurbishment projects.

Generally, everyproject in construction industry gothrough similar kind of phases in their life cycle. Among various classifications, this study identifies the project life cycle in terms of three stages: Procurement, execution, operation and hand over. Consequently, problems in refurbishment projects were identified in first two phasesas most of the problems occur in these phases which influence the successful management.

Some of the important problems identified are inaccurate and incomplete information during design stage, determining client needs, restricted access, unavailability of space on project for storage of materials, potentially reduced security and increased risk to health and/or safety from construction.

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STRATEGIES FOR ENHANCING RESEARCH AND DEVELOPMENT ACTIVITIES IN THE SRI LANKAN CONSTRUCTION INDUSTRY

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Abstract - Research and Development (R&D) activities stimulate growth, sustainability and performance. However, the construction R&D expenditure is in the range of 0.01% - 0.04% of global value addition, compared to 3% - 4% in manufacturing and 2% - 3% in other industries. Thus, this research explores the possible strategies to promote R&D by investigating the perception of innovation, drivers and barriers. 12 experts representing three major sectors: research institutes, construction related academic institutions and large scale contracting organizations were interviewed and their views were analysed using a content analysis. According to more than 70% of participants, the thirst for innovation is yet to be realized by construction organizations and the focus is primarily on cost reduction and profit generation. Expert views reveal that commitment of employees and management is the most prominent aspect to promote R&D activities. Further, the attention given to construction R&D is minimal due to higher cost and invisibility of return on investment within a short period. The findings indicate that lack of collaboration between research institutes and construction organizations to undertake industry driven research, use of conventional industry practices and reluctance to innovation as contributors to minimal R&D in the construction industry. Many participants opined lack of government support as a critical concern to promote R&D. Therefore, this research suggests that developing a culture of innovation and increasing the competition in the market could drive construction R&D.

Keywords: Construction industry, Drivers and Barriers, Strategies, Research and Development

I. INTRODUCTION

Construction industry acts as a prominent player in any country's economy, as it is directly related to the development of infrastructure, industrial facilities and buildings (Myers, 2008). One of the most noteworthy current discussions in the industry is about the significant, favourable impact provided by innovation practices (Jefferson, 2006). Following, Zhang, Skitmore, Wu and Ye (2010) reported that Chinese construction industry invested 1.66% to R&D activities out of the total investment made in 2006, the statistical findings of World Bank Group (2015) confirm that China enjoyed nearly 70% of strong economic growth due to higher expenditure in R&D in year 2011. On the other hand, Dulaimi, Ling, Ofori and Silva (2002) indicated that poor performance in construction industry due to the less attention has given to R&D by organizations.

It is further evidenced that expenditure on construction R&D is minimal in most of the countries. For example, Business enterprise R-D expenditure by industry (2017) indicated that amongst Korea, Israel and Japan, which have the highest gross domestic expenditure on R&D as a percentage of Gross Domestic Production (GDP), only Japan and Korea have R&D expenditure spent on construction industry related activities. However, Wong, Thomas Ng and Chan (2010) express that as per statistics, the highest investment on global construction R&D is spent by Japan which is 3% out of gross receipts of Japanese construction industry. Research findings by Business Enterprise Research and Development (2014,

2017) also point towards the fact that construction industry contribution to economy in United Kingdom (UK) has increased by 45% since year 2013, being the largest industry contributor to economy and only 6% of construction firms engaged in R&D. Zhang et al. (2010) presented that global construction R&D by major organizations was 0.25% of annual revenue in year 2003 globally.On a similar note, Seaden and Manseau (2001) indicated that construction R&D expenditure ranges between 0.01% - 0.40% of value added globally. Authors suggest that reason for poor R&D in construction industry may be due to improper reporting, behaviour of clients, project-based nature in construction and inability to measure innovations properly. CIOB (2007) put forth that unawareness about tax incentives for R&D as the reason for less expenditure by construction firms. Masqood and Finegan (2009) further supported this view stressing that construction firms do not look for mechanisms to embed innovative culture into the core of the organization and merely look for productivity enhancing mechanisms.

In order to obtain productive construction R&D outcomes, Spithoven, Clarysse & Knockaert, (2011) is of opinion that organizations need to employ professionals who possess skills in innovative thinking as it provides a platform for the firms to conquer in R&D. Blayse and Manley (2004) further mentioned that collaborative support provided by educational institutes and contracting organizations is very much important to have rigorous results in construction R&D output. On a similar note, Dulaimi et al. (2002) suggested, having a culture of innovation within construction organizations helps to achieve more productive results, because innovation can occur in many aspects and not only by the number of patents received. Masqood and Finegan (2009) opined the importance of learning and innovative culture in construction firms to achieve greater value for money. As a sound solution to this lack of R&D, Jefferson (2006) stresses the need of performance measurement of the prevailing R&D levels in China.

In the Sri Lankan context, Wickramasinghe (2005) indicated that the numbers of patents applied and received by Sri Lanka are relatively low compared to the other countries. A survey conducted by National Science Foundation (2010) has shown that R&D expenditure by all sectors is 0.11% of GDP in year 2008.Subsequently, Wijesinghe (2013) sates that country's Gross Expenditure on R&D (GERD) has dropped to 0.11% in 2008 from 0.21% in 2004. However, Colombage (2014) reveals that 1% increase in R&D helps to increase GDP by 0.3%. Yet, there is no statistics to represent the status of construction R&D in Sri Lanka. Further, local organizations seem to have less priority and involvement in the subject.

With a view of perception of innovation, this research focus is to develop a culture of innovation in the construction industry of Sri Lanka which will stimulate the growth followed by performance levels of the outputs in construction sector. In order to address this target, the importance and prevailing perception of innovation is identified followed by exploring sectoral R&D improvements and then investigating drivers and barriers to address the aim of the research. The step by step approach of reaching the focus of improving the current perception levels regarding construction R&D is attained as per the research method described below.

II. RESEARCH METHODS

The research adopted an indicative approach, where most of the information emerged from the data collection process itself, rather than the literature survey. A total number of 12 participants representing 03 major construction R&D related institutions, 04 experts from each sector were approached for the data collection.

In order to collect more specific information about the research problem, a semi-structured interviews-based survey was administered where more information was gathered from the respondent by means of open ended questions. Followed by the data collection, data analysis and discussion was done using the NVivo technique as it enables to provide organized and themed views of the collected data. The findings are then used to derive at conclusions and recommendations to decide upon the level of construction R&D perception held by construction industry practitioners of Sri Lanka. These conclusions and recommendations are used to propose strategic mechanisms to implement a culture of innovation followed by addressing the critical need of R&D in the construction industry of Sri Lanka.

H.Profile of Respondents

The research sought views of experts who have exposure and experience in the research activities and construction sector. Semi structured interviews were conducted with 12 experts who have 10-20 years of experience in the research field and construction industry. The limited sample is due to the difficulty in finding construction organizations which engage in R&D intensively and

reaching of saturation level with the repetition of findings from the participants. The subjects were selected based on the position held in the company and the experience gained in the industry. The profile of the respondents who took part in the semi structured interview is presented in Table 1. As given in table, an equal sample was maintained across major categories of participants.

Table 1. Profile of interview participants

Type of Organization (Nature of work)	Position	Experience (Years)
Research Institute (Research Administration)	Director	17
	Assistant Director	08
	Executive Officer	05
	Executive Officer	16
Academic Institution (Research Supervision)	Research Coordinator	19
	Research Supervisor	9
	Research Supervisor	16
	Research Supervisor	13
Contracting Company (Construction)	General Manager	10
	Assistant General Manager	30
	Director	14
	Director	13

III. ANALYSIS AND FINDINGS

In an attempt to make interviewees as comfortable as possible about the research focus, a brief introduction was initially given on the subject area. This was explicitly needed for all participants except for the academic researchers as the chosen academics are thorough with both the construction field and the research activities. The findings of the interviews were organized under four main sections: importance of construction R&D, definition of construction R&D, drivers and barriers of the industry towards construction R&D, and strategic mechanisms to improve the status of construction R&D. Under the importance of construction R&D, several sub themes were emerged addressing the critical needs of the Sri Lankan construction industry.

I. Importance of Construction R&D

Surprisingly, not many respondents have given their views on the importance of construction R&D to the Sri Lankan construction industry as evidenced. One major reason for this could be the lack of awareness held by the respondents about the critical need of R&D which will assist for the advancement of the industry with strategic thinking. Rather, majority of the experts held the idea that R&D is not the earliest need of the Sri Lankan construction industry and having mannerisms to develop cost effective and higher return on investments generated within a shorter period of time becomes more attention seeking attributes.

Out of seven (07) interviewees who provided views on the importance of construction R&D, majority indicated that cost minimization and performance improvement of the construction R&D activities as the prime concern of the practitioners. According to them, this has evolved due to the immense requirement in the construction field, to achieve cost and performance as essentials. It is interesting to note that this finding is in line with Maqsood and Finegan (2009) who suggested that construction firms merely look for productivity enhancing mechanisms rather than strategic development attributes.

The need of cost minimization is further confirmed as majority of participants referred the importance of construction R&D to be basically target oriented rather than innovation based. This perception on construction R&D is of the similar view of Yitmen (2007) as the author has defined innovation to be the finding of new methodologies to undertake the same task at a lesser cost, improved efficiency and performance. The findings confirm the profit-oriented nature of construction industry as the focus is yet on cost cutting and performance enhancing mechanisms rather than meeting sustainability driven new innovations. This is in line with the statistical findings of CIOB (2007) which reveals that many firms in the construction industry are not aware on the major tax incentive provided for R&D activities and hence they simply plan on achieving profits via the traditional construction methods.

The results of this study did not show any significant connection to the productivity-based importance of construction R&D. It is somewhat surprising that only very few participants noted the need of productivity and sustainability when it comes to the importance of construction R&D. A possible explanation for this result is the lack of need and criticality given on construction R&D

activities by majority of the construction practitioners in the country. The study of Dulaimi et al., (2002) also confirms this view where innovation process is essential for the establishment of higher performance levels in the Singapore construction industry. It is proven with the findings and analysis results, as majority of the participants have stressed about the performance-based advantages created by construction R&D practices and not on the sustainability-based returns.

J. Definition of Construction R&D

The next section of the interview survey sought, participants' views in terms of industry practice on construction R&D pertaining to the definition provided by Farrow, Holley & Burt, (2011). The definition classifies construction R&D on the four major elements of manpower and organizational development, management methodologies, innovations in construction methods and construction dynamics. All participants have given much attention in addressing these elements and it is evidenced that majority of the views have occurred in relation to manpower and organizations along with construction dynamics. The minimum amount of references is visible for management methodologies. Lack of understanding about the suitable management methodologies specifically relating to establishment of construction R&D in Sri Lanka can be a reason for this result.

Under manpower and organizational development 3 sub themes were emerged as employee commitment, management commitment, and job security. When it comes to employee commitment, participants were of opinion that financial and non-financial motivational factors were essential to enhance the commitment levels of the human resource of the organization. It was opined in relation to the investments made to develop interest of innovation among employees working in construction sector of Sri Lanka as it would lead to direct involvement in R&D practices. Similarly, in terms of management methodology elements of the definition, themes suggested to have adaptations from other countries, other industries have new process of developments to increase the prevailing construction R&D levels in Sri Lanka. Therefore, this refers to the benchmarking activities that can be carried out to upgrade the present situation of construction industry related research activities and innovative processes in Sri Lanka to the next level. Hence, many inputs can be taken from the R&D based progressive actions like Japan, China, Korea and Israel as identified earlier in the literature synthesis.

Under the third element of the definition, innovations in construction, 4 sub themes came in to light as shown in the cognitive map in Figure 2 below. Undertaking construction innovations as new product developments, innovative practices taken place at the site level, getting patents, and innovations done due to external forces such as green building requirements are these sub-themes. Majority of the participants were with the opinion that even though there are minor level innovations taken place at site level, these do not see the day light in a more recognized manner due to the lack of documentation and the poor level of appreciation made by the management.

Finally, under construction dynamics, almost all the participants gave their views on the critical need of the government involvement in the means of financial incentives, policy making, proper system development and also tax allowances provision for construction R&D. Hence almost all the requirements pertaining to the development of a culture of innovation lead to the fact that manpower and organizational commitment play a significant role in promoting R&D in the construction industry of Sri Lanka.

K. Drivers and Barriers for R&D in the Industry

The next step of the survey involved seeking views on drivers and barriers possessed by the Sri Lankan construction industry with respect to R&D. The lack of a critical need to address innovation and R&D was found as the most crucial barrier. Adding up to the same, many expressed the view that the prevailing infrastructure levels and technological enhancements in terms of lab facilities and similar attributes are not sufficient to improve the R&D of construction industry further. It was known that many researchers were hesitant to carry out their work up to the next level due to the heavy cost which may incur to get the foreign laboratory assistance in the R&D works. On the other hand, participants opined that the level of competition in the market will lead to drive construction R&D to a much-recognized higher status from where it is now. The development of the above identified barriers in a positive approach will essentially act as drivers of the Sri Lankan construction R&D.

L. Strategic Mechanisms to Improve R&D

Finally, the ideas regarding prevailing construction R&D status of Sri Lanka were evaluated to come up with strategic mechanisms which will enhance the culture of innovation in the country and the construction industry

per say. Under this target attainment, it was revealed that, it is essential to focus on financial availability in a rigorous manner due to the heavy investment requirement for R&D activities. Further, a substantial attention was needed on the involvement made by human resource in implementing a culture of innovation within organizations. These factors along with the other findings are mainly focussed on developing strategic mechanisms to improve construction R&D in Sri Lanka as shown in Figure 1.

Figure 2. Cognitive map of research findings

IV. DISCUSSION

Analysis of collected data indicates the importance of R&D for the betterment of the construction industry of Sri Lanka similar to the research findings of Wong et al., (2010), which drives towards the same fact in the perspective of Japanese construction industry. Although the criticality and the benefits of innovative practices are known to the industry practitioners, a culture of innovation is not yet developed within the Sri Lankan construction industry. An implication of this possibility is that construction R&D can be made a trigger factor in the Sri Lankan construction industry with stimulations given through many other factors such as government involvement and management commitment in each of the contracting organizations.

Further, the empirical findings of this study provide a significant insight on the involvement made by the government as a statutory body and the policy making institute. The finding is confirmed by the research result of Blayse and Manly (2004) where the collaboration of research institutes, academia and construction practitioners helps in undertaking more focussed research works. The results of the study indicate that, as the main governing body of the country, the involvement and the attention made by the Sri Lankan government to advance the levels of construction R&D should be improved and so that the strategic mechanisms could be implemented. The findings reveal the critical need of the financial incentives provided to contracting organizations and the strong interference to be made by the regulatory bodies specialized in construction R&D activities.

Taken together, these results suggest that only a minority of the Sri Lankan construction organizations are willing to engage in construction R&D activities in a prominent and an effective manner. Therefore, a trigger factor to stimulate innovations within the industry will be the motivation given to employees to engage in new findings. These motivational factors can be either monetary or non-monetary. The implication of this is the possibility of initiating innovations even from the site levels and then moving it upwards the organizational structure. The study has confirmed the findings of Spithoven et al. (2011), which suggests the bottom-up approach of construction R&D which is initiated by the lower level employees of the construction company. The most obvious finding to emerge from this study is the impact that can be made by the management, which needs to be practiced with severe seriousness to get greater value addition by R&D in organizations.

Moreover, the research has shown the many drivers and barriers which cause for the prevailing situation of construction R&D in local construction industry. Investigations made on the drivers which thrive the industry to the next level reveals that R&D is heavily based on the market competition and the culture of innovation. On the other hand, there are many barriers which cause for the lag, as the local construction industry is still using many traditional practices and is not able to embrace innovation due to the lack of technological infrastructure availability. This implies that the construction industry has a greater potential of adding value to the country's economy addressing the identified barriers as specified by Seaden and Manseau (2001) as well. Once the barriers of R&D are eradicated up to a considerable state, the prevailing perception on a culture of innovation can be changed within the mindset of construction industry practitioners of Sri Lanka. The same will cause for economic boost in terms of industry development occurred via the use of innovation and R&D.

The study implicates the critical need of bridging the gap between universities and the construction industry, so that the construction industry professionals could

make use of the tremendous amount of research work carried out annually. One of the best practices is doing so would be to carry out research to address the critical industrial needs. The research institutes could facilitate by providing the support of mediation with laboratory facilities while the contracting organizations can enhance the commercialization and the marketability of new developments. The practical needs of the contracting organizations in the industrial approach can be communicated to the research institutes and academic institutions to engage in more focussed and result oriented construction R&D activities. This would help to improve the prevailing level of construction R&D and thereby meet higher standards leading to cost benefits and profit generating mechanisms.

Another finding of the study is that innovations taking place in construction sites are not given appreciations and so that it could be repeated and improved in future projects. Hence documenting new systems and process improvements to achieve innovation is found as an action that is doable with minimal inputs and within a short-run of the organizations. However, it is essential to have management commitment to implement any of these strategic mechanisms. Such attention given to advance the current construction R&D levels will make sure the economic growth of the country to be higher as per the statistical findings of Colombage (2014). In addition, the study recommends that the Sri Lankan government takes upper hand in making financial backups for research work as it could boost the R&D performance levels in the construction industry and thereby improve the construction sector as well as economic performance.

V. CONCLUSION

The study has found that generally, R&D perks to be a paramount requirement to achieve excellence in the industry mainly in the long-run rather than the short run. The results of the study indicate that industry practitioners are more concerned about cost minimization and performance achievement along with targets, rather than R&D initiatives. Further, the present study contributes additional evidence that suggests the sectoral improvements in construction R&D to be achieved mainly through manpower and organizational development. The results of the research on the importance of human resource and the need of government involvement assist in our understanding in the role of management and the human resource of construction organizations. Manpower and organizational development is the most dominant sector of the construction R&D. Hence in order to improve the prevailing levels of construction R&D, critical attention needs to be given on human resource. Such involvement of human resource can be carried out by developing a culture of innovation within construction organizations of the country.

The availability of initiatives regarding innovative management methodologies (cost engineering, planning and scheduling) and innovations in construction methods by means of patent applications (prefabrication and standardization) are relatively scarce in the Sri Lankan construction industry. Therefore, focussing on manpower and organizational development (education and training, evaluation of management productivity) and construction dynamics (the most appropriate method to allocate resources by economic modelling, forecasting and environment related policy making) are found as the best approaches to improve the current levels of construction R&D in Sri Lanka.

Although the construction sector has made comparatively less inputs to the R&D attributes, there are no substantial developments made by the already established innovations of other sectors as well. Therefore, taken together, the result enhances the understanding of the prevailing levels of construction R&D, as it is not a critical need at the very moment. Yet, subsequently, times and situations will be of such that the traditional methods used in the Sri Lankan construction sector to be evolved to match the market needs and global needs. By that time, the necessary strategic mechanisms must be implemented to achieve the success in construction R&D activities in a much fruitful manner.

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SPATIAL DISTRIBUTION OF FLOODS IN MATHARA DISTRICT: WITH SPECIAL FOCUS ON 2003 AND 2017 FLOOD EVENTS

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Abstract - Floods are one of the most devastative disasters in the world, and it is most prominent in tropical regions of the world. Sri Lanka being located in between two tropics, witnesses flood every year due to the monsoon, convection rains and sometimes rain due to cyclones. Therefore, this study is mainly focused on Mathara district with the main objective of assessing the impact of floods along with its distribution. Both primary and secondary data were used for the study. Impact data was obtained from the Disaster Management Center and the flood inundation area, and rainfall data was obtained from the Department of Irrigation and Department of Meteorology of Sri Lanka respectively. A questionnaire survey was conducted on selected 100 households from the Peddapitiya Grama Niladhari Division (GND) of Akuressa Divisional Secretariat Division (DSD) which has the highest impact. Spatial analysis techniques were mainly used in this study, specially the weighted overlay method, to identify the affected regions. Statistical analysis methods of descriptive statistics were also used in order to identify the relationship between daily discharge and daily rainfall levels. According to the analysis Kirama ara, Digili oya, Kotapola oya and Urubokka oya tributaries of Nilwala river record the highest impact from floods. It is also clear that April, May and June are the most prominent time period due to the South West Monsoon (SWM) and September, and November due to Second Inter Monsoon (SIM) conventional rains. Comparison between 2003 floods with 2017established that the impact is more devastative in year 2017 flood.

Keywords: Flood, Weighted Overlay, Mathara

I. INTRODUCTION

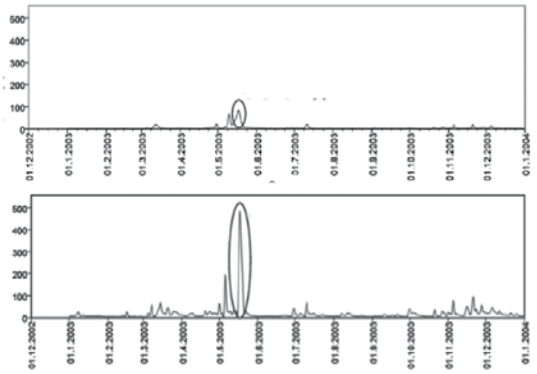
Floods have become most commonly discuss topic under the Disaster Management. There are thousands of strategies all over the world taken to prevent or mitigate flood hazard in the world. Tropical regions are more prone to floods and the coping capacity for the floods and to take proper mitigation methods are considerably low, since most of these countries are still developing nations. But there is international collaboration through various projects to improve flood mitigation and many of these strategies seem to work properly.

Sri Lanka being fed by both SWM and North East Monsoon (NEM) is also highly prone to floods in many parts of the wet zone. Like Kaluthara, Colombo, Rathnapura, Galle Districts, Mathara district has considerable impact on both natural and built environment due to the floods caused by Nilwala River. Nilwala catchment area extends up to 375 square miles with 72 km in length. The area will get 2000 mm – 2500 mm rainfall annually and the lower catchment of the river is highly populated with in many areas. There are previous severe floods recorded in year 1940, 1969, 2003 and the most reason one is in 2017. There were 64 deaths recorded in year 2003 floods with 47637 families being displaced. In 2017 flood also there were 31 deaths recorded and 43382 families were displaced. There were many flood prevention methods being active at the current scenario and flood controlling dam system is one of the main attractions. Due to the dam system small scale floods will not hit severely but with the climate change the intensity of rainfall as well as the floods have become increased. So, if the rainfall exceeds its threshold limits the flooding is unstoppable.

II. METHODOLOGY

Main objective of the study is to assess the impact of the floods in Mathara District and compare the two floods in the year of 2003 and 2017. As the sub objectives, identification of spatial distribution of the floods and its impact along with identify the relationship with river discharge and the rainfall of the area were also considered.

Equal Weights were given to both primary data and the secondary data and a questionnaire survey along with interviews were conducted to obtain the primary information regarding the behaviour and the impact of floods. Among the district the highest impact was recorded in Peddapitiya GN Division which belongs to the Akuressa DS Division and 100 households were selected under the random sampling methods that have been flooded. Interviews were conducted from the key informants of the area like Grama Niladhari, Divisional Secretariat, Police officers and Community leaders of the area. As secondary data flood inundation areas were obtained through the Department of Irrigation, yet they were able to provide only the inundation area of 2017 flood since they have not compiled the 2003 map at the moment. Impact data were obtained from Disaster Management Center and the District Secretariat Office of Mathara District. Data were collected for the GN level under the impact categories of number of deaths, affected families, and numbers of affected people, numbers of houses fully destroyed and numbers of houses partially destroyed. Daily discharge data were obtained from the regional stations and Daily Rainfall data from Department of Meteorology.



Spatial Analytical techniques were used in order to identify the spatial patterns of each parameter of the impact categories. At the end overlay method was applied to identify the agglomerated impact of the study area. Arc GIS 10.1 was used as the tool of analysis and maps as the main visualization techniques. Graphical representation of the rainfall and water discharge was also done along with. Descriptive illustrations were also applied in this study to investigate the matters in deeper context.

III. RESULTS AND DISCUSSIONS

This section is divided in to two groups as in first part is to discuss the relationship with rain fall and flood levels in Nilwala River Bain and second half is to discuss the impact and its relationship with terrain characteristics.

Rainfall in Nilawala river basin comes to its maximum during the South West Monsoon period. During the monsoon the river carries all the water accumulates in basin area and discharge from the estuary located at Matara town. Elevation of the river up to 40 km in to the land area is less than 50 meters but after that it has an accelerated gradient up to 600 meters.

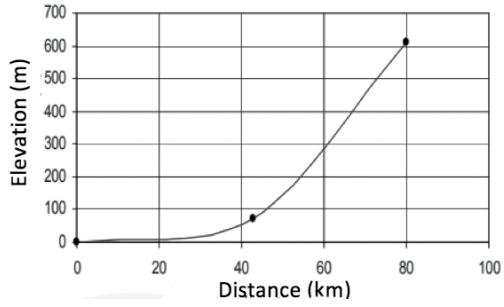


Figure 2. Cognitive map of research findings

According to the gradient it is also clear that the water from upper catchment area where above 40 km from the sea comes with high velocity and suddenly release in to the lower basin where the flooding started.

Not only the main river but also the tributaries of Nilwala River indicate flooding. Department of Irrigation has identified three stages of flooding which they named as High, Moderate and Low. If the water level is less than eight feet it is considered as a low flooding stage and the areas of Matara, Nadugala, Bandaththara and Kadduwa areas are most likely to be flooded. If the water level is less than 13.5 feet, it is considered as a moderate flood where

Mavarala, Mulatiyana and Akuressa areas will be flooded apart from the areas of low level flooding. If the water le vel exceeds 18.5 feet it is considered as high level flooding where flood will extend up to Bopadoda, Pitabeddara, Malimboda and Pasgoda areas.

There were two main flood occurrences which considered being high or severe, which was occurred in 2003 and 2017. There were annual floods but these two events are being considered as the severe. Based on the flood inundation area map of the Matara district the most flooded DS division in 2017 flood was Thihagoda.

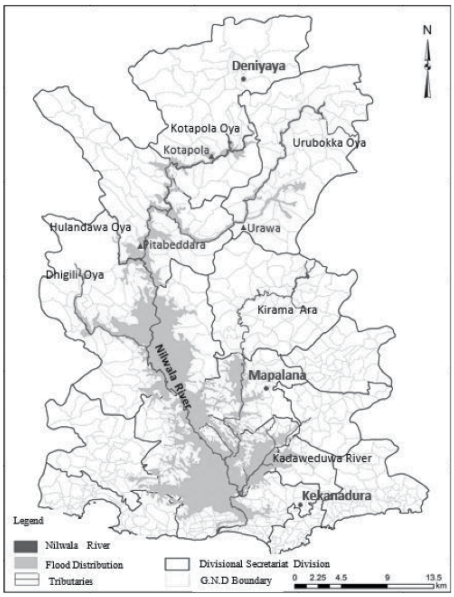


Figure 2. Flood inundation area with rain gauge and water gauge station in Matara District

The map indicates that the highest numbers of deaths were recorded in Morawaka GN division and the main reason for that is the overflow of Urubokka oya, which is a main tributary of the Nilwala River. Second highest is recorded in Makandura west and Batuwita GN divisions. Kirama area is the major reason for the flooding of Makandura and Batuwita is directly located adjacent to the Nilwala river. The deaths in the upper catchment are mainly due to the over flow of tributaries and some of the cases are happened due to the landslides related to floods.

When considering the number of displaces people it is very clear that the large numbers of them are agglomerated on the flood plains of the river basin. Highest number of displaced amount is recorded in Weragampitiya GN division which is located in Matara DSD and it is 4064 to be exact. Also highest displacement is recorded in Matara and Akuressa DSDs and it is 30 and 26 precent respectively. More than half of the displaced population lives in this two DSDs. There are 38127 people have lost their places to live. Considering the fully damaged houses indicates a different pattern where the large number of housed are damaged in upper catchment area.

Figure 7. Number of displaced people in Mathara district due to 2017 flood

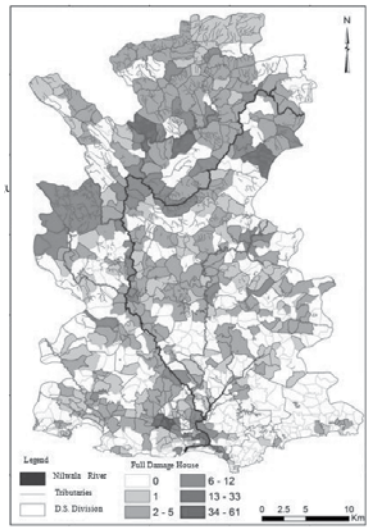


Figure 8. Fully damage in Mathara district in 2017 flood

One reason for the pattern indicated in figure 8 is, when collecting data by the Disaster Management Centre they collect both Floods and landslides together. Therefore the exact picture of the flood impact is not clearly depicted. The authorities have not collected data separately for the flood victims and landslide victims.

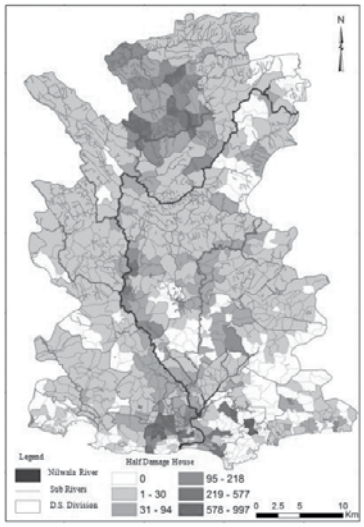


Figure 9. Partially damage in Mathara district in 2017 flood

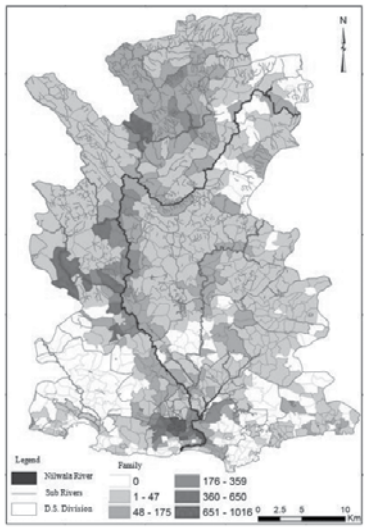


Figure 10. Impact households in Mathara during 2017 flood

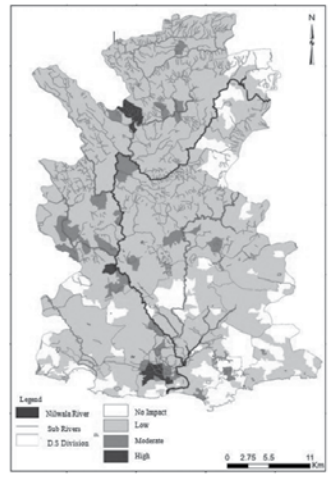


Figure 10. Cumulative impactof Mathara during 2017 flood

There is a scattered distribution of the moderately impacted households in many parts of the district. It is mainly because of the tributaries of the area. Apart from very few GNDs almost all the district was under flood and had some sort of an impact at least based on one parameter.

For the uneven distribution of the impacted GNDs the terrain characteristics were another major influenced factor. Upper catchment of the Nilwala basin consists with high terrain features but the morphology has allowed some areas to have floods during the rainy season. Following diagram indicates three cross sections of the Nilwala basin which belongs to the Matara district.

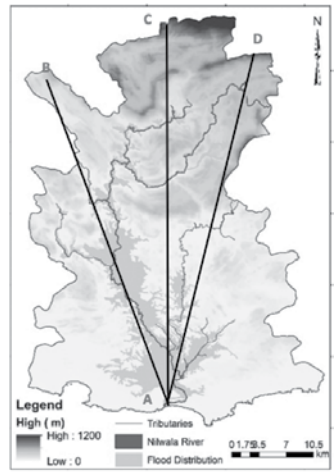


Figure 11. Lines of the cross sections of the district

The cross sections are clearly indicates the terrain variation and it is clear that there are basin areas in the high elevation which can retain floods in some parts. They will act as flood pockets by creating flood hazards in some high elevation sections of the Matara District. The terrain dynamics will always have a huge impact on the floods and considering the Nilwala river basin there are floods which can be identified in the upper part of the basin. Many anthropogenic activities have intensified the flood risk of many areas and the impact even with non-severe flooding has become higher than the previous situation. There is a complex network of tributaries which will act together with relief to intensify the floods.

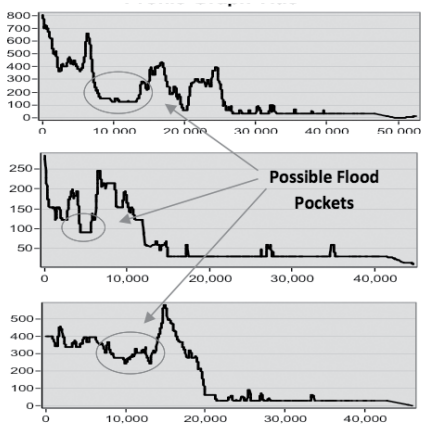


Figure 12. Cross sections of the district profile

III. CONCLUSION

In conclusion it is clear that there are floods which normally annually accruing in the Nilwala river basin and in many occurrences both human and natural environments were severely disturbed. It is our duty to prevent floods or may be to take necessary actions to mitigate and reduce the impact of flooding. But to do that, proper studies of floods has to be conducted to identify the flood characteristics of the given area. This will enables the decision makers to plan for the future floods in mitigating or may be preventing them being occur.

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A COMPARATIVE STUDY ON ANTHROPOMETRIC MEASUREMENT OF SRI LANKA DEFENCE SERVICE (SL ARMY, SL NAVY AND SL AIR FORCE) MALE SOCCER TEAMS

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Abstract - Anthropometry is a branch of anthropology and is concerned with the measurement of the human body. The intent to do this research was because there was no comparison on the anthropometric measurements of Sri Lankan defence service male soccer teams. The purpose of this study was to identify the dependency of anthropometric for performance. In this research Anthropometric measurements of the Sri Lanka Air Force, Army, and Navy male soccer players were taken into consideration. A survey was used as the main data collection method and the total sample population (all soccer team members of defence services) was 29, 27 and 27 from the Air force, Army and Navy respectively. Interviews and measurement were conducted to those samples to gather this data. In addition, the latest Sri Lanka dialogue premier league result was used to identify and compare their performance. According to the results of the research, the Air Force is greater than the Army and the Army is greater than the Navy when considering Sitting height, Waist to hip ratio, Calf girth, Thigh girth, Leg length and Arm Span. Also, when considering the BMI and percentage of fat, the Air force is less than the Army and the Army is less than the Navy. For the Statically Analysis, the SPSS software was used as the tool in this research. According to the study, anthropometry characteristic of players affects their performance.

Keywords: Soccer, Anthropometry, performance, Tri-forces

I. INTRODUCTION

Anthropometry is the branch of the human sciences that deals with body measurements. At it is most basic, anthropometrics is used to help scientists and anthropologists understand physical variations among humans. Anthropometrics is useful for a kind of baseline for human measurement. Anthropometry is the measurement of people and the analyses of those measurements for various purposes. It can be used for talent identification, and also nutritional and physical assessment.

Specifically, Sri Lanka Dialog football premier league is the top of the football tournament in Sri Lanka. This tournament is conducted by Sri Lanka football federation annually with an 18th soccer club in Sri Lanka. These 18th soccer clubs are selected by Sri Lanka football federation through the standard selection procedure. Within these 18th clubs, Sri Lanka air force (Air force), Sri Lanka army (Army S.C) and Sri Lanka Navy (Navy S.C) are important teams. Because these teams represented Sri Lanka three forces and also Sri Lanka national football squad. But according to the 2017- 18 Sri Lanka football premier league table, air force, army S.C and navy S.C soccer teams is not in one level within those 18thsports clubs. Within three forces in that table, air force is in first place with 28 pts, army S.C is second place with 22 pts. And navy S.C is third place with 20 pts.

This research main aim was to assess the anthropometric in Sri Lanka defense service male soccer teams. According to the ISAK (International Society for the Advancement of Kinathropology) standard anthropometric measurements data were collected by the researcher

Elite soccer players have a higher percentage of muscle in comparison to non - exercise population being as high as 62%. But their fat percentage is lower than non -exercise population. But their fat percentage higher than long-

distance runners or endurance runner. The researcher hopes to get full and correct anthropometric data. This method involves a structured interview and measuring.
And also muscle size effect to do maximum training in soccer or any other sport. Because the muscles have the ability to store necessary energy during the game. As well as training. Elite soccer players should focus on maximal strength training, with emphasis on the maximalmobilization of concentric movements, which may improve their sprinting and jump performance.

II. METHODOLOGY AND EXPERIMENTAL DESIGN

A. Problem Specification

These study support coaches for the trained athlete do hard practices in their sports lives in the sporting life as a team without a care about athletes' anthropometry characteristics. Because of nutrition level of athletes depend on anthropometry characteristics. This situation badly affects them when they face competitions and results of those are low performing levels. This guide to anthropometric and biomechanical assessment introduces athletes to the details of standardized protocols and outcomes of the study.

B. Study Area

Anthropometric measurements of defense service male soccer teams (SL Air Force, SL Army, and SL Navy) and analyzing their anthropometric characteristics according to their measured data.

C. Data gathering technique

The research topic and objectives were built depending on the study of the researcher and of the literature review. The researcher used measuring tests of anthropometry for athletes. The procedure involved two measures at each site to calculate a mean value and an acceptable technical error margin. SPSS.16.0 was used for data analysis in this study.

D. Anthropometric Equations

- BMI (Kgm-2) = $\frac{\text{Wight (Kg)}}{\text{Height2 (m)}}$

- Waist to Hip Ratio (cm) = Waist Girth (cm)

- Body Fat percentage % = 0.29288(X2) - 0.00050(X2)2 + 0.15845(X8) – 5.76377

  X2 = sum of triceps, abdomen, suprailliac and thigh skin folds.

  X8 = age in the year(Wellens, Roche et al. 1996)

E. Material

- A weight scale (CONSTANT Digital LCD Glass Top Bathroom Weighing Scale)

- Slim Guide skinfold caliper

- (Fabric Body Sewing Tailor Soft Flat Measure Measuring Tape)

- Seca 201 Ergonomic circumference measuring tape.

The sample consisted of 83 (n= 83) National players = 23 and Non – national players = 60, players from Sri Lanka defense service men's Soccer teams. The data were gathered through measuring their anthropometric. The data were analyzed and presented with the use of SPSS software and Microsoft Excel. Defense service three forces' all the players (83 players) were taken to this research.

National players of each team separately (A) Height

	Mean	Std. Deviation	N
Air Force	170.07	3.17090	9
Army	169.79	3.75119	7
Navy	169.07	3.33452	7

In this study the mean height of national athletes, SL Air Force, SL Army and SL Navy were 170.07 ± 3.17 cm, 169.79 ± 3.75 cm and 169.07 ± 3.33 cm respectively.

BMI(Body Mass Index)

	Mean	Std. Deviation	N
Air Force	22.8311	1.77094	9
Army	22.8843	1.64908	7
Navy	23.1857	1.64796	7

In this study, the mean BMI of national athletes, SL Air Force, SL Army and SL Navy were 22.8311 ± 1.77 kgm-2, 22.8843 ± 1.65 kgm-2 and 23.1857 ± 1.65 kgm-2 respectively.

Sitting Height

In this study the mean Sitting Height of national athletes, SL Air Force, SL Army and SL Navy were 86.0444 ± 3.36 cm, 84.9286 ± 3.12 cm and 84.0286 ± 2.98145 cm respectively.

	Mean	Std. Deviation	N
Air Force	86.0444	3.36122	9
Army	84.9286	3.11700	7
Navy	84.0286	2.98145	7

Fat Percentage

	Mean	Std. Deviation	N
Air Force	9.5367	1.70141	9
Army	9.7443	1.61737	7
Navy	10.1029	1.91100	7

In this study, the mean Fat percentage of national athletes, SL Air Force, SL Army and SL Navy were 9.54 ± 1.70mm, 9.74 ± 1.62mm and 10.10 ± 1.91mm respectively.

Non-National players of each team separately (B)

Height

	Mean	Std. Deviation	N
Air Force	169.53	5.24836	20
Army	169.03	6.07857	20
Navy	168.53	5.70809	20

In this study the mean height of Non - national athletes, SL Air Force, SL Army and SL Navy were 169.53 ± 5.25 cm, 169.03 ± 6.08 cm and 168.53 ± 5.71 cm respectively.

BMI(Body Mass Index)

	Mean	Std. Deviation	N
Air Force	22.8910	1.64283	20
Army	22.9762	1.43601	20
Navy	23.2812	1.54117	20

In this study, the mean BMI of Non - national athletes, SL Air Force, SL Army and SL Navy were 22.89 ± 1.64 kgm2, 22.98 ± 1.44 kgm-2,and 23.28 ± 1.54 kgm-2 respectively.

Sitting Height

	Mean	Std. Deviation	N
Air Force	84.2350	3.85127	20
Army	83.9375	3.85968	20
Navy	83.8438	3.83301	20

In this study the mean Sitting Height of Non - national athletes, SL Air Force, SL Army and SL Navy were 84.24 ± 3.85 cm, 83.94 ± 3.86 cm and 83.84 ± 3.83 cm respectively.

Fat Percentage

	Mean	Std. Deviation	N
Air Force	10.0320	2.25435	20
Army	10.2156	2.68123	20
Navy	10.2188	2.40977	20

In this study the mean Fat Percentage of Non - national athletes, SL Air Force, SL Army and SL Navy were 10.03 ± 2.25 mm, 10.22 ± 2.68 mm and 10.22 ± 2.41 mm respectively.

And also like Height, BMI, Sitting height and fat percentage, according to the Thigh girth, Calf girth, Leg length and Arm span, Sri Lanka Air Force is a greater army, Sri Lanka Army is greater than Sri Lanka Navy. But in the Waist to hip ratio, all the teams in low health risk level.

Different between National players and Non-National players of all defense service (C)

Thigh Girth

	Mean	Std. Deviation	N
National Players	51.3174	3.13074	23
Non-National Players	50.1462	3.59026	60

In this study the mean Thigh Girth of National and Non – national players were 51.3174 ± 3.13 cm and 50.1462 ± 3.59 cm respectively.

Calf Girth

	Mean	Std. Deviation	N
National Players	35.4391	2.39122	23
Non-National Players	34.9865	2.15407	60

In this study the mean Calf Girth of National and Non – national players were 35.4391 ± 2.39 cm and 34.99 ± 2.15 respectively.

Leg Length

	Mean	Std. Deviation	N
National Players	95.6261	3.88051	23
Non-National Players	95.3000	3.07590	60

In this study the mean Leg length of National and Non – national players were 95.6261 ± 3.88 cm and 95.3000 ± 3.08 cm respectively.

Waist to Hip ratio

	Mean	Std. Deviation	N
National Players	0.8335	0.03113	23
Non-National Players	0.8269	0.03943	60

In this study the mean Waist to Hip Ratio of National and Non – national players were 0.8335 ± 0.03 cm and 0.8269 ± 0.04 respectively.

And also like Thigh girth, Calf girth, Leg length and Waist to Hip ratio, according to the Height, BMI, Sitting height, Arm span and Fat percentage, Sri Lanka Air Force are a greater army, Sri Lanka Army is greater than Sri Lanka Navy. But in the Waist to hip ratio, all the teams in low health risk level.

Different between all Air SL Force, SL Army, and SL Navy(D)

Height

	Mean	Std. Deviation	N
Air Force	169.70	5.81571	29
Army	169.26	5.39964	27
Navy	168.70	5.03113	27

In this study, the mean Height of SL Air Force, SL Army, and SL Navy was 169.70 ± 5.82 cm, 169.26 ± 5.40 cm and 168.70 ± 5.03 cm respectively.

Leg length

	Mean	Std. Deviation	N
Air Force	95.8448	3.20185	29
Army	95.3696	3.46822	27
Navy	94.8696	3.38169	27

In this study, the mean Leg length of SL Air Force, SL Army, and SL Navy were 95.84 ± 3.20 cm, 95.37 ± 3.47 cm and 94.87 ± 3.38 cm respectively.

Arm Span

	Mean	Std. Deviation	N
Air Force	177.23	5.42420	29
Army	175.48	5.37423	27
Navy	174.80	5.93529	27

In this study, the mean Arm Span (FW) of SL Air Force, SL Army, and SL Navy were 177.23 ± 5.42 cm, 175.48 ± 5.37 cm and 174.80 ± 5.94 cm respectively.

Fat percentage

	Mean	Std. Deviation	N
Air Force	9.8783	1.50023	29
Army	10.0722	1.58879	27
Navy	10.1835	1.25873	27

In this study, the mean Fat Percentage of SL Air Force, SL Army, and SL Navy were 9.8783 ± 1.50 mm, 10.0722 ± 1.59 mm and 10.1835 ± 1.26 mm respectively.

And also Height, leg length, Arm span and Fat percentage, according to the Sitting height, BMI, Waist to hip ratio, Calf girth, Thigh girth, leg length, Sri Lanka Air Force are a greater army, Sri Lanka Army is greater than Sri Lanka Navy. But in the Waist to hip ratio, all the teams in low health risk level.

IV. DISCUSSION AND CONCLUSION

According to above result of defense service soccer teams, Air force is greater than the army and the army is greater than navy when considering about Height, sitting height, Waist to hip ratio, Calf girth, Thigh girth, Leg length and Arm Span. And also when considering the BMI and percentage of fat, Air force is less than the army and the army is less than navy.

This study focused the study to assess the anthropometric characteristics in athletes of Sri Lanka defense service male soccer teams. There are three soccer teams including Sri Lanka Air Force, Sri Lanka Army and Sri Lanka Navy.

According to the results in chapter III, it emphasizes SL navy soccer team have lowest of anthropometrical characteristics. And SL Army soccer team is middle place within those teams and SL Air Force is greatest with anthropometrical characteristics. Soccer is a game where standard physical characteristics with height, weight, leg length, sitting height, waist to hip ratio, the girth of leg muscles and fat percentage require for good performance. When considering as national and non – national players, there is the difference between them according to their height, SL Air Force, SL Army, and SL Navy differ 0.54 cm, 0.76 cm, and 0.54 cm respectively. According to that, can be considered national players have more height than non-national players. And also, SL Air Force soccer players were greater than SL Army and SL Navy respectively.

When considering as national and Non – national players, there is the difference between them according to their BMI, SL Air Force, SL Army and SL Navy is in normal BMI level. That is good for performance. But within those three teams SL Air Force, SL Army, and SL Navy BMI level are low between normal BMI levels respectively. Actually, when considering BMI level, SL Air Force take success level than SL Army and SL Navy, SL Army takes success level than SL navy.

When considering as national and non – national players, there is the difference between them according to their Sitting height, SL Air Force, SL Army, and SL Navy differ 0.19 cm, 0.99 cm,and 0.18 cm respectively. According to that, can be considered national players have more Sitting height than non- national players. And also, SL Air Force soccer players were greater than SL Army and SL Navy respectively.

According to World Health Organization (WHO), waist to hip ratio is an indicator of obesity. When considering as national and non – national players, there is the difference between them according to their Waist to Hip Ratio in SL Air Force, SL Army, and SL Navy. But all the teams are in less of health risk level. That is good for performance. And also, SL Air Force, SL Army, and SL Navy soccer players were in less of health risk level when considering their mean Waist to Hip Ratio. The WHR is an important predictor of several cardiovascular and other chronic diseases; documentation of a strong effect of physical activity on the WHR selectively in men may provide a partial explanation of how the effect of physical activity is mediated and why physical activity is more effective in reducing disease risk.

A soccer match makes heavy demands on both aerobic and anaerobic metabolism. Elite players run 8-12 km during a game, with aerobic metabolism predominating. Nevertheless, anaerobic metabolism is also crucial in sprints, jumps, and tackles. When considering as national and non – national players, there is the difference between them according to their girth of calf and girth of the thigh in SL Air Force, SL Army, and SL Navy. And also, SL Air Force soccer team have girth circumference greater than SL Army and SL Navy soccer teams respectively, when considering their mean calf and thigh girth. Specifically,the girth of these leg muscles is important factors in the soccer. Because every time in the match, legs are active. And more energy needs to these muscles than other. If this muscle is more size, maximum energy can be stored in muscles. If this muscle is not more size, easily comes to fatigue level.
And also when considering about arm span, it is important anthropometric characteristics. Because arm span can be decided upper body fitness components. When considering as national and non – national players, there is different between them according to their length of arm span in SL Air Force, SL Army, and SL Navy. And also, SL Air Force soccer players were greater than SL Army and SL Navy respectively.

Most athletes attempt to reduce adiposity levels alongside improving their fitness. Normal physiological functioning requires certain levels of body fat, though excess adipose tissue acts as an undesirable load in activities such as soccer in which the body weight must be lifted repeatedly against gravity. When considering as national and non – national players. There is the difference between them according to their percentage of fat, SL Air Force, SL Army and SL Navy is in a good percentage of the fat level. But within these three teams differ 0.50, 0.47 and 0.54 respectively. According to that, can be considered national players have less percentage of fat than non- national players. And also, SL Air Force soccer players were greater than SL Army and SL Navy respectively.

Anthropometry is a branch of anthropology and is concerned with the measurement of the human body. It is well known that the characteristics of physique apparently associated with success in sports and another form of physical performance. Evaluation of these anthropometric characteristics has an immense effect on sports in the preparation and maintenance of training program along with energy consumption and nutrition.

Generally, there was not much of a different body height, BMI, sitting height, girth of thigh and calf, arm span and percentage of body fat of national athletes from different teams. And also non-national athletes in a different team. The national players had a significantly high height when compared to Nan - national athlete. And also sitting height of national athlete higher than non - national athlete. And also circumference of thigh and calf (girth of thigh and calf) higher than comparing to non – national athlete. And also arm span is another characteristic differs from national and non -m national players. Because there is differ range of arm span in national players higher than non - national players. And specifically, the fat percentage of national players in defense service soccer teams, have less percentage than non – national players of teams.

Above data showed that the mean of anthropometric characteristics Sri Lanka Air Force soccer players achieved good characteristics regarding the anthropometry than Sri Lanka Army and Sri Lanka navy respectively. SL Air Force characteristics of anthropometry measurements were greater than Sri Lanka Army's Lanka Army characteristics of anthropometry measurements were greater than Sri Lanka Navy. This investigation indicates the need for further research on the effect of anthropometric characteristics since it is associated with players' performance. In addition, there may be some relationship between anthropometric and team performance when studying Sri Lanka Dialog Premier League in 2017. Because of the team which hasgreater anthropometric characteristics suitable for a soccer game, is top place in a table within Sri Lanka defense service soccer. That team is Sri Lanka Air Force soccer team. And also the team which has greater anthropometric characteristics less than Sri Lanka Air Force suitable fora soccergame is second place in a table within these soccer teams. That team was Sri Lanka Army soccer team. And also the team which hasless anthropometric characteristics was the last place that meansa third place in a table within defense service soccer. That team was Sri Lanka Navy soccer team.

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Poster Sessions

MORPHOLOGY OF THE EVOLVING COURTYARD WITH SPECIAL REFERENCE TO LIGHT HOUSE HOTEL IN GALLE

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Abstract - With the rapid urban development and globalization, the vernacular architectural style of Sri Lanka has been affected by arbitrary and westernized style. Due to these influences the traditional architecture was declined with direct imitation of European architecture models. This caused the disappearance of regional cultural elements such as, courtyards. Vernacular form of courtyard was an expression of the climate of the region and national spatial model of the country. With global climatic issues, the built environment is intended to find more innovations on sustainable architecture. With this, once again, modern architecture paid its attention towards courtyards. As courtyards create a link to history and culture of the country the usage of it in modern architecture is found abundantly. Traditional courtyard was a central open space bounded with four built forms around. This central space was used for the spatial organization and to strengthen the building penetration of indoor and outdoor atmosphere. The courtyards were used for many cultural and social activities throughout the past. Modern adaptation of traditional courtyard is an old topic, which was discussed through many studies. But most of them were based on the value of courtyard usage and theories proving it. The issue here is that the use of practical application methods that have not been summarized. And there aren't many studies on modern courtyard applications and about the morphology of the evolving courtyard. The goal of this paper is to study the application of traditional courtyard space in modern architecture through a case study on the Light House Hotel in Galle, by Architect Geoffrey Bawa. The paper is divided into three sections. Section one describes the origin and evolution of courtyards in history section two defines and describes the usage of courtyards I modernity, and finally conclude the paper with the case study on Light house hotel Galle.

Keywords: Courtyards, evolution, morphology

I. INTRODUCTION

When Ceylon turns into Sri Lanka with the independence in 1948, it provides grounds for a huge change in the country. Loss occurred due to the invaders empowered the rebirth of the country. This socio-cultural background took architecture towards the proud history and direct adaptation results not a unique architectural style but pseudo tradition.

"As an Architect you design for the present with an awareness of the past for a future which is essentially unknown." (Norman Foster)

World renowned Sri Lankan architect, Geoffrey Bawa was one of the leading roles to identify this awareness of past which is essential in present and also to cater the unknown future. Therefore he practiced with his own guide line, "a new vital- and yet essentially Sri Lankan". With this approach they were able to adapt traditional element to modern era. When studying the designs of the great architect, the founder of 'Tropical modernism, continuous use of courtyards is noticeable.

Present day world faces huge global environmental problems as a whole. While conserving projects are ongoing, research shows that a large amount of building contribution to environmental pollution. Still at the present most of the buildings in Sri Lanka are not responding to the immediate micro climate or neither macro climate. Studying the incorporation of traditional building elements in contemporary building would be

a worthwhile study as those forms did not consume nonrenewable energies to achieve internal comfort levels. At this moment, as a country with a great history and a proud culture, its own architectural style should cater for both climatic and socio-cultural requirements. Based on this identification, study is conducted on the main traditional architectural element used continuously in Sri Lanka.

The courtyard was originated thousands of years ago and the birth place got many disputes. But its evolution can be seen through number of stages and even in the contemporary modernity too. Through its long evolutionary history, 'Courtyard' played as a microclimate modifier, which make the interiors livable at any outside climatic levels.

As a country at tropics micro climate modifiers are hardly required compared to other regions. And also with the Sri Lankan society and its culture courtyards act as the private outside space which safeguard the inhabitants and yet provides an outdoor space.

Due to all these reasons courtyards are continuously used in the modernity too. But as an evolving element direct adaptation of basic courtyard form of a square shaped open space bounded from solidity on all four sides won't work in the modern day as predicted depending on the historical proofs. Therefore a study on its evolution and identification of its morphology is a worthwhile study at this present day.

By studying the courtyard origin and its evolution morphology of the evolving courtyard is figured as a timeless element yet with many variations. The ideal way of reusing the courtyard on the place of adaptation is further expressed through the case study at Light house hotel at Galle - one of the master pieces of late iconic Sri Lankan architect Geoffrey Bawa.

II. Origin and Evolution of Courtyards.

Definition of Courtyards

"Courtyard should conclude nothing but the whole universe" Louise Baragan's reference to the court of Myrtles the Alhambra in Spain.

Courtyard was often defined as an open space to the sky usually enclosed by building from all four sides.

During pre-historic ages man was a direct dependent of nature. But with the flowering of human civilization man became spate from nature through the creation of dwellings. But with time man wanted to interact back again with environment while they live behind the frame of their own dwelling. And courtyard was the solution for this, which was an interior space located within the boundaries. And this space accommodated the nature. Courtyard was the place where the whole outdoor universe was established within each separate dwelling.

"Man requires a place of seclusion, meditation, peace in his daily life. The courtyard serves as a 'room without roof'. The sheltered court garden t'ien ching (Well of heaven) served as a tranquil link with the cosmos for various independent ancient civilization including the Egyptian, Mesapothemian and Chinese."

The origin of the courtyard is disputed. Some consider Egypt as the birth place while some consider China as the birth place of the courtyard. It is revealed that the courtyard evolved from the early fire place that was found in the center of the building with a small hole on the roof about it to let the smoke out.

With the time this courtyard or the primal altar evolved into a central space enclosed by buildings from all four sides that open to the sky. According to Marc Olivier the man in the middle of the circular shaped floor of the primitive cosmic house connecting the sky was called as a "shaman" / priest. Reason behind this is that the cosmic energies get connected at the center point and this is why that the center space was left open in houses.

This same concept was what practiced in vasthu shasthra as well. According to vasthu shasthra, the centre point of any plot is known as Brahmasthan and that is the point where forces from all the directions get concentrated therefore this point is kept open to the sky with no hindrances from buildings. In order to keep brahmasthan free from buildings courtyards were used. Both these two concepts primitive cosmic house and vasthu shasthra proves the importance of including a courtyard to a dwelling. Due to followings reasons courtyard often serve as a space for religious activities and mediation. It is popular that in Hindu dwellings they plant their sacred thulsi (basil) plant which they worship daily in the courtyard. In Islamic houses the utmost place was given to the theory of segregation. Furthermore, the privacy is one of the main considerations.

According to Islamic beliefs, women should not be seen by outsiders or exposed to the street. The traditional Islamic courtyard house was designed as a spatial progression. To accommodate this concept, in order to permit women to enjoy leisure activities without being exposed to the outside. Furthermore, the courtyard located between four solid boundaries is considered to be a spatial symbol of inwardness and feminity in the dwelling. Courtyards provide more spaces for interactions among family members while ensuring safety and privacy.

1.2 Origin and Evolution of Courtyards.

Earliest written references to courtyards can be found in bible, book of Exodus. According to earlier written records it may be reasonable to assume that Egypt was the birth place of the courtyard. The generic form of residential courtyard houses has evolved from Egyptian- Sumerian civilization to the Mediterranean areas then up to Indus-Valley. When we consider these earliest stages of the courtyards, it goes back to thousands of years, of where there were Neolithic settlements. Therefore we can assume that the evolution of courtyard started around 3000 BCE. At earliest stages of this evolving courtyards it was only used for the protection from outside forces, marauding animals and from adheres weather effects. Early form of the courtyard is clearly different from the present courtyard. Because the intentions and requirements of having a courtyard get altered with time. When the considerations got focused on elements such as water bodies, plants, walls, the design of courtyard was neglected. Rather than the design these elements were used to enhance the quality, intimacy and quietness. Though the courtyard found today is modified to suit the present needs primarily it was the whole that was found in the middle of our ancestor's dwellings that was designed for the purpose of obtaining light and ventilation. This is the conventional courtyard type which has evolved over centuries. This primary courtyard has now undergone many changes to suite to the topography, site restrictions and building orientation.

With the passing time the primary form of the courtyard which is a central open space surrounded by built forms, evolved into a more complex urban tissue, or a fabric through aggregation of more built forms around a central space. During later periods the quality of the enclosure and its inward looking elements began to emphasize as a place of protection.

When we study the evolution of courtyard there was a distinct moment, it is when a precursor marked an area around a monocellular by an enclosing wall, then it became a reference point and then many aggregation of more cells around the central space. This same distinct moment affected the permanent settlements too. In permanent settlement, placing the dwelling units side by side as a serial cells is less regarded due to the more preference were towards the enclosure with a central opening with inward looking content, as in courtyard houses.

Accommodating the primary concept of courtyard in early stages made the shape of the courtyard either a rectangle or square in plan form. But over time its plan and three dimensional forms continued to evolve in many ways gaining rise to the dynamic modern courtyard. Courtyard is considered to be an extension of the living quarters which accommodates a multiplexing of functions. With these various kinds of activities courtyards were subjected to diverse influences and impacts with many implications. Therefore courtyard can be considered as the single architectural element which contains a huge range of changes.

1.3 Implications

1.3.1 Social implications

Society is main body that could influence an individual. With the formation of permanent settlements people were organize as a society, and they created neighborhoods. Within this society individuals were bound with bonds and norms .As courtyard served as a place where the family and other visitors could interact it became one of the most popular space in a dwellings. Courtyard provides the privacy and safety to a personal while it let the personal to interact with his family and the immediate society. This was one of the reasons that caused the evolution of the courtyard.

As biological clock ticks away human activities, their intentions, requirements got changed. As a result of this the primary courtyard got evolved for centuries to suit the present day requirements. Even though the primary courtyard served as a space that provides only the safety and privacy, present-day courtyard is used more as a decoration element. Today courtyard has become the only room to accommodate the nature in a dwelling.

1.3.2 Cultural implications

Culture comprises a system of beliefs and ways of living common to a specific group of individuals. With time

these cultural influences grew stronger. With the evolution of culture many beliefs were introduced to the daily routines of man. Courtyards found in Islamic dwellings are a better example to show the influence of culture for the evolution of the courtyard. In most of the Islamic houses they have more than one courtyard; main intention here was that to separate the public and private regions of the house. The public sphere is open to the outside visitors therefore it is only used by the male members of the house. Inner courtyards were built for private use; these areas are restricted for outsiders. This probably show how the cultural concept of gender implicated to change the configuration of courtyards.

1.3.3 Climatic implications

Courtyards demonstrate ability to moderate high temperatures, channel breezes, to adjust humidity levels and provide thermal comfort within the interiors. Thus, courtyards are considered as microclimate modifiers in dwellings.

Inherited properties of courtyards such as self – shading and thermal lag are used to reduce the heat gain in houses. Furthermore, properly planned orientation, proportions in designing and materials in construction of courtyards may overcome extra heat gain. Courtyards are normally found in hot arid climates to reduce high heat levels and moderate temperature levels to achieve liveable conditions. As clear sky is a common feature of hot and arid climatic zones, courtyards facilitate heat radiation from surface materials, functioning as a cool air reservoirs, which help to reduce heat in ground level rooms.

III. MODERNITY OF COURTYARDS

Courtyards in Modern buildings.

2.1.1. Place of courtyards in contemporary living.

The contemporary living house is not just a simple shelter but also an image which expose the social class or the status of the inhabitants. Therefore the image of the house is much more concern than the interpretation of spaces within it. The modern house has become one of the mediums that are used to convey their status and power within the society.

Except for this sociological justification societies were further influenced by the outside world due to globalization that took place rapidly with the time. And also with the colonial influences on Sri Lanka the orientation of the house layouts was changed. In traditional forms house was oriented around an internal middle place (courtyard) but with the European influence these houses were reoriented on the basis of access road. There by the internal middle spaces were neglected while the front spaces became prominent.

Furthermore the reorientation of courtyards was neglected as it was no longer useful to symbolize the social status once compared with the front spaces. Courtyards were further neglected with the notion of individualization of rooms. Therefore there was no any need of a central space which interconnect all the spaces. And also with modern socio-cultural changes most of the joint families are now use to live separately as nuclear families. Therefore even they don't want any specially designed courtyard kind spaces for them to integrate, the small living rooms are sufficient enough for this. With the urbanization and imposed housing policies placing a courtyard on a small land plot was difficult. And the inhabitant prefers more functional spaces than courtyards. With all these, courtyard was neglected from the contemporary living. Courtyard was permanently removed with the introduction of high rise apartments and compacted houses on small and narrow land plots.

2.1.2 Need of courtyards in modern buildings.

The modern world faces a vast number of environmental issues. And many different fields are responsible for them. Buildings too contribute for the 40% of the Carbon Dioxide emission. The main cause behind carbon dioxide emission is that the use of mechanical vents and other energy consuming means. With the urbanization and compact neighborhood in contemporary living, these modern small, compact houses are tend to ventilated mechanically. As built environment is responsible for the major portion of these environmental issues, the need of courtyard is exposed in modern buildings especially in tropics. Apart from the climatic factors socio- cultural aspects too expose the need of courtyards. Sri Lanka is a country with a proud history and a complex cultural background. Therefore some of these house layouts and elements like courtyards are bounded to our origin and identity. Therefore courtyard is a better option in modern day architecture. Architecturally courtyard is identified as an element that is beneficial both economically and aesthetically. Courtyards draw cool air and natural light and it reduces the use of mechanical vents and the

energy consumption which is economically beneficial. As courtyard accommodate green plant, water bodies, natural light having a courtyard is aesthetically beneficial.

Descriptively the courtyards are climatically ideal for the tropical regions as it circulate the natural cool air within the interiors. Courtyards can be made beneficial even for non-tropical regions, if the shape and the form of the opening is specifically designed to suit the location. And also due to Hindu influences Sri Lankans too believe in Vasthu –Sashthra and other spiritual theories and norms. And they further clarify the need of courtyards for modern buildings. Climatically a courtyard acts as a connective thermo stat and it provide the comfort and protection for the inhabitants from the weather conditions and the outside threats. The protection given by the courtyards along with its roof projections and orientations from the dust storms can be illustrated as a better example for this. Courtyards were extremely popular and wide spread not only on Sri Lanka but also all over the Indian subcontinent. Courtyard is not a fix element. It can vary from a very tinny opening to a large and a wide opening. And also once central courtyard can be the platform for another five or six courtyards enhancing the uniqueness of modern day architecture. For thousands of years courtyards have been playing a major role in built environment as an element which grabs the natural light and ventilation, creating the thermal and visual comfort within the interior. And also it has been acting as the common space of the dwelling which accommodate gathering of inmates. Though the modern day designs lack these ideal elements of tropics it is an ideal way for sustainability.

2.1.3. Usage of courtyards in contemporary design.

Though courtyards are neglected in contemporary living it was placed back in modern buildings, once the designers and the inhabitants need to incorporate their lives with the nature. Modern courtyards are defined as a room without a ceiling. The courtyard is the central feature of the architecture that brings two separated parent's and children's wings together while being the main private outdoor space. A series of courtyards can be seen instead of a one central courtyard in modern designs. This is clearly emphasized by the house at Walsh Street, Melbourne, Australia by Robin Boyd. The main function of the modern day courtyard is to enhance the aesthetical beauty and to allow natural light to central interior spaces of the house. And also these modern courtyards are used to grow vegetation within compacted dwelling envelope. To soften the built forms of the particular space and it adds a green backdrop to solid built form.

Figure 2.1 - Malalasekara house at Borella. By Archt. C.Anjalendran.

Figure 2.2 - Own house of Archt. C. Anjalendran

In contemporary dwellings and in other non-domestic buildings usage of windows from floor to ceiling is common. This modern trend further influences the use of interior courtyards of the modern houses. Furthermore courtyards are useful for entertainment and leisure activities due to its close proximity with the nature, which indirectly relax human mind. At present small private courtyards are made focusing on a single bedroom or a bathroom. These courtyards help to gather light and ventilation. And also while securing once privacy it gives an internal feeling of being outside in nature.

Figure 2.3 - Maya Resort at Tangalle, Sri Lanka.

Figure 2.4 - Maya Resort at Tangalle, Sri Lanka.

Varying from above mentioned courtyards, it may also accommodate the entrance. In modern designs use of a courtyard just behind the entry hall is very common. This allows the entrance way to get open to a well lighten and a ventilated space that creates a good first impression in human psychic level. And also it allows a cross view through the house.

Figure 2.5 - Cross view through spaces in modern dwellings.

The materials are one of the determining features of an architectural space. Materials that are being used in courtyards are one of the main ways how the present day courtyards are made different from the traditional forms. Natural unadorned materials are used in modern courtyards. Modern trend is a movement against "Featurism" and therefore courtyards are made simple, non-decorated and they expose the basic structure of the building.

Figure 2.6 - Garden house in Sri Lanka

Modern courtyards aren't afterthoughts of the major design. It is used in designs by most of the contemporary architects all around the world. Diverse shapes of courtyards and the designs based on courtyards create interesting forms in modern dwellings. And also it increases the comfort level of the inhabitants as it facilitates with well-ventilated spaces. Therefore this is commonly used in compact urban fabrics. Sometimes courtyards are also used to create interesting unique forms which indirectly create rich spatial progression through the interiors. As seen in the modern house by Roy Grounds, in Trook courtyards can be easily identified due to its perfect geometry with a central circle shaped courtyard blending with a square shaped building around it. The traditional courtyard that was used for rituals and religious activities are now being replaced by *'Al-fresco' kind of courtyards. (*Al-fresco :- an undercover outdoor entertaining areas.)
The traditional courtyard form isn't a fix form, it got evolved with time. But before the modern civilization development of courtyards. It was seen through few distinguish stages such as, Ancient civilization, Classical civilization, Middle age and Renaissance civilization.

2.2. Traditional Courtyard Form Evolving into a Modern Form.

2.2.1 Traditional Courtyard Forms Ancient civilization.

According to Schoenauer and Seemen primeval and the homogenous society in the village of Matamatas, Southern Tunisia, was the first social group to build a courtyard house form. Schoenauer and Seemen define this primeval courtyard house form as, "Each dwelling unit is built around a carter open to the sky with slope wall and flat bottom". [Schoenauer and Seemen,1962]
Except for these primitive societies the first rectangular dwelling in Morocco introduces the first prototype of courtyards.

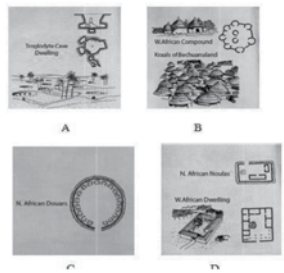

Figure 2.7 - Different types of courtyard form in Africa (Schoenauer, 1962).

Another ancient courtyard form can be found in China. Chinese primary dwelling forms are highly influenced by their religion and their philosophy 'Yin and Yan' [Schoenauer and Seemen,1962]. And therefore the courtyard was used as a private space for meditation. But the noticeable point here is that the un-identical nature of the reasons of using courtyards in the two primeval forms. (Mesopotamian and Chinese traditional forms) And also in Mesopotamian forms courtyards were surrounded by number of rooms and in Chinese courtyards, they are surrounded by individual housing units which were owned by different people.

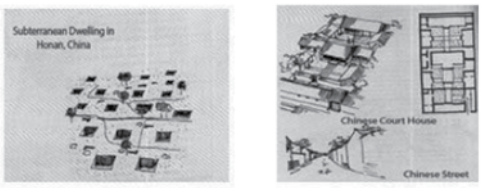

Figure 2.8 Typical layout of Chinese dwelling and courtyard houses (Schoenauer, 1962).\ Classical civilization.

This civilization adds another traditional form known as 'The Atrium' house. This form was developed around 700 BC in Italy. Atrium house has a small form courtyard in the centre with a container kind of opening. It was surrounded by rooms. The significance of this form is that it provides a private outdoor space. Later this container type enclosed courtyard form got mixed up with a Greek pre-style. Therefore the enclosed atrium courtyard turned into a new form of Atrium pre-style in which court was enclosed by columns. Thereby two traditional forms are found as Atrium style and Pre-style atriums. They were placed in large massive built houses. Primitive pure form of courtyards could be seen in classical civilization along with many changes.

Figure 2.9 - Typical courtyard dwellings prevalent during Classical Civilization (Schoenauer, 1962).

Middle ages civilization and Renaissance

This era is significantly marked due to the fall of Roman Empire in 476 AD. Still courtyards prevailed in Christian church was used as a place to conduct meetings and also as a space to place water fountains. And in Islamic countries such as Middle East courtyards were made ensuring their privacy for the sake of their women and children while providing them a place to relax.

When considering dwelling type courtyards there are two specified forms in Northern areas around the Mediterranean Sea. (According to Das, 2006) One of them is in Spain which is basically influenced from Roman Atrium style. And the other one is found in North of Spain which is comparatively solid and used for daily outdoor routines. At later periods due to Spanish Colonists, Patio design style was also got mixed with Latin American courtyard forms.

2.2.2. Modern courtyard forms

2.2.2.1. Origin of modern courtyards.

In the modern era the courtyard was initially found in west coast of North America. Later the courtyard type was popular all over the United States. In these modern houses courtyards were used to separate the living spaces from private bedrooms in a unique way. (Das, 2006) Narrow terrace houses that were seen in States in this era further modernized the use of courtyards. (Duncan, 1973) During the modern era simple one storied courtyard house form was wide spread all over the Europe as it was popular among the low income groups of people. (Duncan, 1973) The first house of this kind was done by Hugo Haring in 1928. This form was later derived into more popular L shaped house form in England and Germany in 1960.

2.2.2.2. Modern courtyard as a static architectural element.

From the very beginning, courtyard was not a static element as it varies from every era to every civilization. Courtyard does not have a rigid form or a specific shape, area or volume. In early traditional forms rectangular, circular or a square shapes could be seen. But with technical innovations, urbanisation, psychological and cultural backgrounds altered the courtyard into different forms. And also the function of courtyards too got evolved with time. The traditional shape was later altered to U, L, T, and V, H or Y shapes in modern buildings.

Positive and Negative impacts of Courtyard usage in contemporary living.

Using a courtyard in the modern design has many positive potential and benefits. And at the same time there are difficulties, negative impacts and short comings as well. The way how a courtyard is been adopted determine whether the impact is negative or positive. Shape of the courtyard determine the benefits. Rectangular shaped courtyards can be used to protect the building basically from solar radiation and dust. (Tablada.2005)

Courtyard which is surrounded by solid built only from three sides is a new form of courtyards. Due to the well planned orientation of these three sided courtyards they create a more comfortable conditions within the interior. (Meir 1995) with further ecological consideration, courtyards can be also used in high rises for sustainable urban living. (Rajapaksha .2003)

Impacts of courtyard are determined by many variables such as, Orientation, Wall enclosure, Courtyard natural elements.

Orientation

Orientation of the courtyard may cause the thermal comfort or discomfort. Therefore courtyard should be planned on the building layout considering, Solar path, Solar angle, Wind direction, Shading performances. (Meir, 1995)

Wall enclosure

The term wall enclosure refers not only to the wall around the courtyard but also to all the elements such as walls, doors, windows, etc. These elements together define the form of courtyard thus the form affect the micro climate. By manipulating these elements at the design stage can increase positive impacts. According to Almhafdy (2013) colour, material, shading devices can also add a direct effect on the micro climate.

Courtyard natural elements.

There are many natural elements within a courtyard such as vegetation, water bodies or spray. These elements can affect the thermal comfort and micro surrounding of the courtyard. According to Almhafdy (2013) vegetation on the courtyard can reduce the air temperature as plants on ground prevent the surface heating. Water bodies, water sprays or fountains further cool down the air and make the interior more cool and liveable even in extremely sunny days.

2.3. Morphology of the evolving Courtyard.

Sustainability is one of the most prominent modern architectural moments due to present global environment issues. Sustainable living is a way of living in which the energy and materials are consumed in a manner it also allows the future generations to use them. In order to achieve sustainability weather should be considered as a co-author with architects, and also building should be considered as a vessel of human activities. Further it enhances materiality and immateriality and also the human topography rather than the material topography.
In an island like Sri Lanka it's not enough to consider only these theoretical approaches to achieve sustainability as its whole system is inspired and originated from its traditional wisdom. In Sri Lankan history of architecture the courtyard is one of the most prominent elements which is used to achieve traditional sustainable living. Therefore it may be beneficial to adopt courtyards to modern buildings. But the courtyard was a dynamic element throughout the evolution. Therefore it is compulsory to identify the morphology or the structure of this evolving element, courtyard, in order to use it appropriately in modern day designs.

According to Yiorgos Hadjichristous, 'Placeness' is the major force behind the evolution of courtyards. 'Placeness' has been further discussed by many architects all over the world.

"the origin of architecture is to provide a physical shelter….. however the primary task of architecture is to create the experience of 'Placeness'…."

[J. Pallasmaa, The Aura of Sacred. Catholic University's School of Architecture and Planning in Washington, DC, 2011.]

" distinction between place and space, where space gain authority not from 'space' appreciated mathematically but 'place' appreciated through human experience."

[M. Heidegger, Building Dwelling Thinking. Harper and Row, 1971.]

" in order to discover the richness of 'place' through architecture, the designer must engage with the specificities of culture, location, and experience that make up everyday existence.

[T. Randall, Building-in-place. Phaenex 3, 2008]

This can be further prove through the diversity of courtyards in different regions such as Mexico, China, Cyprus and India. This diversity occurs only due to the 'Placeness'. Because courtyards are not defined only by the solid built form around it but also by the preference of human mind. Therefore the courtyard should be identified through Placeness as Placeness or the place is an experience of human mind. Even though the courtyard is a dynamic element, it has two basic principles which were constant throughout the history. And they are, 1- to create a micro climate and 2- to provide a private outdoor space exclusive to the residents.

Morphology of the evolving courtyard can be concluded as a dynamic form adapted from past with considerations such as degree of enclosure, spatial configuration, facade proportions, architectural details and materials. But not the basic traditional form. And also the morphology of the evolving courtyard is also identified as a place to accommodate landscape as small plots of present doesn't have any gardens.

When considering about shape it should be Malleable and Flexible.

Figure 2.10 - Network of central and peripheral courtyards

And at last the most important thing is the way to use it on realistic designs, not as an object which adds at the later part of the design but at the very first beginning of designing. Ultimately when considering the morphology of the evolving courtyard it is the compositional element in a design. Therefore it should place at the beginning and then design other spaces will raise the positive potentials. And also morphology of the evolving courtyard should identified by the designers as the core blending medium of human topography with built topography rather than a decorative element.

III. CASE STUDY

3.1 Justification for the Case Study Selection.

This essay is based on the architectural element, 'courtyard' which prevailed over many decades, and its evolving morphology. Theories regarding courtyards, its origin and evolution were presented in previous chapters. The practical Usage of courtyard and correct adaptation is what discussed on this third chapter.

Sri Lanka is an island located in the tropical region, with a unique patter of climate, geography and topography. Architecture of this Island should be in a unique style to suit its tropical climate. Ultimate achievement of architecture is not just the beauty but also the satisfaction of inhabitants through their physical and mental comfort. Therefore adapting European modern architectural style directly to present day designs here on Sri Lanka won't be sufficient enough to achieve its ultimate goal of success.

Sri Lankan professionals understood the requirement of a unique style of architecture to achieve an interior comfort against this tropical climate. Great Sri Lankan iconic architect late Archt. Geoffrey Bawa was the founding member of 'tropical modernism'. This is a unique architectural style that suit for both the tropical climate and modern day movement. Sir Geoffrey Bawa found this style after going through a series of experiments and continuously practicing it in his designs. Later tropical modernism was widespread all over the world.

When we consider the masterpieces of Sir Geoffrey Bawa such as kandalama Hotel, Benthota Beach hotel, his own house, house of Ena De Silva it can be highlighted that courtyards have being used as the major architectural element in tropical modernism. As this essay is based on the courtyard, a design by the founder of its own movement is selected for the case study. Among no of great designs, Light House Hotel at Galle got a series of courtyards throughout the premises. And its whole journey was created through courtyards. Therefore the Light House Hotel by Jetwing was selected for the case study.

Furthermore huge number of positive comments from guests all over the world and its great appearance along with comfort and satisfaction of users, justify studying this 'House of Light' at tropics.

3.2 Light House Hotel in Galle

3.2.1 Introduction

Light House Hotel is located in the outskirt of the ancient city of SriLanka, Galle .Hotel site is on a rocky outcrop, which is three miles long to the west of Galle. The hotel was commissioned by Herbert Cooray in 1995 under his own company "Jetwing". Earlier this site was used as the magistrate's circuit bungalow. The site is demarcated from the Galle- Colombo main road and the Indian Ocean. The ocean status is in hospitable at this site but fortunately the site open for a great vista towards white waves of Indian Ocean.

Galle as a distinct tourist city its coastal line is full of hotels and resorts. Giving the write meaning to its name, "The Light House Hotel "it stands out as the "beacon of light in the dark". And Light House Hotel is the architectural design by the great Sri Lankan Archt .Geoffrey Bawa. Its minimalism along with elegance creates visitors a wonderland.

The Light House Hotel is famous all over the world for its spectacular views and vistas, the journey through the hotel and marvelous pleasant spaces all over the hotel.

3.2.2 Design

Light House Hotel which is a masterpiece of Sir Geoffrey Bawa is a very architectural design that has being appreciated by all the visitors who are related and non – related to the profession of architecture.

Showcasing the greatness of the architectural design of the light house hotel owns a rich and interesting space progression through both vertical and horizontal axis. This space progression act as a connector as well. Through the vertical axis it connects the earth and sky, and horizontally it connects the land and the Indian Ocean

Figure 3.1 – Architectural floor plan of Light house hotel.

The main entrance of the hotel faces the Galle- Colombo main road. Stone licensed walls in the exterior give a grand appearance to the building. Instead of a one single defined space there is a series of spaces at the entrance which gives an exciting first impression.

Figure3.2

Figure 3.3

Right after the reception lobby, visitors are taken five centuries back to the battle of Randeniya, through the sculptural stairway designed by Artist Laki Senanayaka. This historical story is made on the hand railing of the stairway. Reception lobby ends at this round shape well defined space, in which the stairway rolls up. And on the centre of the stairway rocks and water bodies are placed to represent the mother earth.

Figure 3.4

Right after this historical drama, visitors are directed to a huge lobby that opens directly to the infinite Indian Ocean. This make every soul to be so attracted to this place. This lobby basically comprise of two levels. One lobby serve as the main lobby while the other serves as the intermediate lobby that give access to other areas.

Figure 3.5

One side of the intermediate lobby opens to an eye catching dining area that opens to the infinite Indian Ocean. And one side of this dining area opens to a colonnade that leads to beautiful garden courtyard that faces the old Dutch Galle Fort the other side of the intermediate lobby opens to a another colonnade which lead the visitors to private room areas.

Figure 3.6

Further enhancing the soulfulness of this design this colonnade ends at the foot of a statue. At the end of this colonnade there is a natural courtyard comprising all the beautiful elements of nature. In middle of this courtyard there is a small ring of rocks that divide the courtyard into two paths. One of these path leads to private room areas while the other leads to another courtyard and garden where the infinity pool is located.

Figure 3.7

Above detailing present the design of Light House Hotel along its horizontal axis. And this design is much more than what is there we found in this horizontal axis. Light House Hotel has a very unique style in its vertical axis as well.

Apart from the walk you take horizontally at Light House Hotel there is another interesting and exciting part of the journey left which you should climb up along its vertical axis to experience the untold beauty behind it.

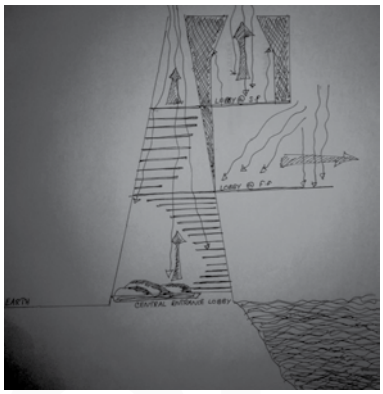

Figure 3.8

3.3 Usage of Courtyards

Light House with its particular location, is really a house of light .It is not just a shelter but also a bridge that let the people to take a walk from this tiny Island, Ceylon to the infinite Indian Ocean and it is also a ladder that let the people climb to the limitless sky. Light House hotel makes every soul surpass all the limitations and makes our heart and soul sore to the infinity. Light House Hotel is a place that stimulates the sixth sense of human mind. Early segments of this chapter emphasized and discussed the greatness of the architectural design of the Light House Hotel. And here in this segment the usage of courtyards and the importance of it will be emphasized.

Figure 3.9 - Plan showing only the solid spaces

Figure 3.10 - Plan showing only the courtyards

Figure 3.11 - Plan showing the complex including solid and courtyards

Folding these plans one by one itself shows the importance of role that has being played by courtyards. Without these courtyards Light House won't be this interesting and appreciated.

Important point out here is not the use of courtyards, but the fine detailing of it. Such as location, size, shape, form, volume and elements. Furthermore this interesting spatial progression was achieved through a series of courtyards. Further the courtyard study can be done through studying each courtyard type separately. Below plan shows the numbering of courtyards.

Figure 3.12

Courtyard 01

It is a round shaped space that opens to the sky. This courtyard represents the primitive form of the courtyard and the cosmic house. Rocks and brackish water on the ground represent the earth. The hole on top allows the light to enter. The person who is standing in between will always feel the soulfulness through the correct touch of Genius Locai.

Courtyard 02

It is a rectangular shaped courtyard which is a modern form of courtyard which bounded by solid built forms only from three side, and works as an intermediate space in circulation. Moreover it is not centered as in early forms.

Courtyard 03

This is much more an evolved form of modern courtyards. The shape of it is a rectangle which represents the modern courtyard forms deviated from the primitive square shape. And also it is not bounded by built forms from all four sides.

Courtyard 04

This form of courtyard can be identified as a pure traditional form. As a traditional one it is a rectangular centered space which opens to sky. And also it is bounded by solid built forms on all four sides. But to adapt to the particular location it holds some stairs, trees and some rocks as elements of modern courtyards.

Courtyard 05

This can be identified as a fusion of modern and traditional courtyard forms. It is a rectangular shaped space which is open to sky. And also as in primitive forms the intention of having this is to gain natural ventilation and to provide privacy for the guests. But still as it not a centered space, and as it is not bounded by solid forms, it express the modernity.

Courtyard 06

This can be identified as the most modern form as it runs from solid to the void of infinity. And also the water body which is added as an element have been the major element at this point, as a swimming pool.

Morphology of a courtyard can be stated as a timeless element. Courtyard study of Light House shows that there are diverse forms of courtyard that belong to different evolving stages. This shows the timeless morphology of the courtyard. Though the design is made to suit the modern day right placement of primitive courtyard forms can add a more colour to the design. Understanding the morphology of the courtyard as a timeless element will enable the designer to use any forms of the courtyard that is at any evolving stage to suit the requirements of modern day. Furthermore Light House design prove that the morphology based only on the shape is not the real understanding. Morphology of the courtyard again is not about the time of the evolving stage. It is all about the "placeness", spirit of place gained through the structure. Though how timeless it is, morphology of courtyards include two basic points such as creating a microclimate and to provide a private outdoor space. This is clearly shown by the Light House design. Courtyard No four can be illustrated as a better example for this is the courtyard 4.

Figure 3.9 - Plan showing only the solid spaces

As the courtyard is in between built forms, this makes the courtyard to take more or less shape of contemporary form of courtyard. This courtyard in between these built forms creates a microclimate all by itself and won't let us feel that this is in the coastal line. Furthermore this courtyard provide a private outdoor space for the users in between their rooms, pool and the lobby

If all these concepts of Light House Hotel are summarized together it could be stated that the morphology of a courtyard is a timeless element, which can be use appropriately for the designs determining the number of courtyards. And also it can be stated that it is an element which accommodates other elements that stimulate the human mind in a pleasant way. Courtyard can be used as an element that brings physical comfort and beauty. This can be concluded by saying that morphology is basically depends on its place, design and concept regardless of the time and the quantity.

IV CONCLUSION

The courtyard which was originated as a central fire place has been evolved into a more modern courtyard complex. This essay shows the entire evolution of the courtyard up to the present day. Moreover as described in second chapter it's not just an element of history but one of the comprehensive solutions to all present day environmental issues. As pointed in scientific researches the built environment contribute in environmental pollution with a noticeable weightage. Therefore modern world appreciate the sustainability of the building more than its appearance. Architects as professionals should be responsible for the built environment of the country. Therefore they should be more concerned on the sustainability of the building. For gaining sustainability courtyard can be easily used.

As presented in this essay timeless morphology express that the designers should use it not as an element which can be added later, but as a design factor which should considered at initial design stages. Moreover there isn't any requirement of using the most modern form of courtyard or neither the pure traditional form but the perfect morphology depending on the site, architectural design and inhabitants.

Long term validity of this whole essay is that the morphology which is expressed in the essay can be easily use for modern high rises and also for future giant buildings too. But the most important thing is that the courtyard can be used in these high rises only if it is

designed considering the one particular high rise at its own site. With that concern courtyard morphology which is described through this essay can be further developed towards the future which is yet unknown.

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IMPACT OF TRADITIONAL SPACE PLANNING ON THE SEMI-PUBLIC SPACES OF CONTEMPORARY SRI LANKAN HOUSES

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Abstract - "Tradition" is the energy of a society and the most valuable asset they have inherited from the past. Since a majority of client population with traditional roots are looking for houses with a traditional semblance, such houses are on high demand. As a result, the field of contemporary Sri Lankan architectural phenomena has addressed by various traditional elements and concepts. Socially and culturally sound semi-public domains such as verandas, living and dining areas are the prominent testimonials which attract clients' demand for designs with traditional qualities. There is a contentious debate as to whether contemporary domestic spaces which "appear" as designs with traditional underpinnings are genuine intellectual application of traditional spaces for the betterment of occupants, or just Imitative and Insensible representation of traditional architecture. The main objective of the research is to evaluate traditional impacts and derive basic planning guidelines illustrating how to incorporate traditional space planning principles for contemporary houses. The first part of the research deals with a study of literature and a field survey conducted among selected pre-colonial and colonial Sri Lankan houses to accumulate the required data for evaluation and design concepts with a special reference given to semi-public domains. The second part is an analytical study of the semi-public spaces in three selected contemporary domestic buildings designed by three Sri Lankan master architects. Final part is the qualitative and quantitative evaluation of the data and experiences gathered in the first two parts of the research. Plot size manipulation, spatial progression, visual axis, geometry of spaces, degree of enclosure, privacy and natural lighting were found as the key factors of space planning and defining spatial qualities of the traditional Sri Lankan houses. Design guidelines were developed based on above factors which help to design domestic semi-public spaces for the physical and psychological comfort of the users.

Keywords : Sri Lankan house, semi-public spaces, Traditional space planning

I. INTRODUCTION

'Tradition' is the energy of a society and the most valuable and important gift they have earned from the past. It may be either tangible or intangible. But that is the driving force and the navigator of a society. A tradition decides the pathway to future. As a highly community related activity, the design and construction of a house was also subjected to traditional influences of past decades. As a result traditional influences were used as a basic generator of architectural designs. There are several Sri Lankan architects, who have performed positively in creating delightful special experiences in domestic contexts by following traditional principles of creating various special expressions. Contradictory, there is another tendency of erotically interpreting the tradition and inserting it for the domestic designs. Within the contemporary architectural practice both types of practitioners and their products are available and this tendency is more likely to proceed for the future by modifying the tradition according to the society as well.

A. Justification And Objectives

Due to the high demand in the current society of Sri Lanka for the term "tradition", domestic buildings are

mushrooming under the label of "Traditional architecture". But it is questionable whether all of those creations are resulted by a genuine design effort with a better perception about traditional architecture and the design principles beneath it or followings,

- Imitative representation of traditional spaces
- Designers own thoughts which present as traditional
- Insensible and alienated implementations of traditional spaces or
- Afterthoughts.
- Therefore a proper study focused on the below mentioned points is needed to guide designer to accomplish their design goals by appreciating traditional Sri Lankan architecture.
- Extract governing forces and generators of traditional space planning methods in domestic buildings
- Identify selected contemporary domestic examples and analytically prove the traditional influences on identified spaces
- Derive basic space planning principles extracted from traditional examples , that can follow in present day designs

"The tradition was not static; it changed with the time and the changing needs of the society" [De Silva, 1990, p.08]

II. METHODOLOGY

A. The study consists in three parts

- Part 01: a study of Formation of spaces in Sri Lankan traditional house and a study of semi-public spaces in Sri Lankan traditional house:

- A literature survey was done to find the universally valid factors behind the concept of the domains in domestic buildings. Afterwards the study directed to explore the Formations of spaces in Sri Lankan traditional house under relevant factors.

- Part 02: analytical study of semi-public spaces in traditional Sri Lankan houses:

- In this section six (06) house types within three (02) main categories were taken as models to study the arrangement of the semi-public spaces in space planning.

Category 01-Sri Lankan Traditional rural houses:
Traditional houses of north central province, Kandyan period yeomen's house, Houses of Kandyan period feudal lords

Category 02-colonial influenced Sri Lankan houses:
Portuguese influenced traditional houses, Dutch influenced traditional houses, and British influenced traditional houses

- Part 03: Impact of the Semi-public Spaces of Contemporary Sri Lankan Houses on the Traditional Space Planning:

- Three cases studies were conducted to explore the space planning techniques with special reference to the semi-public domain.

Spatial parameter	Case study 01	Case study 02	Case study 03
Floor area	2700 ft2	3200 ft2	3800 ft2
Number of bed rooms	03	04	05
No of floors	02	02	01
Area of the site	2722.5ft2 (10 p)	6125sqft2 (22.5 p)	29948ft2 (110 p)
Year of completion	2004	2003	2008

Table 01: Details of case studies

Each case study is a unique contemporary Sri Lankan house designed by three different pioneer Sri Lankan architects

B. Method of data collection and Method of analysis

All necessary details for the study were taken by studying Details briefs of each building, Client overviews, Designer's vision, Architectural drawings and Real time spatial experience. The data was collected by observing each building, by analysing architectural drawings and by interviewing the Architect and the design team. Contemporary and traditional space planning was comparatively analysed graphically using floor plans, cross sections and real time observation of each building. Detailed briefs, construction details, details about the clients and architects vision were taken as supportive information for the analysis.

III. RESULTS & DISCUSSION

A. Major forces

The study found following universally valid two major forces that causing the evolution of spaces in the traditional Sri Lankan house.

- Physical forces
- Socio cultural forces

B. The domestic comfort

Universally people in different parts of the world struggled in space planning process to handle foresaid forces seeking for one important thing called "comfort".

"The need for sensory stimulation and satisfaction, and hence for visual and social complexity in the environment, seems contact of both man and animals". [Rapoport, 1969, p.79]

The comfort can be divided in to two components,

Physical comfort - good sensations experienced by the body

Psychological comfort - good sensations experienced by the mind

C. Generators of the domestic comfort

By examining Sri Lankan traditional domestic examples four (04) generators were identified which can generate the physical comfort and psychological comforts of the user. Four generators are given below and can act independently as well as interdependently in space planning process.

- **Security or protection**

From early childhood Security is a main requirement of a human being to avoid various dangers that can risk his life. The risks are considered as threats coming from natural environment or climate, humans and mystic sources. Therefore psychologically people expect higher degree of security from their domestic environment and it improves their comfort and so do the satisfaction.

- **Territoriality**

As one of the psychological attributes, the territoriality is an important criterion of creating one's own demarcation, especially among the human beings as one of the most territorial animal. Territoriality was demanded when man wanted to maintain his identity and privacy within the household. People tend to define visible and invisible boundaries to develop his own identity in his territory.

- **Privacy**

The nature itself has created "hidden spaces" for its living and non-living species. The secrets of nature have been embodied in the word called "privacy". Privacy in a house is not only related to oral or visual privacy. It spreads through a wide range of personal choices and heavily related to emotional relaxation. And privacy is also is one basic need to form the concept of domains
"The desire for privacy may also take forms related to the separation of domains" [Rapoport, 1969.p.66]

- **Identity and belonging**

The Need of identity and belonging is an essential factor of the human beings. Naturally they tend to acquire some kind of uniqueness within the main society and sub societies. Language, dress, behaviour pattern are some of the social factors, which determine the identity of a specific social group as well as of a person. The concept of "Home Sweet Home" has been a popular term around the world. Irrespective of age or social class, everybody has strong bonds with their homes representing the sense of belonging

D. Formation of the domains

The Four generators directly involves in the process of forming different domains in domestic space. Those domains are essentials in space planning to create a comfortable homely environment. Domains formed by preceding generators as follows:

- **Public domain**

This is always the outside space of the building periphery. Anybody can enter in to this domain. (Ex. Public roads and surroundings, pathways in front of the house)

- **Semi-public domain**

The domain demarcates the social activities within the periphery of domestic environment. House holder's permission is expected for the activities take place under this area. Entering visitors, family gathering, are took place related to semi-public domains. (Ex. Front poach, verandas living areas, dining areas)

- **Private domain**

The space inside the domestic environment is arranged in such a way that they correspond to their degree of privacy

- **Hidden domain**

Space with very higher degree of privacy and with higher degree of attention for hygienic aspects (Ex. Toilets, Bathrooms)

- **Threshold space**

The space between two domains

E. Significance of the semi-public spaces for the traditional Sri Lankan house

Among the domain discussed above the semi-public domain has significantly modified during several eras from post-colonial periods to the present. In Sri Lankan traditional house planning the semi-public domain was important to place other domains successfully. Aesthetical appearance of the house, social relationship with the community and climatic response was also depended on the semi-public spaces. There for semi-public space was a key element formed by physical and sociocultural force under Sri Lankan context

"The addition of an external veranda on the front of the Sinhalese house, constructed with wooden columns or masonry piers, seems likely to be a fashion introduced under the external influence of either the Hindus or the Portuguese, probably the latter" [Sansoni, Ronald, Senanayake, 1998]

"Dutch houses were built to accommodate various officers of life in a colonial family…..

"….Often a wide verandah known as the "stoep" ran along the street frontage, linked to a main reception room, separated from more private quarters by a first inner court yard…"[Robson, 2004. P.37]

F. Parts of a semi-public space

Semi-public spaces of Sri Lankan traditional house were a combination of two main parts according to their orientation

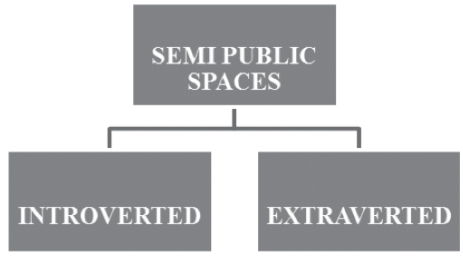

Table .02 Basic classifications of semi-public spaces

- **Extraverted part of semi-public spaces**

Outer space or most open space of a house. "Pila" or the verandah was the main dominating built form in many of traditional examples. This space was more open out to the natural environment with lesser degree of privacy and was the welcome space for visitors. In some cases it functioned as a security space or a threshold space between public and semi-public domains.

- **Introverted part of semi-public spaces**

Inner or the more enclosed part of semi-public space located within the inner proximity of the house. In most of the traditional house this was the centre or the main part and was functioned as a family space as well as the visitor's space. With the development of the semi-public space, courtyard was a dominating element in traditional domestic buildings. Some parts of this space functioned as threshold spaces between semi public and private domains.

G.Common features of space planning in traditional Sri Lankan houses

By examining the six traditional Sri Lankan houses from earliest tank fed village houses to British influenced bungalows some common planning techniques used to arrange semi-public spaces can be found. Such features can be briefly listed out as follows:

- Main and centralized space positioned with number of strong spatial links to other spaces

- Space has located on the centre axis of the house and symmetrical in form
- Space has designed by simple planning and well defined by solids, open spaces and edges.
- Threshold spaces introduced prior to the semi-public areas
- Entrance to the introverted part of semi-public space has located on the centre axis of the building or on a visual axis going across the open spaces.
- semi-public space became the largest volume found through the spatial progression
- Has maintained more closer spatial relationship with natural environment
- Within the domain, less privacy maintained between family members and visitors
- Colonnaded verandas and courtyards were the prominent built forms which was related to semi-public domains
- Diffuse lighting is promoted than direct sun illumination
- Courtyard and open verandas were the main inlets of light and ventilation

H. Case studies

Above discussed features can be seen in the contemporary domestic semi-public spaces in different ways.in selected three cases few space planning techniques has been used incorporate traditional spatial qualities in to the design. They can be discussed as follows:

- **Spatial flow and linkages**

According to spatial flaw and linkages there can be several similarities found between the spaces of traditional and contemporary semi-public spaces. Flow chart of every house has maintained a threshold space prior to enter the semi-public spaces. The Threshold spaces can be located within the built form or out of the building. But in all case studies always built forms of threshold spaces contain lower volume than the immediate semi-public space. Hence spatial flaw always directed from lower to higher volumes. A similar arrangement can be seen traditional houses as well. Most designs consist with a threshold space with lower volume comparatively prior to enter the immediate semi-public space.

- **Visual and physical linkages**

Case study one contains one main space for all semi-public activities including living dining and specially cooking. As a result entire space functions as a single volume by creating generating strong visual and physical linkages. This situation can be seen in Kandyan period yeoman's houses which one internal space facilitating all the activities including visitors meeting dining and cooking. Case study two and three has series of different spaces for different activities such as Living, Dining and Family gathering. All of them have physically linked by linear verandas. But direct visual links between each other have consciously avoided for creating of difference spatial experience through different spaces. Similar arrangement have used in most of colonial influenced examples with verandas , living rooms and dining rooms separated by walls to block the direct vision to each other. Link between natural environments is stronger in all three case studies which is a common situation in traditional designs.

- **Proportion and scale**

Due to impact of rituals and the technological limitations spaces of traditional houses followed simple geometry. Especially living spaces in traditional houses had the highest position with largest scale according to the hierarchical order. Spaces of All the case studies are similar as the traditional houses with simple geometrical in shape and uniform in height. Verandah are always linear, rectangular in shape and their width is always higher than the depth. But other semi-public spaces are rectangular in shape with a higher depth. Scale wise semi-public spaces always higher in size and volume than other spaces.

- **Managing the degree of privacy**

Within the domestic enclosure privacy was not a greater concern in basic Sri Lankan traditional houses. There weren't barrios between domestic activities and visitors. As discussed in presiding section "visual and physical linkages" all activities took place in a single volume. In case study one the internal spatial arrangement of main semi-public space is quite related to this traditional concept. All the day to day activities including family gathering, dining and cooking took place within a single volume. In case study two and three have different level of privacy within semi-public spaces because both of them containing more than one such space with linear linkages. But in case study 02 all the living, dining and family areas have exposed in to the central open space by maintaining the less privacy concept of traditional rural houses.

- **Use elements of the built forms**

Colonnaded verandah spaces with sloping roofs were the prominent elements of extraverted semi-public spaces and open courtyard spaces surrounded by internal verandas were the prominent elements of introverted semi-public spaces in traditional Sri Lankan house. Similarly, in case study two and three consisted with colonnaded verandas as the prominent built form of extraverted semi-public spaces. Case study one which only consisted with introverted semi-public spaces contains two internal courtyards. Even though they are not located in the centre of the spaces they full fill the functional and spatial requirements that traditional examples did. All the natural ventilation and diffuse day lighting is assured by this two courtyard spaces for surroundings which function similar to the internal verandas of traditional houses. Considering about court yards case study two consist with an interesting large central courtyard space such as the courtyard space of a Dutch street house.

IV. CONCLUSION

A.Important factors to be considered in space planning

By examining contemporary houses comparatively with traditional houses, following seven (07) factors can be identified that are important in planning semi-public spaces:

- Plot size
- Spatial progression
- Visual axis
- Geometry of space
- Degree of enclosure
- Privacy
- Natural lighting

B. Proposed Planning techniques
B.I. Plot size

- **Relatively large plot areas contain about 20 perches or more:**

The design should give more priority for extraverted semi-public spaces including verandas and podiums. In such a land introverted open spaces such as courtyards are not necessary to be included. Again the linear spatial arrangement is more suitable for such lands to provide different spatial experiences through the progression (Fi g.01)

Intermediate plot sizes contain about 10 to 20 perches: Both introverted and extraverted semi-public spaces are suitable. Especially relatively large central courtyard spaces with semi-public activities allocated around are infective for such a lands (Fig.02)

- **Small plots contain less than 10 perches:**

House has to locate by maximizing the rear space .more priority should be given into introverted semi-public spaces. One or more small scale courtyard spaces are suitable. But centre courtyards are avoidable due to the compactness of available space. Therefore corner court yards are more suitable (Fig.03)

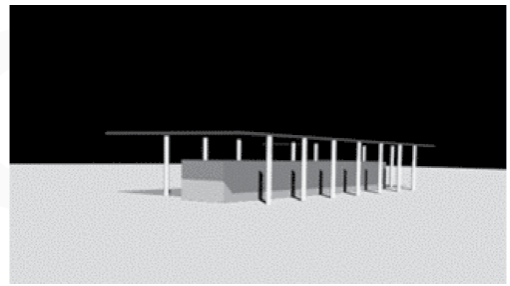

Fig.01. External semi-public spaces suits for larger plots

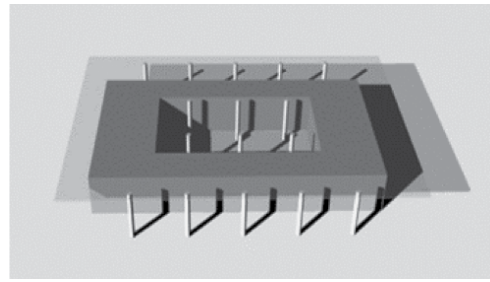

Fig.02. External and internal semi-public spaces suits for intermediate plots

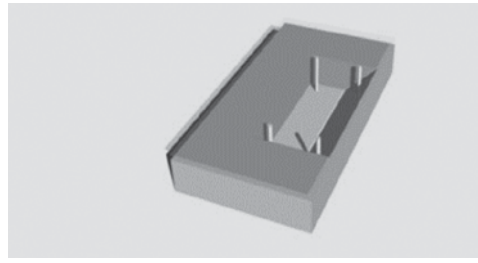

Fig.03. Internal semi-public space with a courtyard for small plots

B.II Visual axis

Centre axis of a semi-public space should run across an open space or a natural element such as tree or water body by visually connecting the two areas. Entrance to the semi-public space is also better to follow the same axis (Fig.04)

B.III Spatial progression

In terms of spatial progression threshold spaces and volume of the spaces is most important. The introduction of threshold space prior to a semi-public space is important. Always the volume of threshold space should be less than the immediate semi-public space. Weather there are several semi-public spaces some kind of difference in volumes of each space should feel to the observer in the progression (Fig.05)

B.IV Geometry of spaces

Simple geometry is the most suitable for spaces. Odd shapes are better to avoid as much as possible (Fig.06)

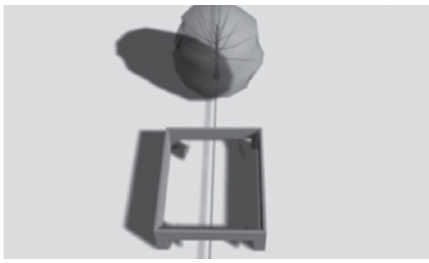

Fig.04. Orientation of visual axis

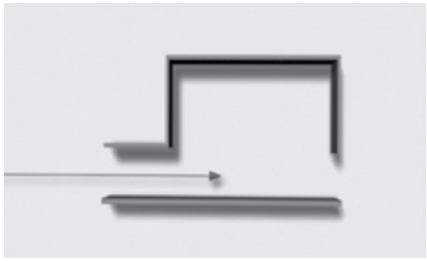

Fig.05. Spatial progression

Through different volumes

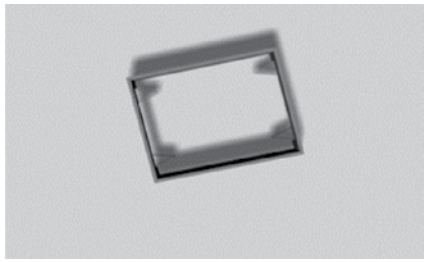

Fig.06. Simple geometrical space

B.IV Degree of enclosure

Semi-public spaces have to open to the environment as much as possible. Designing of highly enclosed spaces should be avoided

B.V Privacy

In terms of privacy the private areas have to visually separate by semi-public areas. Within one semi-public space or between two semi-public spaces privacy should be less. Then the different territories within single enclosure should be demarcated by furniture arrangements or by finishes.

B.VI Natural lighting

Direct sunlight should be avoided by shading devices such as verandas, extended eaves and diffuse light to be promoted using spaces such as courtyards

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REDUCING THE CONCRETE WASTE WHILE OPTIMIZING THE COST, TIME & QUALITY IN SRI LANKAN CONSTRUCTION INDUSTRY

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Abstract - Construction projects attempt to reduce wastage. In the present days, many projects are moving towards sustainable development while minimizing construction wastage. Among these construction waste material, waste has been recognized as a major problem in the construction industry. Construction Industry consumes a relatively large volume of material that have been wasted due to various reasons. It can happen due to the labour attitude towards the material, labour arrangement, and lack of knowledge in reusing or recycling the material. The main problem arising out of this waste is that it directly influences the project characteristic (Cost, Time & Quality). Along with this material waste 'Wasting Concrete' takes a high percentage that must be given considerable attention. The cost related to this concrete waste directly creates unnecessary expenditure for the employer's budget. As a result, most countries have found several factors to minimize the concrete waste where all stakeholders can collaborate with the project. This research aims to analysed analyse those factors within the Sri Lankan construction projects to reduce the concrete waste based on case studies of three on-going construction projects. Data will be collected by interviewing few stakeholders from each of the selected on-going construction projects. Based on the case study findings, a framework will be developed for the reduction of concrete waste in construction projects, which can lead to a cost effective and on-time completion of projects.

Keywords: Reducing concrete wastage, financial expenses, construction projects, Stakeholders

I. INTRODUCTION

A. Background

Construction industry comprises a wide range of activities that covers the erection, repair, and demolition of all types of buildings and civil engineering structures. Generally, in this industry includes for different types of construction activities that will be carried under namely by "Projects". Project represents a discrete piece of work with a clear start and finish dates, providing specified benefits at the accepted cost (Frank Harris, Ronald McCaffer, 2005). To choreographed above mentioned construction activities the involvement of the stakeholders are essential who are the once gain the benefits and have the interest for the final product directly or indirectly to complete the project in successful manner. In order to successfully complete the project, there was a most important factor as 'Project Characteristics' that need to be considered by the stakeholders. In construction, there were three main project characteristics as Time aspects (speed construction), Cost aspects (level of price), and the Performance (quality of the final product) that is essential to fulfilled in order to complete the project successfully.

To go for the stated aims and targets, it is essential need to maintain a proper management within the project for resource handling. Material, Labour, Plant and Machineries be the main inputs or the resources in the construction project. Both during the construction and demolition creates a large percentage of waste (Allain & Veuille, 2010). Material waste has been recognized a major problem in the construction industry. Construction Industry consumes relatively a large volume of material,

which have, being wasted due to various number of reasons. It can be the labour attitude towards the material, labour arrangement, and lack of knowledge in reuse the material. Every year, most of the countries sent these material wastes to landfill instead of being reuse and recycled those materials for new construction.

Now a day, many projects are moving towards sustainable developments while minimizing this construction waste. According to (Kulatunga, U, Amaratunga, RDG, Haigh, R and Rameezdeen, R, 2006) define the construction waste "by-product generated and removed from construction, renovation and demolition work places or sites of building and civil engineering structures". Therefore, due to this waste most of the construction projects are suffer with the material waste that create direct impact on project characteristics. (Jeyaraja Jayamathan; Raufdeen Rameezdeen, 2014) Stated that material waste can be non-site based which occurs due to design errors, design changes, ordering excessive material and site based which occurs at the time of construction carry out due to the labour attitudes, arrangement of storage and workforce. Out of this material waste, concrete wastage take a greatest place.

The problem arising out of this waste is directly influenced on the project characteristics. Among this material waste 'Wasting Concrete', take a high percentage that must take a considerable attention. The cost relates to this concrete waste directly creates an unnecessary expenditure for the Employer's budget. In most countries found that concrete is used as recycled aggregate in construction (R.A, Silva; J, de Brito; R.K, Dhir, 2014). The main problem raised for the concrete waste directly creates due to the human behaviour, their attitudes and as well as the arrangement of the work. (J, Saunders; P, Wynn, 2004) Found that the attitudes towards the waste minimization among labour and the other contracting parties in the construction. This minimization of the concrete waste will increase the productivity and it will optimize the main project characteristics.

The best way to minimize those concrete material wastes by reusing and recycling concrete or adding new techniques to the construction projects. Further (Allain & Veuille, 2010) discuss that the use of recycle material provides environment benefits as well as creates cost effective construction project. Therefore, the current trend in most of the countries are to use recycled waste and by-products in concrete to replace binders and aggregates (Allain & Veuille, 2010).

The main aim and the objectives of this research is to identify the factors effects to concrete waste and how it impact to the project characteristics while comparing the minimizing techniques that used by the other countries and propose most suitable precautions to reduce this concrete waste in Sri Lankan construction industry.

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II. METHODOLOGY AND EXPERIMENTAL DESIGN

This study has adopted qualitative research approach, the essence of which, according to Wigren (2007), consists of focusing on understanding the naturalistic setting, or everyday life, of a certain phenomenon by the investigator. Qualitative methods are essentially descriptive and inferential in character and focus primarily on the kind of evidence that will enable to understand the meaning of what is going on. Accordingly, among various approaches available in the qualitative approach, case study (Yin, 2003) has been selected.

The case study research method provides an in-depth investigation by studying 'cases' in an uncontrollable environment. According to Yin (2003), case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events and when the focus is on contemporary phenomenon within real-life context. Considering these points, the case study method was seen as suitable for this study.

In this study, cases were selected from the construction industries, which are focusing on reducing concrete waste to reap the potential advantages to uplift their standards. Accordingly, three industries were selected. From each case, three semi-structured interviews were conducted with three representatives from top management and middle management.

Altogether, nine (9) interviews were conducted and each normally lasted for 30 minutes to 45 minutes.

Table 1 provides the case studies and interviewees' with the details of reducing concrete waste in construction projects that were taken into account with the intention of collecting more accurate data for the research project.

Table 1. Details of Case Studies

	Project A	Project B	Project C
Interviewees	supervisor	Project Manager	Project Manager
	Project Manager	Supervisor	Labourer
	Quantity Surveyor	Labourer	Civil Engineer

Key themes (codes) emerging from the findings were identified within each case and replication of findings were tested using 'cross-case analysis.' The research results are presented and discussed next.

III. RESULTS

A. Material waste define in the context of Sri Lankan Construction Industry.

Many ways have been applied to classify the types of construction waste. Waste can be classified by their state, by their characteristics or by their origin. Construction waste has been defined in various countries in different ways.

Cost relates with the waste that creates a significant impact to the Sri Lankan construction industry. Wastage of materials in most of the construction sites in Sri Lanka is beyond the acceptable limits. In Sri Lankan context, construction waste debris from construction, refurbishment and repairing work and can emerge at any stage of a project from inspection to completion.

Many factors contribute to the generation of material waste. These factors can be grouped by under four categories as, design, procurement, handling of material and in the operational period.

Through the case studies that were taken into account, it shows that there is a majority who were not properly aware of construction as well as material waste; thus, it is clear that the knowledge matters are the main reason for not taking the best use of construction waste.

However, as per the Project Manager in project C and the Quantity Surveyor in project A states that, "there were mainly few causes of waste as design, procurement, handling of materials, and at the time of operation". Human factor involvement within the both pre and post contract stage has an influence for the increment of material waste. Further, the Supervisors in both project A and project B empherzied that, "causes of waste directly and indirectly affected by the attitudes and perception involved in construction industry". Civil Engineer in the project C states that, "most of the material waste cause due to design issues where the improper design results unnecessary amount of material waste". The challenge is likely to arise from the resistance to change and fear with relates to use new methods in reduce the material waste in construction. To receive the true benefits of reducing material waste, changes in procurement, processes, cultures and attitudes become necessary. Project B supervisor states that, "Important need to focus on labourers' attitudes towards waste and on waste generated as a result of construction site activities". Project Manager in project B expressed that, "Material reconciliation was carried out by comparing the difference between the store records and actual requirement of the material as the items in the bill of quantities (BOQ)".

The challenge may not be severe as much as the current experience would suggest. There has been evidence of positive changes in cultures and attitudes with the change of traditional strategies of material handling within the projects.

B. Stakeholders involvement in Construction Industry via Concrete Waste

Construction Industry is comprises with wide variety of complex activities where having relationships with large number of parties known as 'Stakeholder'. These stakeholders are the people who has an interest on the outcome of the project. Mainly the stakeholders be the Employer, the Architect, the Engineer, Project Manager, Quantity Surveyor, Contractors and other respective parties. Among the number of material waste, wastage in concrete directly effects to the construction projects.

The Quantity Surveyor in project A expressed that, "there was number of concrete waste due to variations which also happens due to design changes". Supervisor on project B states that," attitudes regarding the concrete waste differs from one person to another". However, in project C the Civil Engineer emphasized that, "concrete waste within the site is huge due to improper arrangements and the lack of storage facilities". In project B and project C, Labourer states, "they were not very much aware of the material waste within the construction and the material

arrangements". Quantity Surveyor in project A, "Concrete waste minimization practices must employed during the design stage where that need to conduct feasibility study of waste estimation by the designers". In project C, Civil Engineer states that, "due to delivery method and delivery schedules a huge percentage of concrete waste occur". Project Manager in project B expressed," people involve in the construction industry Sri Lanka is not much aware with the new methods as reuse of concrete for the projects will creates huge loss in their projects". Supervisor in project A expressed that, "due to using useless concrete transport pipes creates large amount of concrete waste".

When considering on above findings and the stakeholder in construction industry who are likeable to optimize the cost, time and quality within the project by reducing the concrete waste by using different techniques and recycling methods in Sri Lanka.

C. Drivers and Barriers creates due to use of new technology in reducing concrete wastage

To optimize cost, time and quality by reducing the concrete waste will brings both drivers and barriers to the construction industry. Development of new technologies, the amount of wasting concrete can reduce by involve with new techniques as, recycle concrete, use value engineering methods and few more. As per the findings, the Project Manager in project A expressed that, "to reduce the concrete waste within the project they mainly use value engineering techniques" and as a barriers, "Most of the people relates within the construction is not much aware with those new techniques". Supervisor in project B expressed that, "lack of attitudes on workers regards to new technologies". When considering and observing all the findings, the drivers and barriers that creates while implementing new techniques to reduce concrete waste can commonly gathered to a one place as follows.
Drivers:

- Reduction of landfill space required for concrete debris.
- Cost saving within the project.
- Enhancing the stakeholder collaboration on projects.
- Introduce new technologies to the construction industry.
- Creates more employment opportunities when introducing new methods to the industry.
- Financial benefits.
- Ranked up the contractors' standards among the others by using waste management practices.
- Barriers:
- Technical problems occurs when implementing concrete reduction techniques.
- People are fear to change their usual practice and they refuse to learn innovations and resist to alteration in roles.
- Huge cost need to invest to implement those innovations.
- Lack of skill persons.
- New techniques for the reduction of concrete may bring lower quality aggregates.
- Lack of experienced in the use of recycled products.
- Huge investment in management systems.
- Difficulties in placing new machineries in the project area.

D. Competitive advantages of using new technology for the reduction of concrete waste

New technologies for the reduction of concrete waste will gain more advantages to the on-going projects in the construction industry. While considering on the findings of the case studies, it clearly expressed the projects who are not very much aware about reducing the concrete waste by use of these new techniques that gain advantages. The Quantity Surveyor in project A expressed that, "Most of the time they apply various mechanisms or build up norms to stop unnecessary cost for wastage in concrete". Additionally, the Project Manager in project C emphasized that, "Concrete recycling practices within the projects are newly going to develop within the projects". In project B, Project Manager states that "Developed countries as Japan, United Kingdom and few use of recycled aggregate concrete in construction". Similarly, Quantity Surveyor in project A explains that, "most of the construction projects tends to use prefabricated elements rather than use in-situ concrete within their projects". Finally, observing the findings the advantages can categorized as follows:

- Reduce unnecessary expenses.
- Improve the bottom line of the project.
- Save resources and greenhouse emissions by breaking down landfill areas.
- Saving project cost by using recycled materials.
- Bring out value to the final product.
- Increasing the competiveness among other contractors.
- Changes in drawings and other modelling will update automatically.
- Saving the use of natural materials.
- Leads to handover a neat and a quality work.

E. Optimization of time, quality and cost via Recycled concrete

Construction Industry has main three words as Time, Cost and Quality. These three words are going hand in hand. These three words also known as ' Project Characteristics'. As the Quantity Surveyor in project A emphasized, "In cost wise concrete recycling method will reduce unnecessary costs spending for new raw materials". In addition, "time reduction is really essential". Further, "quality productivity may create and brings a huge value by use of vale engineering techniques". While observing other findings the Project Manager in project B stated that, "the material cost, installation time and the wastages in construction materials be minimize due to the practice of new techniques". Supervisor in project C expressed, "the type of attitude that with the labourers through minimizing concrete waste will help to reduce high accuracy on cost estimation and project time save".

Finally, these observations are pertaining to optimize the cost, time and quality in a certain construction project due to the new methods for concrete wastage.

F. Challenges arise while use of new methods to reduce concrete waste in Sri Lankan construction projects

Recycled concrete and new techniques gained advantages as well as challenges to the construction projects. There should be proper planning and management system when using those new techniques and recycle methods within the construction projects. However, projects needs to assess those challenges and collectively as a team must addresses for them with the help of rapidly changing technology.

Project Manager in project A states that, "most of the wastages occurs due to design changes where variations creates will effects for concrete wastage". Further in project B the Supervisor emphasized, "when ordering the concrete without having a knowledge relates to the actual work on site will also create wastages".

Finally, the observations of the all findings on challenges can categorize in common as follows:

- Affordability recycling machineries to the project.
- Untried liability issues.
- Design changes by the Client or the Architect.
- Improper storing capacities.
- Lack of knowledge in new techniques and the use of recycling concrete.
- Attitudes with the construction professionals.
- Improper placing and the delivery methods.
- Improper planning in the operational stage.

IV. DISCUSSION AND CONCLUSION

Massive generation of concrete waste causes a serious problem to the environment. Most of the developing countries are making efforts for minimization of the construction waste and reuse of waste in construction. Among number of construction waste, concrete waste tends to make huge lose in the project cost. Therefore, most of the stakeholders in the projects tries to bring number of ways to reduce this concrete wast by introducing value-engineering techniques, build up notes, and recycling the waste and some few other ways.

The main aim of this paper discuss the reduction in concrete wastage through different aspects while proposing new techniques to optimize the project characteristics in Sri Lankan construction industry by interviewing few stakeholders in an on-going construction projects. As per the result, that revealed that most of the professionals who were involved in the Sri Lankan construction field are seemed reluctant to adopt and not very much familiar with the use of recycled concrete and new methods for the construction projects. Therefore, a change in attitudes and perceptions towards concrete waste recycling and use value engineering techniques as 'Post Tensioning' will effect to minimize the concrete wastage in the construction projects.

To encourage the use of new technologies and recycle materials, there should be a proper communication method within the organization, provide proper information regard to the waste management practices, and provide clear technical specification or standards in use of recycled concrete for construction and thereby optimize the cost, time and quality within the construction project.

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