FARU PROCEEDINGS - 2015

8th FARU International Conference

11th & 12th December 2015, Colombo, Sri Lanka

'Making built environments responsive'

Faculty of Architecture Research Unit
University of Moratuwa
Sri Lanka

NATIONAL SCIENCE FOUNDATION

FARU PROCEEDINGS – 2015

‘Making built environments responsive’

The peer reviewed and accepted research papers of the conference are included in this volume

About FARU
FARU is the research unit of Faculty of Architecture, University of Moratuwa, Sri Lanka. FARU which consists of four academic departments (architecture, town and country planning, building economics and integrated design) organizes international conferences for the past seven years. It attracts academics, students, and practicing professionals.

FARU 2015 is held in Colombo and co-organized by National Science Foundation (NSF) of Sri Lanka.

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ISBN: 978-955- 9027- 53-9

Published by
Faculty of Architecture
University of Moratuwa
Moratuwa, Sri Lanka
December 2015

Editor
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Formatting & cover design
AMS Attanayake

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Editor's Note

FARU (Faculty of Architecture Research Unit) has been bringing together academics, students and professionals to share research outcome and knowledge in the field of built environments. This year’s theme, “*making built environments responsive*”, focuses on multi-dimensional responsibilities of the designers of built environment. This conference is focused on discussing the need to make our living indoors and outdoors responsive in many ways which involves socio-cultural needs, economic sustainability, psychological and physical needs, environmental sustainability etc. The conference is organized around several main topics involving urban environments, energy sustainability and human comfort, design technology, materiality, economizing space, knowledge and education on current practices, historic environments and practice.

Negligence of our responsibilities when creating built environment for people is making our living environments vulnerable, people uncomfortable and transforming our built environments less responsive for the needs. Since we spend most of our time indoors, making built environments responsive to our needs and nature becomes essential. However, with the development economies and advancement of sciences, there are many ways of minimizing problems but such responsiveness is less visible in current practices. Within this context, the conference of this year invites us to critically think of our responsibilities as stakeholders of the built environments and observe outcomes obtained so far through responsive built environments encouraging us to take a step forward towards a holistic approach.

Through the two day conference of FARU 2015 we will realize that research on built environments and their impacts on the behavior and comfort of people are immense and the need for promoting a research culture among design professionals and academics. This in turn influences policy makers and other government agencies to promote and facilitate research on built environments.

In order to achieve this target, we should have the research skills and courage to start thinking needs of people and response through innovative design and economic solutions. Research will help in this way to a greater extend more meaningfully. Finally, we will be able to discourage all inappropriate attitudes and be free to design responsive built environments.

It is glad to mention that all the conference papers went through a rigorous double-blind peer review process. I acknowledge the hard work done by our national and international reviewers, and authors who revised their papers after addressing valuable comments given by reviewers.

Dr. Upendra Rajapaksha
Director, Faculty of Architecture Research Unit
Faculty of Architecture
University of Moratuwa
Sri Lanka

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KEYNOTE ADDRESS 1

DIGITAL DESIGN REALITIES AND FUTURES
Educating Architectural Scientists

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Abstract
In the recent years, qualitative developments in the architectural profession are affecting substantively all facets of design praxis. The way how professional relationships, construction techniques, buildings- materials, design instruments and ways of working are changing is often faster than an educational system can react to. Hereby digital instruments are often the driving forces that facilitate change in praxis and the understanding of architectural education. Computational instruments are by far no longer basic recording and drawing media but progressive partner in design that allow the power of computational logic to be applied to design. The evolution of contemporary digital architecture facilitated by complex software and mostly online networked communications as well as data mining capabilities are among several technological and cultural developments that are driving architectural education to novel directions.

Keywords: *Thermal Comfort, Outdoor, Urban Form, Education, Learning*

Paradigm Shift

The digital technologies have already moved beyond CAD, such as, Building Information Modelling (BIM), parametric design, and digital fabrication. These methodologies have fundamentally altered the how and what of architectural design, especially in the professional context. Both, the 'how' of how we do, and the 'what' of what we do has changed. The way we make architecture has been transformed by the digital instruments, processes and methodologies. How the architectural education evolves to reflect, interpret, translate, or challenge the modes of contemporary practice presents a variety of opportunities as well as risks to 'digital scholars' and 'digital practitioners'. The possibilities afforded by BIM and parametric technologies have directly affected not only 'what' we make with them but at the same time also 'how' we educate architects. Integrating BIM into the way students are educated does subsequently shift the thinking about the generation and definition of architecture, design, its communication and the context it is placed in. New definitions have been developed, not based on the abstract theories or assumptions of the past, but instead on emergent data based in systems of simulation and information management. As the conventions of communication and representation of the past were determinant factors in those architectures the new conventions have proposed new architectures that we can see worldwide. The design studio or architectural praxis that embraces these new conventions in the age of growing computational design sophistication will transform the architectural design product as much as the architectural design process. This model for a comprehensive design praxis examines the relationship between the scale of design and the scale of representation and how this relationship undermines the primacy of abstract representation in architectural design. The future of architectural production and representation in practice and concept is at a crossroads between parametric modelling and BIM as the profession moves beyond traditional practice and its drawing-centric model into a dynamic process/component oriented model of digital practices and the subsequent re-definition of professional services and contractual deliverables.

A computational based architectural design praxis won't take the design of a building as destination but begin with a data-model of one already designed, or that would define a building. The design process has to deal with multi-dimensional logistical planning for construction and staged building processes as well as detailed investigations or analyses of structural, electrical or mechanical systems in consultation and so on. Hereby the network with allied disciplines or consultants is crucial to allow architects to engage in a larger environment of data, people and issues that the digital realm offers to access. Fabrication of building elements, its various systems at 1:1 scale from CNC-processes is hereby one conceptual vehicle for the pedagogical lessons. The computational applications allow a far more detailed simulation and actual construction of the design that conventional studios cannot engage in. The possibility of starting with a data of a building rather than ending with building data has fundamentally changed design pedagogy and opened new possibilities for students in the architectural education.

Digitally Driven Process as Design Partner

The possibility of starting with building rather than ending with building might radically reposition curricular goals, concepts and knowledge in the design studio. The design studio must now reflect new ways of teaching and addressing emergent digital design methods and processes, and critically evaluate their effects and possibilities in architectural production.

Still, it seems necessary to acknowledge that the subject areas must move beyond acting as end users of commercially available software in order that architectural praxis and education as well as all stakeholders from students to teachers, to professionals and end-users have to be engaged substantively in shaping the direction of digital design, its instruments and technologies. Students are impoverished by the blind use of the technology, such as by not exercising the three-dimensional thinking skills of descriptive geometry, unless their engagement goes beyond a superficial level. Here too, the means to that engagement may vary widely. In all cases, some deeper reflection on the nature of computation processes, such as might even be afforded by considering how a calculator works, may provide a much needed foundation over the sometimes superficial, gratuitous and flashy use of that technology. The ultimate condemnation of digital design media is for it to be perceived as a representational device, simply and solely. That it is seen in that way is itself a condemnation of the teaching of digital design.

Social Intelligence

In the above context there is a need for researchers, educators, and professionals to interact efficiently and effectively. However, this is not always possible due to the different knowledge background or complexity of the matter. In recent years, online interactions, multimedia, mobile computing and face-to-face interactions create blended design environments to which some universities or professional have reacted. Social networks, as instruments for knowledge sharing, have provided a potentially fruitful operative base in architecture. These technologies transfer communication, leadership, democratic interaction, teamwork, social engagement and responsibility away from the instructors to the participants. Implementing responsive interactions can move design beyond its conventional realm and enables stakeholders to develop architectural knowledge that is embedded into a community experts with their expertise both online and offline.

Readily available as well as emerging technologies offers users from various disciplines to tap into knowledge and share their ideas. Virtual and augmented realties are employed more readily and such systems provide increased potentials to compensate for other issues that are typically hidden with in conventional representations. For example, by employing an intelligent multi-dimensional model of a building environment, it is possible to explore the influence that environment form micro to macro scales. The results are interactively presented in media that allows architects, planners and stakeholder to make informed decisions on the impact of their design.

Yet it is not as simple as using another tool; parametric designing fundamentally shifts the engagement with the design problem. Parametric designing allows architects to be substantially deeper involved in the overall design and development process extending it effectively beyond production and lifecycle. Leaning parametric design strategies enhance architects' critical engagement with their designs and their communication. Subsequently, the computational aid of parametric modelling alters substantially how and what students learn and architects practice.

While problem-based communication becomes an iterative and reflexive process these current ways of interaction have pedagogical implications that are empowering learners to collaborate and communicate differently by integrating a variety of skills, knowledge and social environments with a rich learning experience. There is a need for educators react proactively to these possibilities of design activities and their digital instruments to allow learners to understand complex dependencies and engage in interprofessional collaboration right from the start. In developing learning opportunities and curricula designer are offered novel opportunities to extend their contribution beyond subject specific problems.

Using media-rich and social platforms allow us to reframe our problems and subsequently the ways in which these problems can be explored in learning activities. They are much more effective at tapping into social capital; thus the process is less dependent on the teacher's formulation of the problem as it becomes possible to embrace global professional and interprofessional social communities and achieve higher levels of collective and social intelligence.

Architectural Scientists

The consequences of digitally driven processes and thinking on architectural education will be profound. The underlying premise for design processes, fabrication and construction will increasingly challenge the historic relationships between architecture and its means of production leading to new demands of the profession on education to adapt and prepare students for digitally enabled Integrated Practice. Academia must completely revisit the curricula and imagine a system that acknowledges the obsolescence of the how and what of that which is taught in today's schools of architecture. Digital design realities already have shifted thinking that calls large segments of contemporary architectural education into question and engages in aspects of science that co-design our built environment.

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KEYNOTE ADDRESS 2

PROFESSOR DIPL.- ING. JUERGEN REICHARDT
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Summary
Prof. Juergen Reichardt, MSA Muenster School of Architecture, director of RMA architects Essen, Germany, and BRAE architects and engineers, Bangalore, India, has been engaged in various fields of research in programming techniques, digital driven holistic planning energy and ecology efficiency, comprising analysed and executed projects from domestical to complex industrial architectural structures. Following are rough outlines for research in passive houses, contribution to Solar Decathlon competition 2011, GENEering™ programming and SYNFAP® integrated design techniques, moreover TRILOKA international academic university collaboration and student exchange idea.

1. According official 2013 statistical government database 28% of overall german energy demand is caused by private domestical households, 69% of that share is due to mainly winter heating demands. A new European energy strategy tries to cut down these heating demands dramatically. The term **passive house** (Passivhaus in German) refers to a rigorous, voluntary standard for energy efficiency, resulting in ultra low energy demands for heating and cooling, reducing ecological footprint as well. The standard is not only constricted to residential properties; several office buildings, schools, kindergardens and even supermarkets have also been constructed to this standard. Passive design is not an attachment or supplement to architectural design, but a design process that is integrated with architectural design. Although it is mostly applied to new buildings, it has also been widely used for refurbishments. Estimates of the number of passive house projects erected around the world as as late 2014 range from 25,000 to 30,000 structures. The vast majority of passive structures have been built in German-speaking countries and Scandinavia.There was also other previous experience with low-energy building standards, notably the German "Niedrigenergiehaus" (low-energy house) standard, as well as from buildings constructed to the demanding energy codes of Sweden

Denmark and Switzerland ("Min-Energie"). The passive house standard requires that the building fulfills the following requirements:

1.1 The building must be designed to have an annual heating and cooling demand as calculated with the Passivhaus Planning Package of **not more than 15 kWh/m2** (4,755 BTU/sq ft; 5.017 MJ/ sq ft) per year in heating or cooling energy OR be designed with a peak heat load of 10 W/m2 (1.2 hp/1000 sq ft)

1.2 Total primary energy (source energy for electricity, etc.) consumption (primary energy for heating, hot water and electricity) **must not be more than 120 kWh/m2** (38,040 BTU/sq ft; 40.13 MJ/sq ft) per year.

1.3 The building **must not leak more air than 0.6 times the house volume per hour** ($n50 \leq 0.6$ / hour) at 50 Pa (0.0073 psi) as tested by a blower door

Research engagement of MSA, department Prof. Reichardt, in collaboration with HBZ Muenster, was the development of a teaching course for passive housing integrated design, available to architects and utility engineer professionals as well as MSA students. (1)

2. Critical discussion towards "high tech" german passive house engineering approach led to **collaboration with Wellington University, New Zealand**, department of Prof. Reichardt contributing BIM techniques and energy simulation to energy plus house approach for New Zealands "First Light House" entry to **2011 Solar Decathlon** global competition. The digital 3D- modelling was supported with REVIT BIM techniques and IES dynamic energy simulation. The project was rewarded with 1st rank in engineering and 3rd rank in overall categories

3. **GENEering™** is a meanwhile proven method for holistic workshop programming. As the term – which linguistically combines 'gene' and 'engineering' – indicates this method is concerned with developing a 'DNA code' from the perspective of the object planning. This sets the structural forming parameters in the buildings future lifecycle and thus the performance of the object's form under the motto "form follows performance: Eight factors are identified and discussed in special reference for individual project, then in further steps visualized through expressive images out of these areas. Each individual factor is broken down once more into three sub-concepts and examined from internal and

external company perspectives. Through the ensuing group discussion of the target concepts often arise highly original ideas, which may be formative for solutions of building. GENEering™ gains particular importance in the discussion on sustainability in construction. Already in 2002, in their highly acclaimed book “Cradle to Cradle” Braungart and McDonough pointed to the – at the time still minimally considered – side effects of industrial societies such as contaminants in products, unresolved waste disposal or irreplaceable resources. The method of using fractal analysis for solving complex problems with the aid of question and answer dialogues within a field of mutually influencing spheres of activity was discovered in 1919 and is referred to as the “Sierpinksi Gasket” after the Polish mathematician who first formulated it. Similarly, GENEering™ aims to exploit the creativity of workshop participants by supporting spheres of activity and fractals of the factory planning with visual association techniques. (3)

Once the goals have been defined, the basis for the actual planning data base is set from the perspective of the functional and spatial planning requires, introducing synergetic building design techniques SYNFAP®.

4. A critical view on the common practice of building design reveals serious differences between ‘state of the art workflow’ in progressive industries e.g. the aircraft or automobile industry and the design and manufacturing methodologies of a building projects. In the thirties of the last century already, masterminds like Buckminster Fuller referred to the traditional backwardness of the building industry as opposed to more progressive industries as ‘cultural lag’ at 20 years delay, due to the focussing to non holistic sub-projects with a vast amount of interfaces. For example process, location, building and building services (HVAC/R) are carried out in a sequential planning method and therefore consecutive design phases as opposed to timesaving simultaneous engineering which is standard practice in the automobile industry. According to **synergetic building design SYNFAP®** the new quality of cooperative building lies in merging the spatially designed sub-projects such as function, location, building and building services (HVAC/R) at the earliest possible stage. Thus an integral operation continuously refines a project’s 3D-structure from rough (presumption) to fine (specification) and evaluates the decision making process by comprehensively discussing variants. The set-up and maintenance of an integrated and universal 3D-data model utilises the potential of state of the art CAD/ CAM/ database technology in favour of comprehensive project improvement and cyclic 3D-quality. Regarding the four traditional levels of design synergetical planning is highly advantageous:

4.1 design level location

A valuation system for alternative locations takes into account the aspects of infrastructure, supply, disposal, site, labour market, environment, expandability, planning and building laws as well as purchasing price and communal promotion. At this the evaluation criterions are being assessed and rated according to their relevance to a project's objective.

4.2 design level general development

The general development's characteristics can either be stimulating or restraining for future mutability. The types of requirements that have to be met determine the choice of shapes as well as the criteria regarding protection of property. A general master plan combines guidelines for the layout of buildings and zoning of public thoroughfares and open spaces within potential construction stages

4.3 design level building

Architectural design of a single part of the general development, namely the building, embodies the four shaping design fields regarding the components of a built structure: load bearing structure, outer shell, media and finishings. These functional and construction relevant criteria are complemented by the focus on the more subjective aesthetic qualities of a building within the design field of impression.

4.4 design level function and comfort

The structural possibilities for promoting physical and mental well-being spatial environments calls for the most important parameters on the design fields of communication, lighting, comfort, recreation and fire prevention. These particular design elements and their relevance to mutability must be looked into in detail.

Therefore the most urgent aim in designing a building has to be in-depth discussion and amicable coordination of comprehensive performance characteristics among everyone involved. These respective design elements are compiled in matrix, advantages and disadvantages are assessed in team discussion.(4)

5. A systematic approach is recommended with complete documentation of assumptions, definitions and decisions, digital tools currently in use for planning deny rash individual solutions and advocate a more integrated approach of all subprojects. State of the art digital technology is based upon object oriented 3D models, permitting integration of architecture,

utilities, construction and further dynamic simulations for evaluation of energy or light. **BIM (Building Information Modeling)** engineering allows for appropriate know-how, discipline and transparency in planning and in particular, exact space and cost evaluations throughout all project phases. The implementation of integral digital 3D concept is relatively new, technical basis are standardized 3D-CAD IFC interfaces (Industry Foundation Classes). Based upon the software system, a detailed precise three-dimensional building model is created during the design stage. In addition to the object geometry, the central database of BIM collects and networks all data related to production, analysis and optimization as well as subsequent operations. All those participating in the construction – from the users, to the architects and experts in statics and building services, finally those erecting the building refer to the central building information model, some major advantages are (5):

5.1 Parametric Geometry

The virtual building information model consists of parametric elements with digital attachments of a lot of information as well as relationship to other objects. Moreover all related documents such as floor plans, sections and elevations are generated automatically.

5.2 Surfaces and Mass Analysis

The building information model can generate a lot of additional views based upon the available geometric data of the objects. Building element may be grouped to special schedules, offering numerical representation of objects in the form of tables and reports besides classical planning documents such as floor plans. The user has the option to consider, filter and change individual information as and when required. Areas and rooms can for example be represented in the form of a clearly ascertainable space book.

5.3 Virtual Construction Process

Finally after presentation and optimization of design variants, necessary approvals from the client and tendering processes, the next step would be a trouble-free construction of the building project, a very important phase due to the usual time and cost pressure. Both planners and construction companies strain to avoid site driven conflicts and time schedule overlaps. Thus, not only individual construction phases, but also complex construction processes can be simulated and visualized 3 dimensionally before the groundbreaking.

5.4 Simulation of daylight and artificial light

The BIM technology also makes it possible to understanding of light and shade. Conditions can be simulated, along with necessary qualitative and quantitative calculations. In the 3D building model is transferred into light simulation software, along with informations about the site, surroundings, global positioning and the sun’s location. After defining the site specific weather information and the required time intervals for simulations, evaluations can be made.

5.5 Energy analysis

In the past, often low construction investment and the possibility of amortization of the pure construction costs in a few years, were decisive criteria for design selections.Over the years rising energy prices, the introduction of the Renewable Energy Heat Acts and the introduction and steady tightening of Energy Saving Ordinance for buildings have substantially changed the thinking of those involved in planning like architects, engineers and especially investors and users. Even seemingly simple design decisions in the early design stages, such as the geographic positioning of building volumes on a site, can have significant impact on the future energy balance of a building and avoid unnecessarily high life cycle operating costs for heating and cooling.

6. **TRILOKA** is the idea of academic and cultural multinational cooperation in architecture between Europe and South Asia. Aim is to organize international symposiums enabling facetted views on environmental as well as architectural focus points, common work on projects, contributing to multilevel potential of international teaching and research. TRILOKA is moreover a field- related university-partnership between MSA, Muenster School of Architecture, and Faculty of Architecture, University of Moratuwa. German Government through DAAD institute was able to donate the program 2004 till 2008, with annual year books reflecting activities and specifocus points of programs.(6)

The credo of **FARU** conference Colombo 2015, **Making Built nvironments Responsive**, is mirrored nicely in the TRILOKA idea framework. Thus SA Muenster School of Architecture underlines admiration for the Moratuwa University organisation of the FARU congress 2015, and wishes all participants, speakers and auditorium, brilliant days of symposium.

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KEYNOTE ADDRESS 3

URBANIZATION AND RESPONSIVENESS TO HEALTH:
Exploring multi- disciplinary attributes for a holistic approach

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Urbanization is a leading global trend. With the intensifying drift in urbanization in developing nations, 70% of global population will concentrate in the cities of Asia and Africa by the year 2030. Sri Lanka is also seeing a process of rapid planned and unplanned urbanization estimates are that close to 3 million (or 17%) of the population live in urban areas. This figure is likely to increase further with the planned ambitious Megapolis project of the government covering the whole of the Western Province.

Urbanization has the ability to widen socio-economic opportunities (e.g. trade, employment) and promote health gains (e.g. easier access to amenities and health services). However, the urban environment and the process of urbanization carry unexpected challenges to health and wellbeing. These include adverse effects on quality of life due to lack of recreation space, thermal discomfort from heat islands within cities due to anthropogenic heat generation and buildings that trap environmental heat, and the direct promotion of certain illnesses. An example of the latter is the increased prevalence of bronchial asthma and chronic obstructive pulmonary disease associated with air pollution from vehicles. Other varying examples of health impacts of the urban environment include the following:

a. Urban living leads to higher rates of non-communicable diseases partly due to lack of opportunities for physical exercise, increased stress, and easy availability of unhealthy ‘fast’ food
b. Ill-structured buildings promote illnesses such as respiratory diseases (e.g. the ‘sick building syndrome’) and social fragmentation (e.g. due to lack of space for community activities)
c. High-rise apartment blocks become nuclei for drug dealers, crime and inner city violence.

d. Highway conduits become sources for disease transmission (e.g. dengue from increased human mobility, and HIV by long-haul drivers due to availability of commercial sex workers along the route).
e. Development of highways leading to an increased incidence of high impact accidents from speeding vehicles, which requires management by emergency teams and dedicated trauma units

This close link between health and urbanization has three potential linkage or influences on the health sector. Firstly, to identify solutions at the planning stage that mitigates or minimises adverse health impacts. This requires collaboration, research and policymaking by multi-disciplinary teams. Secondly, a response by the health sector to meet changing needs and increased demand (e.g. trauma centres, new clinics and other services by the Ministry of Health and private providers). Finally, urbanization offers investment opportunities in the medical industry (e.g. bio-technology) and in health services (e.g. medical tourism). The latter includes the growth of an affluent urban population that would include foreigners.

The presentation focuses on the potential effects of urbanization on non-communicable diseases and their prevention through appropriate planning measures. This is increasingly of relevance because Sri Lanka is undergoing rapid urbanization as well as facing an epidemic of NCDs. Obesity, one of the important risk factors for NCDs, is also on the increase. Data from a nationally representative sample of 18 years and above found overweight and obesity to be as high as 25.2% and 9.2% respectively. Similar figures are now seen even in rural areas of Moneragala and spells and impending crisis for Sri Lanka. Therefore, interventions at the planning stages of urbanization are crucial if we are to mitigate a future health crisis.

The built environment comprises of urban design, land use and transportation access. It is one of the many factors in the urban environment that can influence individual behavior and lifestyle associated with obesity and NCDs (e.g. low physical activity due to motorized transport and lack of urban open spaces). Availability and accessibility to facilities in the built-environment for recreation and healthy eating influences weight gain among its residents. Other factors in the built environment that encourage unhealthy life styles include easy availability of calorie dense food and lack of dedicated road networks for walking or cycling. Stress from overcrowding, ill-planned urban areas and noise pollution will all contribute to further NCDs. Recent data suggests that vehicle induced air pollutants too have an important influence in promoting NCDs from their action on the immune system. Thus, a range of factors in urbanization have the ability to interact with each other in a dynamic manner, to generate, promote or inhibit the epidemic of NCDs.

Urban planners, architects, engineers and policymakers need to be responsive to these health impacts of urbanization. It is necessary to take a more holistic view and attempt to predict likely health impacts of these at the urban planning stages. This would require conceptualizing urban areas to consist of interacting dynamic systems, and novel analytical techniques such as mathematical modelling and computer simulation. A large body of science exists in these areas, which needs to be tapped by Sri Lanka. The strides made by the University of Moratuwa (e.g. in modelling transport and impacts on health) in this regards is commendable. It is also encouraging to note that organizations such as the National Science Foundation, Universities of Moratuwa, and Colombo, and Urban Development Authority are showing a keen interest in these areas of multi-disciplinary research.

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Invited paper

SOUTH ASIA AND SOCIETAL CHALLENGES: A REGIONAL PERSPECTIVE

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Abstract

This paper is a summary of the South Asian region's status and interests concerning the seven thematic societal challenges identified under the EU's Horizon 2020 research programme: Health, demographic change and wellbeing; Food security, sustainable agricultures, marine and maritime research and the bio-based economy; Clean and efficient energy; Smart, green and integrated transport; Climate action, resource efficiency and raw materials; A changing world - inclusive, innovative and reflective societies; and, Secure societies - protecting freedom and security of the country and its citizens.

This paper considers the position of seven countries in South Asia: Afghanistan; Bangladesh; Bhutan; Maldives; Nepal; Pakistan; and, Sri Lanka[1]. It also identifies national and regional priorities for the seven themes under consideration.

This paper is an output of the CASCADE project (Collaborative Action towards Societal Challenges through Awareness, Development, and Education) that aims to provide the foundation for a future International Cooperation Network programme targeting South Asian Countries, which will promote bi-regional coordination of Science & Technology cooperation. The EU recognise a need to strengthen internationalisation through strategic policy action. The need for linkages with Asian countries has been highlighted given the region's rapidly growing research and innovation capacities and the urgency to address global challenges.
The project coincides with the launch of Horizon 2020, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Running from 2014 to 2020 with a budget of just over €80 billion, the EU's new programme for research and innovation is part of the drive to tackle

global societal challenges, and create new growth and jobs. International cooperation in research and innovation is an essential element for meeting the objectives of Europe 2020. Recognising the global nature of producing and using knowledge, Horizon 2020 builds on the success of international cooperation in previous framework programmes and is fully open to participation from third countries.

1. Introduction

This paper is a summary of the South Asian region's status and interests concerning the seven thematic societal challenges identified under the EU's Horizon 2020 research programme: Health, demographic change and wellbeing; Food security, sustainable agricultures, marine and maritime research and the bio-based economy; Clean and efficient energy; Smart, green and integrated transport; Climate action, resource efficiency and raw materials; A changing world - inclusive, innovative and reflective societies; and, Secure societies - protecting freedom and security of the country and its citizens.

The paper considers the position of seven countries in South Asia: Afghanistan; Bangladesh; Bhutan; Maldives; Nepal; Pakistan; and, Sri Lanka. It also identifies national and regional priorities for the seven themes under consideration.

Table 1: Country profiles (adapted from World Bank, 2014)

South Asian Country	Income level	Population (2013, million)	Population growth (annual %)	Land area (sq. km)	GDP per capita (2013, current US$)	Life expectancy at birth (2012, years)	Literacy rate, Adult total (% of people ages 15 and above)
Afghanistan	Low	30.55	2.4	652,860	664.8	61	32
Bangladesh	Low	156.60	1.2	130,170	957.8	70	59
Bhutan	Lower middle	0.75	1.6	38,117	2,362.6	68	-
Maldives	Upper middle	0.35	1.9	300	6,665.8	78	-
Nepal	Low	27.80	1.2	143,350	694.1	68	57
Pakistan	Lower middle	182.14	1.7	770,880	1,275.3	66	55
Sri Lanka	Lower middle	20.48	0.8	62,710	3,279.9	74	91

There is great diversity among the seven South Asian countries considered within this paper, as summarised in Table 1.

There are several countries covering a large land area (Afghanistan, Pakistan), while there are also very small countries by land area (Bhutan), including a small island state (Maldives). Several are land locked (Afghanistan, Bhutan and Nepal), while others are islands (Maldives, Sri Lanka) or have substantial coastal regions (Bangladesh, Pakistan).

Similarly, populations range from the very small (Maldives, Bhutan) to some of the largest in the world[3] (Bangladesh is 8th, Pakistan is 6th). All seven countries are experiencing population growth, but the rate of growth varies greatly, from 0.8% per annum (Maldives), to 2.4% (Afghanistan).

The region has three low income countries (Afghanistan, Bangladesh and Nepal) but also an upper middle income country (Maldives). The others (Bhutan, Pakistan and Sri Lanka) are all lower middle. Health and education also vary greatly. Conflict affected Afghanistan has very poor indicators in health and education, while Sri Lanka for example, has a comparatively high adult literacy rate.

Despite these diverse profiles, the region faces many common concerns that link to the Horizon 2020 societal challenges.

2. Context of this paper

2.1 CASCADE project

This paper is an output of the CASCADE project (Collaborative Action towards Societal Challenges through Awareness, Development, and Education) that aims to provide the foundation for a future International Cooperation Network programme targeting South Asian Countries, which will promote bi-regional coordination of Science & Technology cooperation. The EU, whilst representing only 7% of the world's population, is responsible for 24% of world expenditure on research, 32% of high impact publications and 32% of patent applications, making it a world leader in research and innovation (European Commission, 2012). However, over the past few decades, new key players have emerged within the international landscape shifting the previously dominant position held by the EU towards emerging economies.

The EU recognise a need to strengthen internationalisation through strategic policy action. The need for linkages with Asian countries has been highlighted given the region's rapidly growing research and innovation capacities and the urgency to address global challenges (Annerberg et al, 2010). South Asia in particular is home to more than 40% of the world's absolute poor, but will contribute nearly 40% of the growth in the world's working-age population in the coming decades.

CASCADE is an opportunity for raising awareness of the potential for EU-Southern Asia cooperation and stimulating regional and international participation. With the active contribution of South Asian countries, the endeavour will be to pave the way for more advanced, inclusive and innovative societies.

The 18 month CASCADE project is led by Professors Dilanthi Amaratunga & Richard Haigh from the University of Huddersfield, UK but targets and has the participation of all seven South Asian countries specified in the call: Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka. The project set out to:

1. Compile a regional position paper that identifies global challenges and research priorities
2. Map and develop an inventory of national and regional stakeholders related to global challenges
3. Raise awareness on research & innovation priorities for fostering cooperation and towards building mutual understanding on how to address common global societal challenges

2.2 Horizon 2020

The project coincides with the launch of Horizon 2020, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. Running from 2014 to 2020 with a budget of just over €80 billion, the EU's new programme for research and innovation is part of the drive to tackle global societal challenges, and create new growth and jobs. International cooperation in research and innovation is an essential element for meeting the objectives of Europe 2020. Recognising the global nature of producing and using knowledge, Horizon 2020 builds on the success of international cooperation in previous framework programmes and is fully open to participation from third countries.

2.3 Methodology

This regional paper draws upon the findings of seven national positions developed for Afghanistan (Sherzaman, 2014), Bangladesh (Asian Disaster Preparedness Center and Patuakhali Science and Technology University, 2014), Bhutan (Tshering, 2014), Maldives (Khalid, 2014), Nepal (Sitoula, 2014), Pakistan (Hussain et al, 2014) and Sri Lanka (Goonesekera et al, 2014). In doing so, it provides a regional perspective on global societal challenges of mutual interest to the EU and South Asian region.

Table 2: Lead contributors to national and regional papers

National / regional paper	Lead contributors
Afghanistan	Nangarhar University
Bangladesh	Patuakhali Science and Technology University Asian Disaster Preparedness Center
Bhutan	Royal Institute of Management
Maldives	ECO CARE
Nepal	Institute of Engineering Volunteers for Development Nepal
Pakistan	University of Engineering & Technology, Peshawar Local Councils Association of the Punjab
Sri Lanka	University of Moratuwa, Sri Lanka Federation of Sri Lankan Local Government Authorities
South Asia	University of Huddersfield University of Central Lancashire Asian Disaster Preparedness Center

Although each national paper was developed and written by a local, in-country team (Table 2), data collection and analysis was coordinated to ensure consistency. This was achieved through a series of briefing and training events, as well as the issuing of standard protocols and templates. A detailed presentation of the data collection and analysis carried out for each country can be found in the respective national position papers. Below is a summary of the overall methodology.

The methodology was carried out in two phases. Phase 1 of consisted of a detailed policy analysis and Phase 2 used a combination of semi-structured interviews and focus groups.

During phase 1, a content analysis approach was carried out to analyse available policies in the seven South Asian countries targeted by the CASCADE project. The focus was specifically on each of the seven societal challenges targeted under Horizon 2020. This phase set out the current statistics and trends, assessed the policy availability in each area, carried out a situational analysis, and finally, identified key informants that have knowledge or are responsible for developing policies in those areas. These key informants provided the basis for identifying interview and focus group respondents in phase 2.

During the 2nd Phase of the project, semi-structured interviews were used to gather information on each of the Horizon 2020 challenges (Challenge 1 - Health, demographic change and wellbeing; Challenge 2 - Food security, sustainable agricultures, marine and maritime research and the bio-based economy; Challenge 3 - Clean and efficient energy; Challenge 4 - Smart, green and integrated transport; Challenge 5 - Climate action, resource efficiency and raw materials; Challenge 6 - A changing world - inclusive, innovative and reflective societies; and, Challenge 7 - Secure societies - protecting freedom and security of the country and its citizens) and to gain an understanding of each challenge and its impact to the society and country. The experts represented academia, industry and public organisations. 348 interviews were conducted across the seven countries, as summarised in Table 3.

Following analysis of the interview data, a series of focus groups was conducted to get an overall perspective and consensus on all seven Horizon 2020 challenges, and to get an understanding of the key challenges and their impact to the society and country. There were 135 participants in sixteen focus groups across the seven countries, as summarised in Table 4. The experts represented academia, industry and public organisations.

The analysis and writing up of the national position papers was led by the local in-country teams from the CASCADE partner organisations (Table 2). Draft papers were presented to the CASCADE steering committee, and subject to a cycle of feedback and re-writing.

Table 3: Interviews conducted

Challenge	Afghanistan	Bangladesh	Bhutan	Maldives	Nepal	Pakistan	Sri Lanka	Total
1	2	13	5	4	3	18	2	47
2	2	18	7	6	2	19	1	55
3	4	7	3	5	2	13	1	35
4	3	6	4	4	2	19	1	39
5	5	27	7	5	2	29	2	77
6	2	13	4	2	4	8	2	35
7	2	7	4	4	2	39	2	60
Total	20	91	34	30	17	145	11	348

Upon completion of the national papers, a team was appointed to draft the regional paper, which would draw upon the findings of all seven national papers. Priorities and opportunities for EU-South Asian cooperation in research and innovation were proposed based on a summary of the national papers, and subsequently discussed and agreed during several project meetings with the CASCADE consortium.

Table 4: Focus groups participants (number of focus groups in brackets)

	Afghanistan	Bangladesh	Bhutan	Maldives	Nepal	Pakistan	Sri Lanka	Total
Total	13 (1)	21 (3)	23 (1)	11 (2)	22 (1)	12 (2)	33 (6)	135

3. Thematic societal challenges: Regional priorities and pportunities for EU-South Asia collaboration in research and innovation

Below sections highlight the policy and interests of seven countries in South Asia with respect to the seven thematic societal challenges identified under the EU's Horizon 2020 research and innovation programme: Health, demographic change and wellbeing; Food security, sustainable agricultures, marine and maritime research and the bio-based economy; Clean and efficient energy; Smart, green and integrated transport; Climate action, resource efficiency and raw materials; A changing world - inclusive, innovative and reflective societies; and, Secure societies - protecting freedom and security of the country and its citizens.

3.1 Health, demographic change and wellbeing

- **Poor health indicators:** Low life expectancy and high rates of malnutrition, infant mortality, and incidence of tuberculosis (TB) and HIV/AIDS, as well as widespread malaria are some of the major health challenges facing the region. Exchange of science and technology in the health sector is considered a key area of mutual collaboration. The transfer of knowledge will help South Asian countries to adopt new technologies, used for diagnosis, which can help in the early mitigation of diseases and by taking early steps through preventive measures. Priority areas for mutual collaboration with the EU in the health sector include devising integrated health policies, developing physical and technological infrastructure for health care services and delivery, designing and practicing state-of-the-art surveillance systems to detect outbreaks of diseases treat early in time (e.g. cango virus, dengue fever, bird flue), and designing cost-effective and efficient vaccines for prevention of diseases (e.g. hepatitis, TB, malaria, polio, rabies, measles).
- **Reducing the burden of NCDs:** Lower-income countries generally have lower capacity for the prevention and control of NCDs. To lessen the impact of NCDs on individuals and society, a comprehensive

approach is needed that requires all sectors, including health, finance, foreign affairs, education, agriculture, planning and others, to work together to reduce the risks associated with NCDs, as well as promote the interventions to prevent and control them. There is an urgent need to lessen the risk factors associated with these diseases. Low-cost solutions exist to reduce the common modifiable risk factors (mainly tobacco use, unhealthy diet and physical inactivity, and the harmful use of alcohol) and map the epidemic of NCDs and their risk factors. Other ways to reduce NCDs are high impact, essential NCD interventions that can be delivered through a primary health-care approach to strengthen early detection and timely treatment. The creation of healthy public policies that promote NCD prevention and control, and reorienting health systems to address the needs of people with such diseases, are also priorities.

- **Financing healthcare and affordability:** Most countries in South Asia need to give more people access to affordable, quality health care. Too many people, especially women, cannot get the medical treatment they need due to high costs, difficulties in getting permission to see a doctor or a lack of health care providers in rural areas. There is a need for capacity building for health personnel, disease awareness and prevention.
- **Addressing the care and well being of the ageing population:** South Asia faces significant challenges in dealing with how future economic growth rates respond to the aging of the work force and the ultimate slowing in its growth. The region will need to ensure their social insurance systems are well adapted to confront the issues posed by an ageing population, and that the medical systems and social insurance are able to cope with the requirements of rising longevity, including the associated costs.

3.2 Food security, sustainable agricultures, marine and maritime research and the bio-based economy

- **New and climate resistant crops and varieties (e.g., high yield varieties) and technologies to increase productivity and sustainability:** The health and well-being of the world's growing population are largely dependent on the ability of the agricultural industry to raise high yielding and climate resistant food crops. Inclusive growth provides opportunities for those with meagre assets and skills, and improves the livelihoods and incomes of the poor, especially in agriculture. It is therefore among the most effective tools for fighting hunger and food insecurity, and for attaining sustainable progress. Enhancing the productivity of resources held by smallholder family farmers, fishing and forest communities, and promoting their rural economic integration through well-functioning markets, are also essential elements of inclusive growth. Technology and knowledge transfers can also help in achieving increased productivity and quality standards (particularly in relation to packaging and transportation) of agricultural and fish produce. This would, in turn, aid in the creation of new international markets for local produce.

- **Protecting agricultural lands:** A large proportion of South Asian land area is in agricultural use. How this important natural resource is used is vital to sustainable development. This includes taking the right decisions about protecting it from inappropriate development.

- **Improve farmers' quality of life and livelihood security:** Improving the quality of life of farmers and fishermen will be important to sustain agriculture and redress the rural to urban migration. Improving the productivity of resources held by family farmers and smallholders is, in most cases, an essential element of inclusive growth and has broad implications for the livelihoods of the rural poor and for the rural economy in general. Well-functioning markets for food, inputs and labour can help to integrate family farmers and smallholders in the rural economy and enable the rural poor to diversify their livelihoods, which is critical for managing risk, and reducing hunger and malnutrition.

- **Use of bio-technology in marine and fisheries to exploit sea based resources:** Marine biotechnology is essential to satisfy the growing demand for healthy products from fisheries and aquaculture in a sustainable way. The growing demand for marine food will need to be increasingly delivered through intensive aquaculture. Marine biotechnology has the potential to contribute significantly to increasing production efficiency and product quality, to the introduction of new species for intensive cultivation and to the development of sustainable practices in South Asia.

3.3 Clean and efficient energy

- **Harness hydro, wind, solar, biomass and other renewables:** Achieving ambitious deep cuts in emissions and accelerating green growth will require the development and diffusion of carbon-efficient technologies. South Asia has great potential for energy efficiency and renewable energy, including hydro, geothermal, wind, solar and tidal energy.

- **Conservation and efficiency improvements through smart national power grid, including transmission and distribution:** Innovative finance mechanisms and policies are needed to reduce the risks perceived by mainstream lending institutions in cleaner technology investments and to enhance their capacity to finance low-carbon technologies and resource options. Extensive research activities on energy consumption and the efficient use of energy is required, including exchange of science knowledge on the use of smart technologies used in the energy sector for improving efficiency and security, and introducing environmentally friendly technologies for producing energy.
- **Regional cooperation in knowledge sharing, energy development and trade:** There is a need to understand the national energy policies and resource endowments of these countries in order to identify common features and complementarities necessary for a viable regional energy security framework. South Asian countries need enhanced regional energy transfer to leverage economies of scale through a more vibrant intra and inter regional energy trade structure. Key issues faced in energy sector cooperation are centered on the need to develop a regional power market, energy supply availability, energy trade infrastructure, and harmonised legal and regulatory frameworks.

3.4 Smart, green and integrated transport

- **Environmentally friendly, green transport:** Given the rapid rise in vehicular traffic, a trend that is likely to continue due to population and economic growth, affordable, green private and public transport will be essential to control emissions.
- **Introduce / improve ‘smart’ traffic management:** With limited financial capacity to expand transport infrastructure, intelligent use of existing capacity will be vital to support growth.
- **Integrated transport:** An integrated and efficient transport network is an essential element of the enabling environment for a globalised economy. Effective integration of the transport system in South Asia could also contribute greatly in enhancing access to remote areas, thereby extending economic development.
- **Improved safety standards for all transport infrastructure and services:** Establish missing safety regulations, supported by strict enforcement and policing. Create awareness among people about road safety and also help developing countries to attract investment from multilateral institutions to improve their accident-prone highways.

Priorities also include awareness programmes to influence the behaviour of road users, and improving care and rehabilitation following accidents.

3.5 Climate action, resource efficiency and raw materials

- **Integration of climate change adaptation within national policies and planning:** This may include appropriate land-use planning, conservation and biodiversity, community empowerment, and investing in innovative, adaptive and absorptive capacity building activities.

- **Early warning, preparedness and mitigation towards increased resilience:** Shift development towards a mindset of resilience and innovation. Much of South Asia is economically poor, socially and politically marginalised and otherwise vulnerable. Resilience building measures must be inclusive. Research activities are needed on the rapid increase of global warming and air pollution in the southern Asian region, encouraging low carbon growth through the use of new technologies, introducing cost-effective and innovative climate change adaptation methodologies, developing disaster management systems through early warning systems, the efficient use of material, waste management and recycling, and encouraging environmentally friendly innovations in the new private sector.
- **Promote the green and blue economy, develop climate resistant crops and promote economically viable ecosystems and services:** Economic diversification is not the key response needed. What is needed is for all sectors of the economy to be prepared to withstand climate change. In agriculture, for example, new technologies such as rice cultivation systems with more efficient water and nutrient use should be promoted. Altering planting times, using resistant varieties, and diversifying crops can help.
- **Management of resources and development of pollution standards and compliance:** Countries need to look at better management of resources and services. Better coastal zone management, efforts to protect riverbanks from erosion and building climate-proofed roads, bridges and other infrastructure is needed. In the water sector, groundwater should be protected.

3.6 A changing world: inclusive, innovative and reflective societies

- **Improve transparency and accountability towards good governance:** Good governance depends on an ability to exercise power, and to make good decisions over time, across a spectrum of economic, social, environmental and other areas. This is linked with the government's capacity for knowledge, mediation, resource allocation, implementation and maintenance of key relationships. Key factors for the development

of better governance and transparency in South Asia include: technical and managerial competence: organisational capacity, reliability, predictability and the rule of law; accountability; transparency and open information systems; participation.

- **Greater inclusivity and improved social harmonisation among diverse populations:** This includes participation of women and youth, and consideration of the vulnerable, internationalisation, and employment. Labour market policies are also in need of reform. There is a need to move from protecting "jobs" to protecting "workers". Public works in countries like Bangladesh have been around for decades, but have lacked an explicit youth component. Employment programmes can directly produce jobs, in addition to spreading good labour practices and growing markets. Social protection for first-time job seekers, including unemployment assistance and employment guarantee schemes are also needed to protect the most vulnerable.
- **Cooperation in education system reform:** This may include introducing modern teaching technologies, updating curricula and education system management, and strengthening relationships with foreign universities to exchange lecturers and students. It may also involve conducting studies on how to strengthen commercial connections to regional and global economies, and research activities to gather accurate data on the labour market to provide research- and evidence-based policies, and strengthen the governance system.

3.7 Secure societies: protecting freedom and security of the country and its citizens

- **Disaster risk reduction, including related information systems:** In accordance with the new Sendai Framework (2015-2030), there is a need for South Asia to 'prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience'. Priorities include a shift from disaster loss to disaster risk, and from disaster management to disaster risk management. A focus on a people-centred preventive approach to risk reduction will be vital, as will defining the primary responsibility of States for risk reduction, but also shared responsibility with stakeholders. The scope of such measures must include slow-onset, man-made and biohazards.

- **Border security, crime, and surveillance:** Fighting crime and terrorism will require new technologies and capabilities for fighting and preventing crime (including cyber-crime), illegal trafficking and terrorism (including cyber-terrorism), including understanding and tackling terrorist ideas and beliefs to also avoid aviation-related threats. The EU's external security policies in civilian tasks, ranging from civil protection to humanitarian relief, border management or peace-keeping and post-crisis stabilisation, including conflict prevention, peace-building and mediation, will also be invaluable in the region. Other priorities include collaboration in the field of smart technologies for civil registration, to strengthen border management with high-tech protection tools and introducing e-governance.

3.8 Cross cutting themes

- **Development and financing of infrastructure:** Adequate physical infrastructure is a key element of economic growth. However, the developing world needs far more financing for infrastructure than can be provided through overseas development aid and domestic public finances alone. The cost of maintaining existing infrastructure and undertaking necessary extensions of its coverage is estimated at 7 per cent of developing country GDP, equivalent to about 600 billion US dollars (USD) per year. Public spending on infrastructure in developing countries is presently around 3 per cent. Given the shortage of public funds in most developing countries, one solution is to invite greater private sector participation and expand the use of public-private partnerships (PPP).

- **Adopt an evidence-based approach to policy:** The national position papers identified that most of the seven countries under consideration had developed policies aimed towards the thematic areas in Horizon 2020. However, the quality of the policymaking, as well as policy implementation and evaluation, was frequently questioned. Evidence based policy can have an even more significant impact in developing countries. Evidence based policy is a discourse or set of methods which informs the policy process, rather than aiming to directly affect the eventual goals of the policy. It advocates a more rational, rigorous and systematic approach. The pursuit of evidence based policy is based on the premise that policy decisions should be better informed by available evidence and should include rational analysis. This is because policy which is based on systematic evidence is seen to produce better outcomes. The approach has also come to incorporate evidence-based practices. Evidence based policy tends to be less well established in developing countries than in developed ones, and therefore the potential for change is greater. Better utilisation of evidence in policy and practice can help save lives, reduce poverty and improve development performance in developing countries.

- **Capacity building and sustainable development:** International cooperation and collaborations will be essential to address and tackle common global societal challenges, and the need for cooperation towards capacity development was frequently identified at the national level within South Asia.

The concept of capacity building or capacity development appeared in the late 1980s and became deeply entrenched within the development agenda in the 1990s. Rather than representing a new idea, it reflected growing criticism of many development assistance programmes. In contrast to this extraneous approach, it emphasised the need to build development on indigenous resources, ownership and leadership and by bringing human resources development to the fore. The concept of capacity development was therefore a move away from 'aid' or 'assistance' towards a 'help yourself' approach that was designed to prevent a dependency on aid emerging. Capacity development is based on learning and acquisition of skills and resources among individuals and organisations. While this process may rely on some imported resources, external capacity is seen as a knowledge-sharing device, which allows the strengthening and developing of the local capacity. As such, it relates closely to some definitions of resilience, which stress the objective is to build resilience by maximising the capacity to adapt to complex situations, and whereby resilience describes an active process of self-righting, learned resourcefulness and growth.

Capacity development is committed to sustainable development, to a long rather than short term perspective, and attempts to overcome the shortcomings of traditional donor- led projects that have been prevalent in many development projects — typically criticised for being too short term rather than sustainable, and not always addressing the needs of the recipients. Development within a capacity building context allows communities and countries to identify their own needs, and design and implement the best strategy within the local context. As a process, it builds on monitoring and evaluation in order to identify existing capacities, deficiencies and the progress and achievements of development.

4. Final note

Research activity based on which this brief is written has been carried out with the financial assistance of the European Union. The contents are the sole responsibility of the Network consortium and can under no circumstances be regarded as reflecting the position of the European Union.

The following institutions and individuals have directly contributed to the CASCADE project. We hereby acknowledge the valuable input of these organisations and individuals in contributing to this report.

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Maldives	ECO CARE	Hinna Khalid Ahmed Riyaz Jauhary
Nepal	Institute of Engineering	Nagendra Raj Sitoula
Nepal	Volunteers for Development Nepal	Basanta Kumar Parajuli
Pakistan	University of Engineering & Technology, Peshawar	Dr Naveed Ahmad
Pakistan	Local Councils Association of the Punjab	Anwar Hussain Muhammad Umar
Sri Lanka	University of Moratuwa, Sri Lanka	Professor Samantha Hettiarachchi Shayani Weeresinghe
Sri Lanka	Federation of Sri Lankan Local Government Authorities	Hemanthi Goonasekera Dr Sachie Gunathilake Avindra Shivantha
Thailand	Asian Disaster Preparedness Center	N.M.S.I. Arambepola Dr Rishiraj Dutta
United Kingdom	University of Central Lancashire	Dr Champika Liyanage
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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8thInternational Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 41–53. ©

COLOUR ASSOCIATED THERMAL PERCEPTION
Manifestation and contributing factors with reference to red and blue

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Abstract

Theory of colour, a long-established tradition of artists, differentiates between the impacts of warm and cool colours on human beings. The lack of scientific and statistically substantiated knowledge on aforesaid colour associated thermal perception (CTP) deems to hinder its optimum integration in creating responsive built environments. Current investigation seeks scientific explanation on manifestation and contributing factors of CTP with reference to a warm colour (red-RTP) and a cool colour (blue-BTP). Hypothesised potentials of CTP to manifest as a psychological response, a biological response, altering core body temperature or an actual thermal sensation caused via the human skin due to heat radiation emitted via coloured surfaces were tested. A crossover experiment was executed with a sample of healthy male undergraduates (n=111) selected via stratified simple random sampling (age 19 – 30) under controlled laboratory conditions. Substantiating colour theory, subjects demonstrated a propensity to perceive red as warm/hot (64.2%) and blue as cool/cold (59.3%). As revealed by logistic regression, CTP neither manifests due to a fluctuation in core body temperature nor as an actual thermal sensation. It is a psychological response characterised by common as well as colour specific factors. Accordingly, thermal impacts of colour could be integrated in built environments to psychologically manipulate the perceived thermal environment against the real thermal condition to achieve the desirable thermal milieu.

Keywords: *Colour associated thermal perception, infrared thermal monitoring, Likert Scale, temporal artery temperature.*

1. Introduction

Focusing on the imperative role of colour in creating environments responsive for human behavior, the current study accentuates that a colour scheme, while being pleasing aesthetically, should aptly contribute to the appropriate milieu corresponding to the feelings, emotions, expressions and

behavioral patterns associated with the intended activities of any built space. The human responses to colour which could be integrated in creating responsive environments are threefold.
Colour is an expressive agent (Rihlama, 1999) which can convey ideas, concepts, signs, symbols, meanings, and messages associated with the intended ambience of built spaces. Colours are found to alter perceived dimensions and properties of a space; height, width, depth, proportions, weight, temperature, stability and smell (Mahnke 1996). Most notably colour is a psychophysiological agent which could trigger corresponding emotional and behavioral responses within humans in built spaces (Mahnke 1996 and Rihlama 1999). Amidst the diverse colour associated human responses, the current study focuses on a less investigated and less utilized, yet an extremely important association; Colour associated Thermal Perception (CTP) of human beings, which is the macro research paradigm under consideration.

2. Background to research

As per Ballast (2002 cited in Daggett, at el, 2008), colours have been theoretically explained in temperature terms. Theory of colour has been pioneered and evolved through practice over the course of time by artists and painters and has taken the form of a long held tradition followed up to date, though not satisfactorily substantiated with scientific proof. The colour wheel, being the nucleolus of the traditional theory of colour, makes a clear division between duality of warm and cool colours.

Hypothetically, colour has the power to suggest warmth or coolness (Mahnke, 1996). The theories and principles on the properties, characteristics and effects of colour too are principally explained to be dual based on the aforesaid warm / cool dichotomy. For instance warm colors are identified to be stimulating and cool colours are pacifying (Whitfield &Wiltshire 1990, Stone 2001 and Ballast 2002).

A considerable amount of research in the fields of experimental psychology, applied psychology and psychological ergonomics has been done on the possible influence of colours or coloured surfaces on thermal sensation and thermal comfort (Albers et al, 2013). The studies conducted by Itten (1961), Morton (1995), Mahnke (1996), Stone (2001), Hutchison (2003) has been able to witness the thermal impacts of colour while the investigations done by Bennett and Rey (1972), Pedersen, Johnson and West (1978) and Greene and Bell (1980) has not been able to identify a significant association between colour and perceived temperature. The supportive evidence on the thermal effects of colours in the 20th century was found to be quite substandard. It has long been assumed that the impact of visual and thermal stimulation is interactive, yet this long-held belief has accumulated surprisingly little experimental support (Candas and Dufour, 2005).

The handful of scholars who have attempted thus far in generalizing CTP have yielded controversial outcomes. Even though there are many hypothetical explanations, there is a significant lack of scientific investigation conducted seeking the logic, or rather the justification behind manifestation of CTP and its significant parameters.

3. Research Problem:

"The problems associated with the usage habits of colour associated temperature in prescribing colours have always been a matter of debate and puzzlement" (Gage, 1995). The lack of recently conducted empirical research supported with statistically validated evidences on CTP and the nature of its manifestation may have contributed to such controversy, hindering the utilization of CTP to create responsive built environments. The current study intends to investigate the nature of manifestation and the significant parameters of CTP.

4. Research Objectives:

The investigation aimed at providing empirical evidence to the thermal impacts of colour and to reveal the basis behind the manifestation and statistically significant factors of CTP with reference to a warm colour; red (RTP) and a cool colour; blue (BTP).

5. Contributions

Each human activity demands a corresponding comfortable thermal ambience characterized by the nature and the pace of existence for its optimum performance. For instance, class room temperature is found to have an impact on the learning process (Pawel & Wyon 2006 and Fisher 2001). Holmberg and Wyon (1969) revealed that student's reading comprehension and speed were reduced during elevated classroom temperature conditions. As revealed by Stone (2001), reading task was found to be lowered in a red environment. It is suggestive that red being the predominantly warm colour in the colour wheel has caused similar impacts on reading. Setting up this thermal ambience is vital in creating environments responsive to the intended human behavior. Accordingly, comprehending the nature and parameters of colour associated thermal impacts will enable strategic integration of colours to manipulate the thermal environment responsive to human activities in an optimal manner.

6. Theoretical Framework: Review of Literature

Colour is a visual stimulus in the form of electromagnetic energy recognized to be perceived by the visual sense of humans; the eye, particularly by the photo receptive corns in the retina which enables the visual perception process (Rihlama, 1999). Gardner (1992) defines visual perception as the ability of the human brain to understand, make sense and interpret the sensory stimulus of the things seen by the eye. Preceiving thermal stimuli is firmly established to take place via the human skin, significantly by the thermal sensitive skin receptors; Ruffini's endings, Krause end bulbs (Hedge, 2008). The possibilities as to how colour, which is a visual stimulus could be perceived in thermal terms is the question under consideration. Carefully synthesizing the available literature from several disciplines, a comprehensive explanation for the nature and manifestation of CTP is summed up below.

It was assumed that a clear distinction between the phenomenon of CTP and colour temperature (black body theory) prevails. Red occurs at lower temperatures while blue occurs at higher temperatures when referring to colour temperature based on black body theory, which is the extreme opposite of the common cultural association of colour in thermal terms which sees red as hot and blue as cold (Gage, 1995, George, 2008). ‘Hue-Heat Hypothesis’ as explained by physicists was distinguished as the most discussed and frequently studied potential explanation for CTP. The hue-heat hypothesis puts forward the idea that light waves with long wavelengths at the red end of the spectrum are felt as warm and those at the blue end of the spectrum with shorter wavelengths are felt as being cool (Landgrebe et al., 2008, Michael et al., 2010; Kanaya, Matsushima and Yokosawa 2012). In view of this, the possibility of human skin cells and/or domains in the human eye to perceive colour in the form of heat is proposed. Based on the colour experience pyramid of Mahnke (1996), colour associated thermal impacts can be argued to be a learnt, subjective psychological response, while a part is played by the universal, archetypal associations which are common to all. Another strong theory in literature identifies CTP to be a biologically fixed bodily reaction caused due to altered core body temperature correlated with the corresponding frequency/wavelength of each colour (Mahnke 1996, Kopacz 2003, Cornelissen and Knoop 2012). Another supposition is that CTP is a synesthetic response uniting the visual and thermal senses, which is not yet substantiated and thus, inconclusive (Marks 1978, Cytowic 1989, 1993 and Mahnke 1996). Principles of colour therapy put forward the opinion that colour energy is capable of altering core body temperature of human beings via the fixed metaphysical association between colour energy and human energy field, consequently altering their thermal perception as well (Farser 2011, Manuel 2011, Lung 2011).

Accordingly, suppositions found in literature to explain the CTP are many. Scrutinizing and synthesising the aforementioned suppositions, three hypotheses were arrived at demarcating the scope and limitations of the study which set the baseline in formulating the research design, seeking scientific justification for CTP.

7. Hypotheses

7.1 HYPOTHESIS 1: CTP AS A PSYCHOLOGICAL RESPONSE.
Possibility of CTP to be a learnt subjective psychological reaction which is unique from person to person, molded by socio, cultural, religious influences and mannerisms and the ability of CTP to manifest as a fixed innate psychological reaction where the humans react in a universal pattern based on primordial associations was questioned here.

7.2 HYPOTHESIS 2: CTP AS A FIXED BIOLOGICAL RESPONSE; AN ALTERATION IN CORE BODY TEMPERATURE.

The possibility of colour stimuli to trigger an actual change in the core body temperature as a part of the established biological and physiological responses to colour, enabling to perceive red as warm and blue as cool in general terms was questioned here.

7.3 HYPOTHESIS 3: CTP AS AN ACTUAL THERMAL SENSATION CAUSED DUE TO HEAT RADIATION EMITTED VIA THE COLOURED SURFACE.

Manifestation of CTP due to the distinctive surface temperature generated by applied colour is considered here. It is assumed that the properties of the colour such as the reflective value, absorption value and emissivity may contribute to differences in the temperature of the colored surface, consequently causing an actual thermal sensation pertaining to differences in CTP.

There may be other theories and philosophies that could be used to explain CTP, for instance synesthesia and metaphysical correlation could be considered. However all these cannot be covered due the vastness of the area and considered as future research directions.

8. Research Design

Qualitative and quantitative methods being mixed in several stages, the current study was executed as a mixed model research. A sample representing the undergraduate male population of Faculty of Architecture, University of Moratuwa, Sri Lanka was selected via stratified simple random sampling representing four affiliated sub populations; departments. This sample has a rich mix of students representing a fair cross-section of the whole country and the different secondary educational streams followed, enabling the findings to be generalized to a greater extent. The sample was limited only to males to assure more validity in data as females are established to demonstrate fluctuations in the core body temperature caused by ovulation (Swedan 2001, Barron and Fehring 2005).

A three stage thorough screening process was designed to filter the best fitting subjects from the initial sample (n=155), which also served as the first phase of data collection. Preliminary screening was conducted via a questionnaire survey on known medical history (self-report) while the written consent of subjects was obtained via a letter of consent, fulfilling ethical clearance.

The second phase of screening was a general health checkup carried out by a registered medical practitioner. It was conducted to test the vision, general physical and mental health condition and most importantly to screen the subjects having illnesses pertaining to a high or low core body temperature than the normal range. Subjects qualifying for the next level were provided with an explicit set of guidelines to follow as preparation for the final trial.

Final screening was an eligibility interview done just before entering the lab to recheck the physical and psychological fitness of the subjects. Checks on adherence to the set guidelines were made and subjects with temperatures beyond normal core body temperature were screened out. The final sample consisted of most eligible 111 (n=111 with 95% confidence level and 7.5% margin of error).

Fig 1; Colour Lab with three colour workstations

Thermal perception of the subjects was tested in two coloured workstations; Red (RWS) and Blue (BWS), positioned within controlled laboratory conditions; fixed room temperature (78.8 ^{o} F; 26^{0} C), humidity (50% rh), lighting level (350 lux - Asian standards) and fixed interior finishes (matt) and colour (black). Red and blue were selected in the investigation to study the associated thermal impacts with careful deliberation to have the best representation of warm and cool dual colour paradigms. The study investigated the impact of a single, flat colour with a matt finish and did not measure any outcomes for the effect of colour combinations, finishes, textures or colour patterns as this would widen the scope of research.

A White Workstation (WWS) having identical conditions was integrated as the control and to washout carryover effects from first colour treatment. The investigation was conducted as a crossover trial having two study arms; BR Study arm (Blue treatment followed by red treatment) and RB study arm (Red treatment followed by blue treatment). Prior to first colour treatment each subject was kept inside the WWS for 10-15 minutes until he reached his basal temperature level. Experiment started with the subject being exposed to RWS (alternately BWS) for 15 minutes. In order to washout carry over effects from the first treatment he was sent back to the WWS for another 10 minutes. Once the subject reached a constant/basal temperature level he was exposed to the BWS (alternately RWS) for another 15 minutes. Out of 10 research subjects that underwent through the trial per a day, equal number of subjects were allocated to both study arms (RB study arm = 5 and BR study arm = 5; in total 50-RB and 51-BR).

Colour of the Work Stations being the independent variable, was manipulated to test the impact on thermal perception, the dependent variable. All the aspects of experiment was designed to control the diverse participant and situational extraneous parameters of visual perception and thermal perception. The confounding factors beyond control of the investigation were recorded or measured and included in the regression model.

During the first phase of data collection which took place simultaneously with the screening process, part of qualitative data associated with predictor variables; vision (Vis), level of previous exposure to colour theory and usage (Loe), religion (Rlgn), race (Rce) , study stream followed for secondary education (Sec_Edu), favorite colour/colours (Fvc) , sensitivity to warm conditions (Sen_Warm) , sensitivity to cool conditions (Sen_Cool), rate of sweating (Ros) and quantitative data; average temperature of the home town (HT_temp), body mass index (BMI) and age were recorded.

Second phase of data collection was done during the lab experiment where CTP in RWS and BWS (RTP and BTP) was rated by the subjects in a 5-pont Likert scale. Qualitative data related to predictor variables; feelings and emotions induced (R_Psy/B_Psy) and preference to colour exposure (R_Pre/B_Pre) in RWS and BWS were reported by the subjects via a questionnaire survey.

Quantitative data related to predictor variables too were recorded. Temporal artery temperature (TAT) of subjects in RWS and BWS via a Temporal Scanner, Surface temperature of RWS (R_SFT) and BWS (B_SFT) using Inferred thermal monitoring (FLIR i60 camera), outdoor temperature (OT) via a mini data logger and test time zone (TTZ) by a digital clock were monitored.

Analysis of the data was done with the use of statistical regression. Complex Sampling Ordinal Logistic Regression Model (CSOLRM) was applied for both RTP and BTP including 18 predictor variables in order to provide a statistically significant explanation and to understand the most powerful explanatory variables.

Fig 2; Research subjects undergoing colour exposure

9. Analysis

9.1 RTP VS BTP

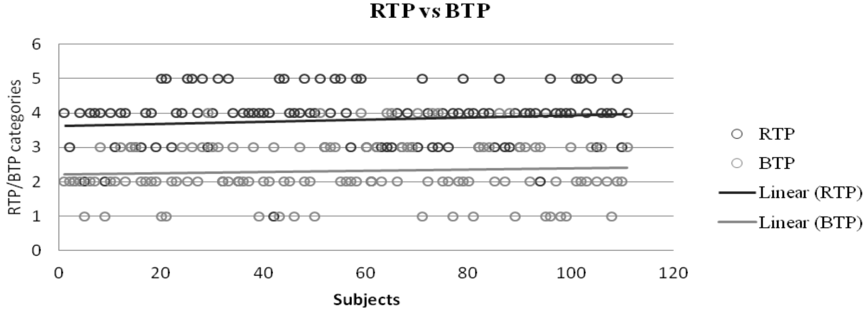

Figure 3: RTP vs. BTP

Substantiating thermal impacts of warm and cool colours 64.20% of the subjects perceived red as warm/hot and 59.30% perceived blue as cool/ cold. The above graph demonstrates that the trend line of RTP values lie on a higher level than BTP. Accordingly, BTP is found to be cooler and RTP to be warmer.

9.2 COMPARISON BETWEEN RTAT AND BTAT

RTAT fluctuation: - 0.4 ^{o}F – 0.8 ^{o}F, Avg: 0.083 ^{o}F.
BTAT fluctuation: - 0.4 ^{o}F – 0.9 ^{o}F, Avg: 0.08 ^{o}F.

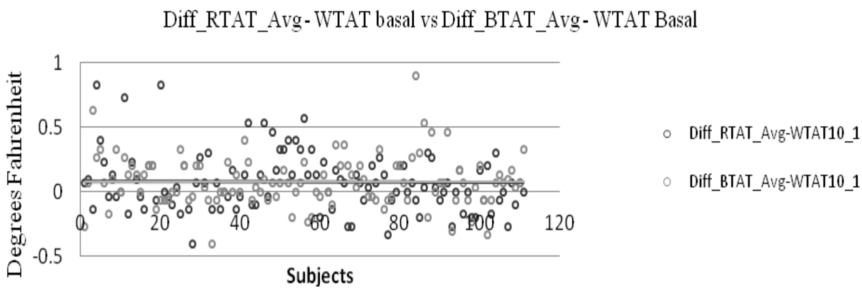

Figure 4; Body Temperature Fluctuations for Red and Blue exposure

As per the scatter plot representing the average temporal artery temperature fluctuation of each subject when exposed to red and blue from the basal temperature level reached in WWS, both trend lines overlap and run horizontally. Accordingly it is suggestive that CTP is not associated with an alteration in core body temperature.

9.3 SURFACE TEMPERATURE OF RWS VS. BWS

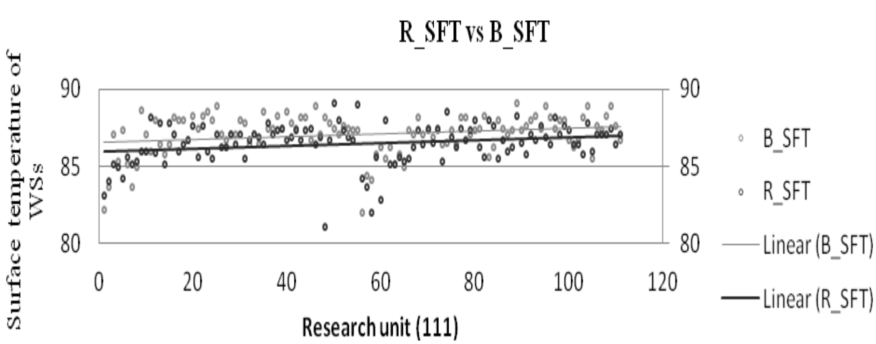

Figure 5; Surface Temperature of Red/ Blue Work Stations

The temperature of blue surface (B_SFT) was found to be mildly higher than temperature of the red surface (R_SFT), suggesting the possibility of colour to emit heat/radiation, potentially playing a part in the external thermal milieu (average difference: 0.71 ^{o} F) even if a majority of subjects perceived BWS to be cooler and RWS as warmer. However, considering the measurement error of the camera (2% of the reading) observed average increase of B_SFT value (0.71 ^{o} F) cannot be considered as a significant increase.

9.4) COMPLEX SAMPLING: ORDINAL REGRESSION RTP - SIGNIFICANT MODEL

RTP = b0 x Sec_Edu + b1 x FVC + b2 x Rlgn + +b3 x R_Psy + b4 x R_Pre
As per the test of model effects it was found that the predictors Sec_Edu, FVC, Rlgn, R_Psy, R_Pre are statistically significant for RTP.

9.5) COMPLEX SAMPLING: ORDINAL REGRESSION BTP - SIGNIFICANT MODEL

BTP = b0 (Sec_Edu) + b 1 (Age) + b2 (B_Psy) + b3 (B_Pre) + b4 (B_SFT)
As per the test of model effects it was found that the predictors Sec_Edu, Age, B_Psy, B_Pre and B_SFT are statistically significant for BTP.

A major finding of the statistical analysis is the common significance of psychological factors for CTP. Psychological state induced by the colour exposure (R_Psy / B_Psy), preference to colour exposure (R_Pre / B_Pre) and preconceived learnt ideas of the secondary education stream followed (Sec_Edu) dominate as commonly significant factors for both RTP and BTP. Adding to psychological factors, favorite colour (FVC) and religion (Rlgn) were identified as statistically significant for RTP. BTP was found to be affected by the subject's age. Parallel to the hunch that SFT could have an impact on RTP/BTP, it was found that B_SFT is significant for BTP.

None of the considered parameters of (actual) thermal perception were identified as significant for neither RTP nor BTP (other than B_SFT which was found to be significant for BTP) by the statistical model, suggesting that CTP is not linked to an actual thermal sensation. Average B_SFT being 0.71 ^{o} F higher than R_SFT signified possibility of colored surfaces to emit heat/radiation, yet not in an impacting level. CSOLR model rejected temporal artery temperature fluctuation as being significant for both RTP and BTP.

RTP Model: Pseudo R2 = .334 (Cox and Snell); .364 (Nagelkerke)
BTP Model: Pseudo R2 = .371 (Cox and Snell); .405 (Nagelkerke)

In the current investigation RTP models gave correct classification for 55.2% of the predictors studied. BTP provided classification for 58.3% suggesting a good model fit.

10. Conclusions

This investigation, while adding to the minimal amount of supportive empirical evidence on the dichotomous impacts of warm and cool colors on thermal perception, claims it's originality for filling the long awaited research gap for an empirical explanation on the nature of CTP with reference to its manifestation and significant parameters. It was revealed that CTP neither manifests as a result of a fluctuation in core body temperature by means of a biological reaction nor does it demonstrate traits of an actual thermal sensation caused physically via the human skin. CTP experienced by normal sighted healthy subjects demonstrates traits to be a psychological response with combinations of learnt reactions as well as certain common connotations. Further, CTP manifests to the most part as a response to visually transmitted thermal information which are interpreted via this psychological process. Accordingly, colour is a 'non-thermal stimuli' and the associated impacts are induced psychologically. Irrespective of the real indoor thermal condition of the laboratory which was regulated at 78.8 ^{o}F, the presence of red colour in the RWS has been able to psychologically manipulate the subjects to perceive the environment as warmer while exposure to blue colour in BWS has psychologically induced a cooler perception. This key new knowledge has a greater significance in architectural and design related solutions which may lead the future colour applications in to a different dimension where colour works as a psychological agent to generate thermally conducive, comfortable and responsive environments supportive in engendering optimum human behaviour.

12. Acknowledgments

We would acknowledge the assistance of all the academic and non-academic staff members of the Post Graduate Studies Division of the Faculty of Architecture in carrying out this research. The assistance of Mr. A.M.S. Attanayake is greately appreciated.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 54-65. ©

ARCHITECTURE'S NEGOTIATING CAPACITY
Investigating the interface between high-performance building envelopes and planning standards in Hong Kong

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Abstract
This paper aims to demonstrate that high-performance building envelopes can improve both the ventilation of urban space and the revenue of real estate industry, and will investigate how such improvements can be used to negotiate between objective and regulation in planning standards. Building on the observations made by architecture and other related disciplines, that planning standards often fail to meet their own objectives, this paper addresses a research site with a small public open space in Mong Kok, Hong Kong, to contextualize design research at the interface between high-performance building envelopes and planning standards. Escalating property values catalyse high redevelopment pressure in Mong Kok. Due to amended planning standards, architecture in the vicinity is successively replaced by grander development. If the building mass is maximized in concurrence with amended planning standards, it will obstruct the climatological conditions of light and ventilation, and thus diminish the performance of the small public open space, which produces a socio-economic conflict between public good and real estate interests. To mediate the conflict, this paper will show that negotiations between high-performance building envelope and zoning envelope can both improve the performance of small public open space, and accommodate the amplified turn-over rate on land coverage.

Keywords. *high-performance building envelope; zoning envelope; airflow*

1. Planning objectives

Zoning is the key tool for carrying out planning policy. Aldo Rossi (1982) verifies that zoning was modernized in the 1870s by the Prussian planner Reinhard Baumeister, and Carol Willis (1995) describes that zoning was exported to the USA at the turn of the nineteenth century to tame the intensified problems of the laissez-faire city. The first comprehensive zoning ordinance was enacted 1916 in New York. Edward M. Bassett (1932) clarifies its objective to protect “the public safety, health, morals and general welfare.” Dividing New York into three classes of districts (residence, business, and unclassified), the ordinance consequently implemented the zoning envelope, which Per-Johan Dahl (2014) describes as “a formula in which height and setback restrictions combine to outline the maximum allowable construction.”

Following New York, comprehensive zoning was introduced to Hong Kong in 1939, which Lawrence Lai (1996) clarifies. Richard F. Babcock (1966) describes that zoning was molded into a universal tool for land-use control, while Jonathan Barnett (1982) and Christine M. Boyer (1983) combine to elucidate that comprehensive zoning was widely criticized during the post-World War II era for failing to comply with social, cultural, and technical advancements. Impervious to critical reviews, comprehensive zoning remained the key tool for carrying out planning policy in global cities. While the premises of urbanization have changed dramatically since the early twentieth century, the premises of comprehensive zoning remain largely unchanged. In Hong Kong, for example, the Town Planning Ordinance (1997) deploys comprehensive zoning to “promote the health, safety, convenience, and general welfare of the community.”

1.2 THE HEIGHT RESTRICTIONS

The building height restrictions at Mong Kok were introduced to guide future development and redevelopment. The Hong Kong Town Planning Board (HKTPB) (2010) says that “[g]iven its location and the fact that there are many old buildings in [Mong Kok, the] area is under immense redevelopment pressure.” Thus, the HKTPB imposed building height restrictions in Mong Kok because the existing building stock is likely to be demolished and replaced with grander developments.

1.3 THE GAP BETWEEN OBJECTIVE AND REGULATION IN PLANNING STANDARDS

Any comprehensive zoning prompts the standards for maximum allowable real estate. When the development pressure is high, as the in case of Mong Kok, real estate speculation will successively replace the existing building stock with developments that maximize the floor area ratio in concurrence with enacted provision. As the building height restrictions have been limited to 80 and 100 meters, depending on the plot area, we may expect the building mass in Mong Kok to increase with more than 200%, which will affect the ventilation of the sitting-out areas. Scholars have correlated ventilation with wind speed to demonstrate how building form affects the wind environment at the ground level. Edward Ng (2009), for example, explains that varying building heights in dense urban space diverts winds to the lower levels, and S.H.L Yim et.al. (2009) show that buildings shaped as a "wall" hamper the flow of natural air, which reduces wind ventilation and causes pollution to accumulate at the ground level. Drawing from previous scholarship, we can predict that the increased building mass in Mong Kok will obstruct the ventilation of the sitting-out areas, thus diminishing their performance.

Light and ventilation determine the performative aspects of public space; ventilation is interconnected with the health of urban dwellers. Ricky Burdett (2011), director of the London School of Economics Cities and Urban Age, argues that with "70 per cent of the world's population forecast to be living in urban areas by 2050, global well-being will increasingly be determined by the health of urban dwellers." Addressing the health of urban dwellers, Anna Tibaijuka (2005), executive director of the United Nations Human Settlements, argues that "city parks and recreation facilities make for better living environments." Thus, these arguments suggest that the health of urban dwellers improves in accordance with access to well performing sitting-out areas.

As the increased building mass amplifies the turn-over rate on land coverage, the regulation responds to the financial interests of real estate industry by diminishing the ventilation of sitting-out areas. As already verified, the objective in Hong Kong's planning standards serves the public good by promoting the health of the community. When the regulation in planning standards stimulates intensified building mass, which will have negative impact on the health of urban dwellers, then comprehensive zoning produces a socio-economic conflict between the public good and real estate interests. This conflict, thus, is upheld by the gap between objective and regulation in planning standards.

1.4 RESEARCH DESIGN

This research project puts forth the hypothesis that planning standards tend to prevent architecture from actively participating in improving the performance of sitting-out areas. The objective of this research project is, therefore, to demonstrate that architects can shape building forms that accelerate wind speeds and, thus, improve the performance of sitting-out areas by advancing the ventilation of the ground level in a high density urban area. As such an objective requires negotiation between design and regulation, this project targets the interface between high-performance building envelopes and planning standards to postulate the research question: Can architecture mediate the conflict between real estate interests and the public good by designing a building form that accommodates both the financial interests of maximized floor area ratio, and the community interests of ventilated urban space? Design thinking was deployed for this project because such methodology allows research to oscillate between empirical data, scientific data, and form experiments.

2. Study method

Eight city blocks in the Mong Kok district of Hong Kong were used to contextualize design research (See Figure 1). The massing of the eight city blocks is comprised of medium-sized buildings, and five sitting-out areas. A building inventory was made for the research area, which informed the creation of a digital model for computer simulation purposes, with Rhinoceros software used for digital modelling: the Rhinoceros software was deployed because it supports both Euclidian geometry and topological transformations. Climatological data was obtained from the Hong Kong Observatory. The data verified median values during the 30-year period of 1981-2010: the average wind speed is 11 km/h (3.056 m/s), the prevailing wind direction is 90° (east wind), and the average temperature is 23.2℃.

Fig. 1. Research area and research site.

Following the building inventory, the documents that combine to outline comprehensive zoning in Hong Kong were collected, and the empirical data was consolidated. These documents are the Outline Zoning Plan (OZP S/K3/30) and the CAP 123F Building (Planning) Regulations (BPR). Hence a zoning table was compiled to outline the comprehensive zoning of the research area. (See Table 1) By correlating the zoning table with the size of each plot, the zoning envelopes of the eight city blocks were drafted to guide the subsequent investigation.

Table 1. (a) Comprehensive zoning at Mong Kok.

Code	Measure	Condition	Source
Height restriction	100 m	R(A), R(A)4; Site Area > 400 m^2	OZP S/K3/30
Height restriction	80 m	R(A), R(A)4; Site Area < 400 m^2	OZP S/K3/30
Plot ratio	3.3-7.5	Domestic in R(A)	OZP S/K3/30, BPR
Plot ratio	3.3-9.0	Non-domestic in R(A), R(A)4	OZP S/K3/30, BPR
Site coverage	33.33%-80%	Domestic	BPR
Height of story	2-2.5 m	Floor/Ceiling 2.5; Floor/Beam 2.3; Inclination ≥2	BPR
Open space	1/2-1/4	Domestic; A: 1/2, B: 1/3, C, 1/4 of covered area	BPR
Setback, open space	1.5 m	Setback to open space	BPR
Setback, street	2.25 m	Street width <4.5 m, setback from center line	BPR
Setback, cuttings	2.5 m	2.5 m, 1/4 height of the cuttings	BPR
Setback, retaining wall	1.5 m	Height of retaining wall > 4.5 m	BPR

Table 1 (b) Building height, site coverage, and plot ratio (buildings in Class A – C).

Building height (meters)	Site coverage (%)			Plot Ratio		
	Class A	Class B	Class C	Class A	Class B	Class C
H≤15	66.6	75	80	3.3	3.75	4.0
15<H≤18	60	67	72	3.6	4.0	4.3
18<H≤21	56	62	67	3.9	4.3	4.7
21<H≤24	52	58	63	4.2	4.6	5.0
24<H≤27	49	55	59	4.4	4.9	5.3
27<H≤30	46	52	55	4.6	5.2	5.5
30<H≤36	42	47.5	50	5.0	5.7	6.0
36<H≤43	39	44	47	5.4	6.1	6.5
43<H≤49	37	41	44	5.9	6.5	7.0
49<H≤55	35	39	42	6.3	7.0	7.5
55<H≤61	34	38	41	6.8	7.6	8.0
H≥61	33.33	37.5	40	8.0	9.0	10.0

With climatological data and empirical data that verifies the discrepancy between current building mass and planning standards, computer simulations were executed to verify wind flow, illumination, and solar radiation at the ground level in Mong Kok's urban canyons (See Figure 2). Both the existing building stock and the projected building stock, which maximizes the floor area ratio in concurrence with comprehensive zoning, were used for simulations. As singular buildings can be replaced in the digital model, form experiments were additionally initiated, and scientific data was collected on the correlation between the shifting climatological conditions at the ground level and the specific shape of buildings. Multiple data with relevance to the fields of urbanism, urban design, environmental science, and architecture was collected. The extensive data additionally served to verify the accuracy of obtained values. As this article takes the ventilation of sitting-out areas as the subject matter to problematize the interface between high-performance building envelopes and planning standards, the following text will focus on the relationship between wind speeds and building forms.

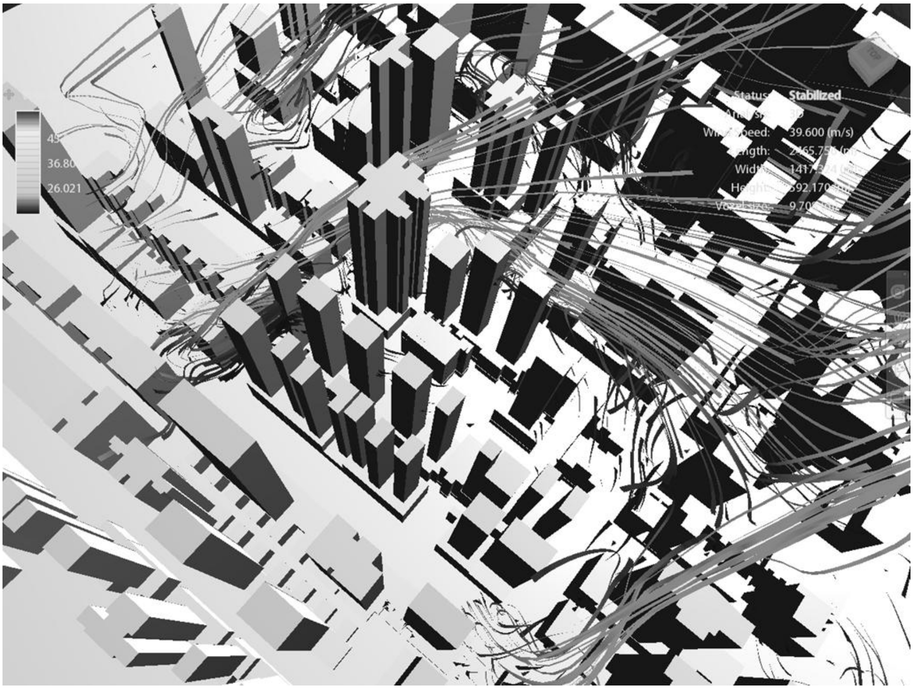

Fig. 2. Computer simulation of wind flows.

2.1. DETECTING THE RESEARCH SITE

To answer the research question, a research site was needed for in-depth analysis (See Figure 1). As the research objective was to collect data on building forms that improve the performance of small public open spaces by accelerating wind speeds at the ground level, the research site ought to include one sitting-out area and one built-out plot. The research plan was to measure the impact from the existing building envelope; from the as-of-right building envelope; and from multiple high-performance building envelopes. Comparison analysis would, hence, point to correlations and discrepancies between the efficiency of planning standards and the performative aspects of building form.

Fig. 3. The research site with the Portland Street/Man Ming Lane Sitting-Out area.

As computer simulations of the eight city blocks had proved the eastern façades to be superior in advancing ventilation at the ground level in Mong Kok, a research site was composed to include the east-facing Portland Street/Man Ming Lane Sitting-Out Area, and the two aligning plots at 370 Shanghai Street and 364-368 Shanghai Street (See Figure 3). The research site measures 857 m²; the sitting-out area measures 443 m². As the larger plot at 364-368 Shanghai Street comprises 270 m², the zoning envelope measures 80 meters; as the combined plots with easement comprise 414 m², the zoning envelope measures 100 meters.

3. Results

Any dense urban block affects wind flow, thus the performance of a small public open space is linked to the density of the surrounding building mass. With a digital model of the research area, and with wind data from the Hong Kong Observatory, wind flow at the ground level of the research site was measured through computer simulation. An 80-meter as-of-right tower was modeled with the Rhinoceros software and inserted into the digital model. Two software products were deployed for computer simulation: Autodesk Ecotect Analysis, and Autodesk Flow Design. Both software products verified the prevailing wind speed at the ground level of the research site to 0.09 m/s.

As the zoning envelope at the research site measures 100 meters, the 80-meter tower was replaced by a 100-meter tower. The computer simulation verified that the prevailing wind speed remained at 0.09 m/s, which demonstrates that a tower as-of-right does not accelerate wind speeds at the ground level of the research site.

3.1. SHAPING THE HIGH-PERFORMANCE BUILDING ENVELOPE

Per-Johan Dahl (2014) argues that comprehensive zoning complies with Euclidian geometry, while Greg Lynn (2004) states that the performative aspect of building form complies with topology. As the speculative forces of real estate tend to maximize the floor area ratio in concurrence with enacted provision, the geometrical principles implicit in zoning tend to guide the architecture of most developments. As economics comprise our main mode of city governance – a connotation Pier Vittorio Aureli (2011) clearly articulates – topology is rarely an alternative for building designs as-of-right. We may therefor assume that building envelopes shaped beyond the zoning envelope can comply with topology and thus accelerate stronger wind speeds than building envelopes shaped as-of-right.

While scholarship on high-performance building envelopes, such as scholarship by Sheila J. Hayter, Paul A. Torcellini, Richard B. Hayter and Ron Judkoff (2001), tends to focus on the functions taking place within the private realm of buildings, this paper expands disciplinary impact by elucidating means for high-performance building envelopes to improve the quality of public space. If the regulations in planning standards prevent architecture from shaping high-performance building envelopes capable of improving the performance of public space, then the objective in planning standards may assist architecture in negotiating the restrictions imposed by the zoning envelope.

After measuring the wind speed created by the tower as-of-right, 20 high-performance building envelopes were modelled with the Rhinoceros software and used for simulation: ten high-performance building envelopes measured 100 meters, thus the same height as the tower as-of-right, and ten high-performance building envelopes measured 120 meters, thus 20 meters above the tower as-of- right. All 20 high-performance building envelopes were modelled as closed polysurface volumes, and they all rebelled against the zoning envelope because they accelerated wind speeds through correlation between maximized building footprints and cantilevering façades (See Figure 4). The cantilevering façades were composed of flat and curved angulations of 2°, 4°, 6°, 8°, and 10°. All 20 high-performance building envelopes exceeded the zoning envelope, thus they all submitted to the real estate interests at Mong Kok by implying floor area ratios beyond the tower as-of-right.

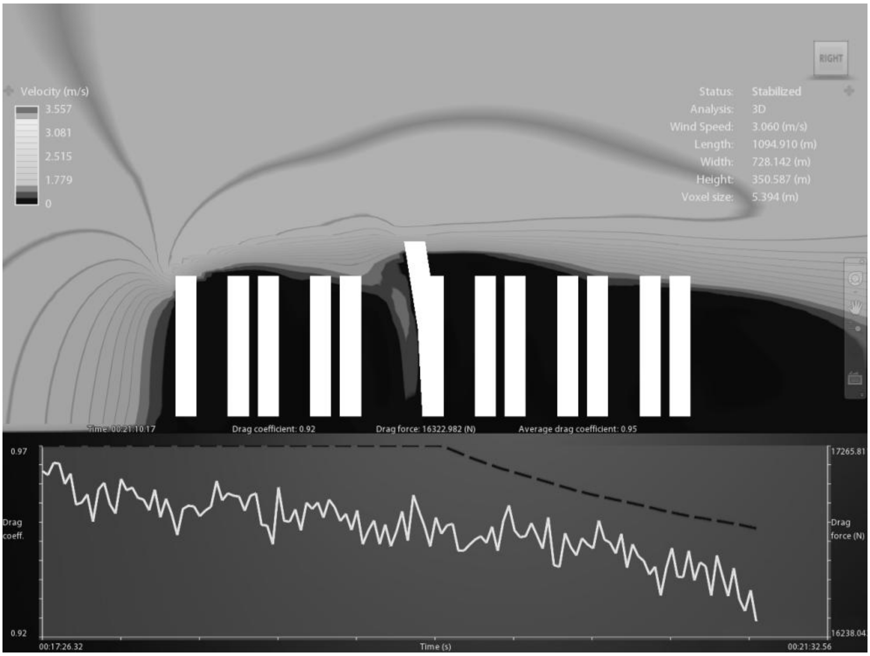

Fig. 4. Computer simulation of a 120-meter high-performance building envelope.

3.2. ANALYZING THE HIGH-PERFORMANCE BUILDING ENVELOPE

As Autodesk Ecotect Analysis proved incapable of measuring data on cantilevering façades, Autodesk Flow Design was deployed for computer simulations of the 20 high-performance building envelopes. An axonometric drawing was composed to instigate comparison analysis between the 20 high-performance building envelopes, and the zoning envelope, see Fig. 5. The axonometric drawing was used because it correlates the urban plan with the building profiles and the massing impacts. While representing the relationship between the different profiles and the sitting-out area, the axonometric drawing also facilitated the drafting of an 80-meter street wall, which measures relationships between the different building height regulations of the zoning plan and the building height beyond the zoning plan, which was used by the research project, see Fig. 5. Of the ten 100-meter high-performance building envelopes, eight increased the wind speeds at the research site, while two decreased the wind speeds, see Fig. 5. Of the ten 120-meter high-performance building envelopes, seven increased the wind speeds at the research site, while one proved similar capacities as the tower as-of-right and two decreased the wind speeds, see Fig. 5.

The high-performance building envelope that accelerated the strongest wind speeds at the research site, and thus proved to be most successful in improving the performance of the sitting-out area, was composed of curved angulation of 8° (8° Tilt + Curve) and measured 120 meters: this high-performance building envelope increased the wind speed at the ground level of the research area with 290%, see Fig. 5.

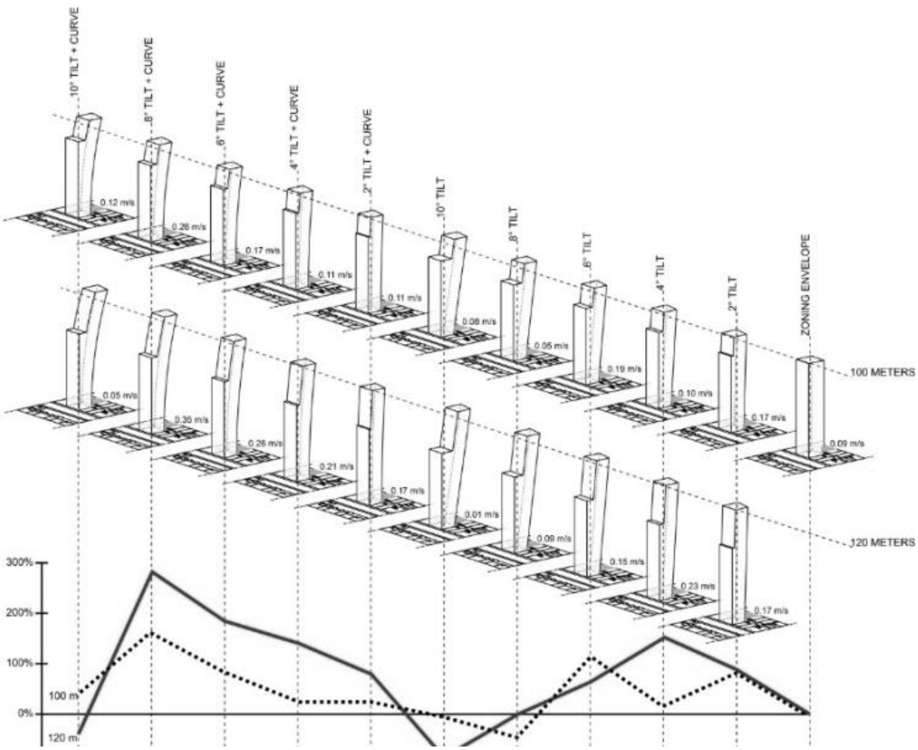

Fig. 5. Wind speed fluctuations at the center of the small public open space (%) building heights 100 meters and 120 meters (m).

4. Conclusions

This research project elucidates discrepancies between the planning objectives and the planning standards in Mong Kok, Hong Kong. The research project shows that negotiations between architectural design and comprehensive zoning encompass a viable method for the Hong Kong Town Planning Board to deploy when seeking to accomplish the objective in planning standards. This project additionally demonstrates that well-performing public spaces do not necessary correlate with building height restrictions, which call for new routines in planning administration. As this project is limited to one in-depth analysis, further studies are needed to verify its impact on the wider scope of urbanization.

This research project deployed architecture to investigate issues of urbanization. As the discipline of architecture addresses the question of scale, which tends to be disregarded by urban practices, this research project uncovers new information on the detail in urban processes. City agencies administrate urban space through planning; architects shape urban space through design. As design is much more responsive to the specific qualities of a site, architecture provides valuable methods for how to negotiate the private interests of building form with the public interests of the urban realm. The results from this research project, for example, demonstrate that miniscule adjustments of façade geometries catalyses tremendous impact on the performative aspects of public space. Thus the care for detail should go beyond the discipline of architecture and involve also the discipline of urbanism. Such a shift in the attention to scale opens up a field of research on the proficiency of planning standards to embrace incremental approaches to urban development and transformation.

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'COST' AND THE NOTION OF 'EXPERIMENT' IN ARCHITECTURAL DESIGN IN SRI LANKA - *Study with reference to factors effect in experiment in material usage in personalized houses in Sri Lanka.*

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Abstract
This research is an enquiry into architectural design and construction. The study looks at the personalized houses done by local Chartered Architects in Sri Lanka. It is an examination on how architects 'experiment and innovate'. Key hypotheses for the research were; "Architects are not sufficiently involved in experimenting with building material and technology" and "the limited experimenting is mainly due to cost issues". This sector receives the most active contribution from the professionals but the approaches are confined to a limited set of practice conventions. Therefore, this segment of the industry is identified as the most appropriate section to carry throughout the research. The study investigates the effects of 'cost' in relation to experiment and attempts to establish the notion of 'experiment' in architectural design process and practice in Sri Lanka. The study finds out the 'factors limiting the experimentation' in the field of architecture. The research carries out with a questionnaire survey and case study interviews. Both qualitative and quantitative analyses are made to analyse the factors affect in experiment in architecture and the most effective backgrounds in experimenting.

Keywords: *Experiment in Architecture, Materials and Technology, Building Process, Conventions, Cost*

1. Introduction

Based on the key hypothesises the study looks at the possible factors preventing and limiting experimentation in architecture. The final outcome of architecture is a 'built product'. This 'product' is made using materials and technology. Experimenting is a way to deviate from the conventional and innovate in practice. In architecture, experimenting;

- Bring economic benefits to the building industry

- Expand existing knowledge and add new knowledge to the industry and its practices
- Leads to most responsive methods of building construction
- Leads to innovating, developing materials and technologies deviated from the convention
- Satisfy academic, intellectual curiosity and research.

In Building, any attempt to deviate from the standard modes of practice will have considerable cost implications. Surveys show that this has restricted experiment and innovation by the architect. The study intends to find out what key factors define the scope of their practices in engaging in experiment.

2. Background to the study

This research is formed on the inquiry into the importance of craft in architectural design and construction as propagated by William J Carpenter in Learning by Building: *Design and Construction in Architectural Education* (1997). Carpenter highlights the fact that the contemporary architectural practice is separated from the construction process and how this schism is preventing the evolution and innovation of the practice and the practices.

The main theoretical basis if the research is formulated on broad aspects related to architecture and building industry on the writings of Steven Groak – The Idea of Building (1992). The research hypothesis is formed around Groak's frameworks of buildings and building processes.

Chartered Architect Vijitha Basnayake explains, "…*what we learn from the school of architecture is like the food we eat, we can name them and divide them in names. But, the outcome of it is 'energy', which we cannot describe in bits and pieces, architecture should also be like that…. You have to find a new thing out of what you have learned…*" (Basnayake, V, personal communication, February 8, 2015)

Architect Basnayake's reasoning highlight the need to widen the scope of the experiment interventions in Architecture. Dr. Pathiraja sets out the wider parameters of architectural interventions thus; *"The ability to understand and negotiate differences in cultural and economic and eventually operative frameworks of building production, hence become the key success of any Architectural Design Intervention..."*(Pathiraja, M, 2014)

Both statements establishes the need for the architect to be responsive to a wider range of criteria and to innovate responding to those.

"Buildings are not achievements in individual entities. Social development, social cultural Infrastructure, Technical system, Material Investigation, Labour Training has become act of Flexible creative synthesis that brings problems and solutions..." (Pathiraja, M, 2014).

Within these arguments, architecture can be defined as a process that combines aesthetic and social issues with economy of means, tectonic research and sensory comfort.

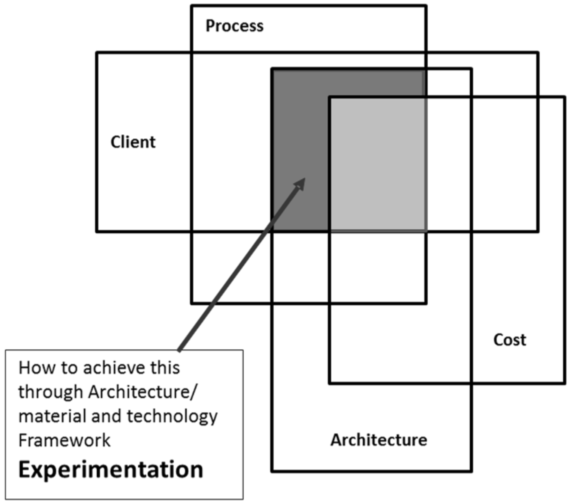

Figure 1: Building Process Framework

The scope of experiment in architecture is a matter of the behavior of the process, the client and the cost. This framework (Figure 1) provides the scope and limitations of experiment. The research intended to investigate the following in relation to architecture;

1. Investigate the Experimental approach to architecture
2. Investigate what is meant by architectural experiment in material and technology.
3. Find out the architectural community's perception about architectural experiment.
4. Find out about time – cost implications in Architectural Experiment.
5. Find out what are the advantages and benefits of experimenting?
6. Find answers to what makes architects' practice experiment.

3. Significance of the Study

The research acknowledges that experimenting is fundamentally to the advancement of the practice and the profession. It is also noted that there is limited research carried out within the field in relation to the research area. Hence, the research intends to gather knowledge in experiment in architecture.

The lack of awareness of the significance of the research area may also lead to vast amount of valuable knowledge 'getting lost' in practice. Raising awareness of the significance of experimenting as well as the benefits of doing the same may encourage and promote initiatives in that direction.

It is noted in the hypothesis that the material and technology application in architecture is limited to a convention. The reasoning for the above matter is mainly the cost effect. The intention is to find out the possibilities of building, responsive, innovative building in terms of material s and technology. Hence to find out the real factors effect in experimentation in architecture.

4. **Methodology**

This study is carried out 'combining qualitative and quantitative data to best understand and explain a research problem' (Creswell, 2002, p. 59) and therefore follows a 'Mixed Method Research' procedure.

The following methods were used to gather information and data for this study.

1. Pilot survey to find out general norms in relation to experimentation in architecture.
2. Survey on published architectural work to establish the convention and analyse the extents of experimentation carried out within the practice.
3. Selection of case studies and Interviews to analyse the factors effect and not effect in experimentation.

5. Findings and Data analysis

The study will conclude by summarizing the findings of the survey and answering the key questions.

6. Experiment in Architecture.

The research investigates implications in architecture in relation to experiment by looking at;

- Modes of interventions and the types of outcomes
- Where such interventions take place
- The significance of studying such interventions in experimental housing designed and supervised by individual practitioners.

7. Field Surveys and Case Studies.

The research reflects how certain architects have managed to engage in experiment in architecture within the current system and important features of their experience.

The research is carried out in four main stages.

1. Pilot survey and questionnaire
2. Survey on published architectural work
3. Selection of case studies and Interviews
4. Findings and Data analysis

8. Research Outcomes.

From the pilot survey the study finds out the factors effect in experimentation according to the general perception of the architects. Then the questionnaire survey provides data to make a hierarchy of the intensity of effects of the factors provided in the questionnaire.

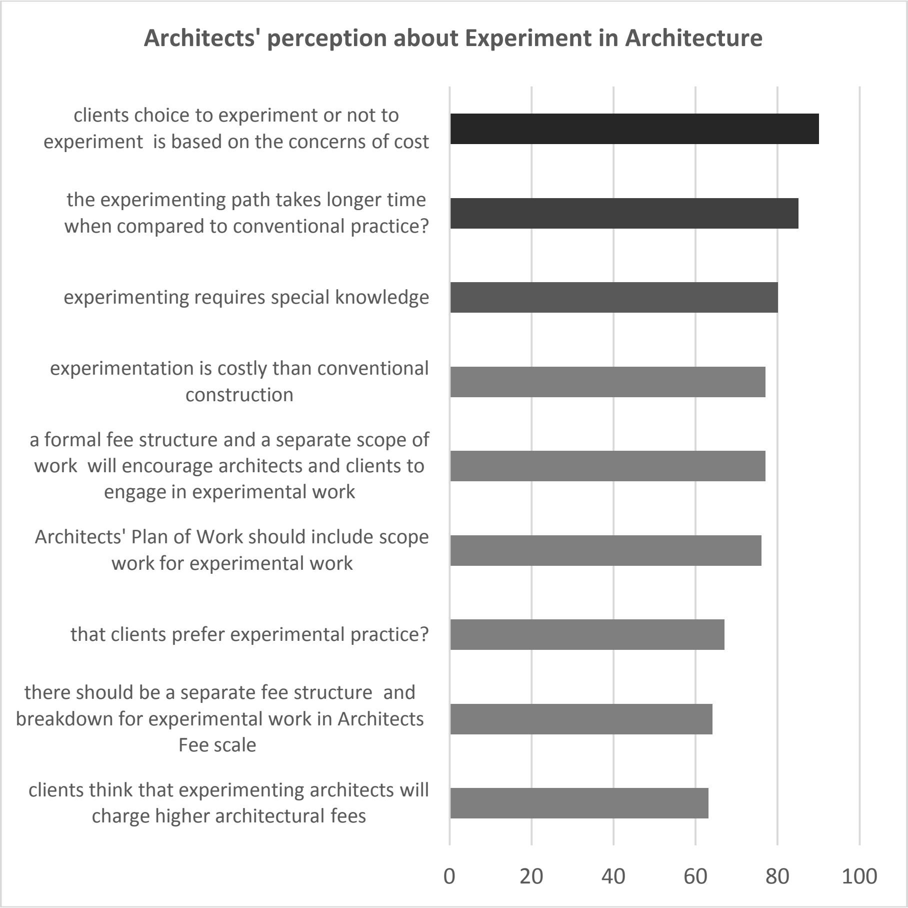

Figure 2: Architects' Perception about experiment in architecture
Source: Author based on the responds from the questionnaire survey

The graphical representation above figure 2 shows that architects perception is that clients' choice of experiment is based on 'cost'. And also the time factor and the knowledge factor are the key elements that limits experiment in architecture.

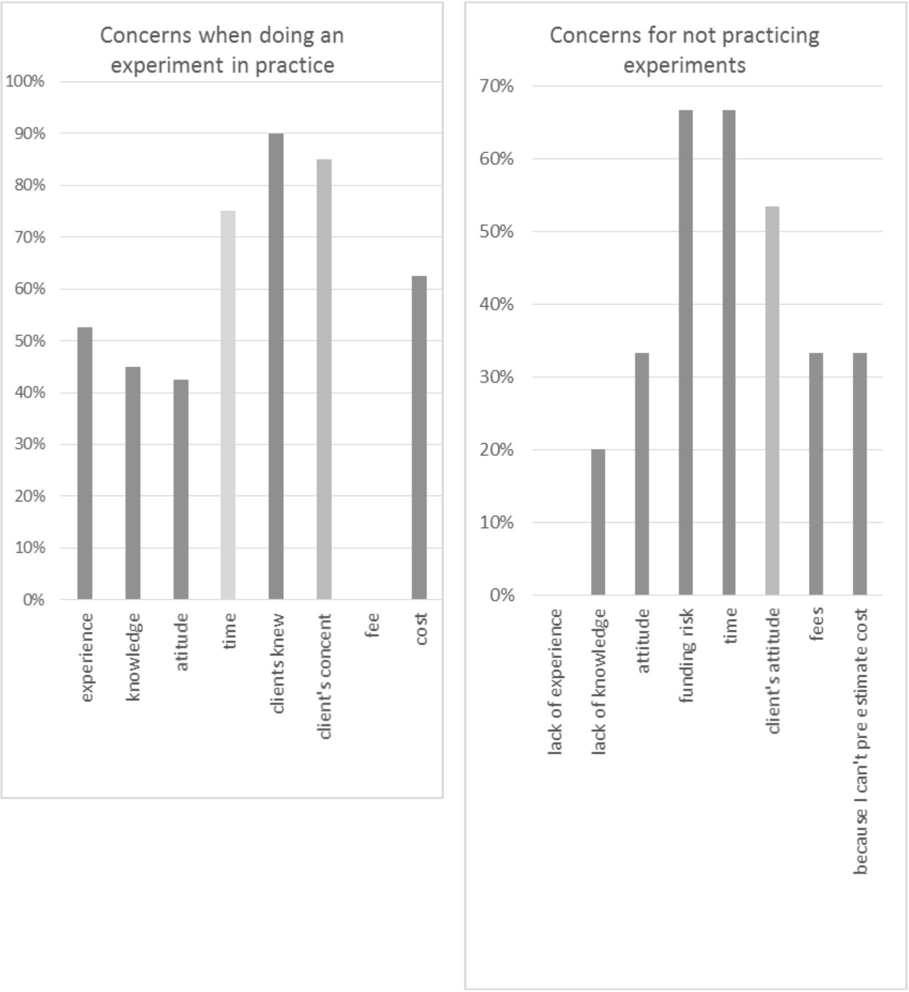

Figure 3: The Concerns in Experimenting
Source: Author based on questionnaire survey

However these graphs (figure 3) shows that the key factors for practicing experiments in architecture for the architects who have engaged in experiment are to save time with the clients' consent and the cost factor comes in fourth place. Here the architect's intention was to reduce the cost.

But the architects who say they are not practicing experimentation says the three main factors for not practicing experimentation are cost, time and clients attitude.

Those above results conclude that cost, time and client's attitude are the factors deciding experimentation in architecture or not.

This result lead the research to find out the other variables in experimentation in architecture.

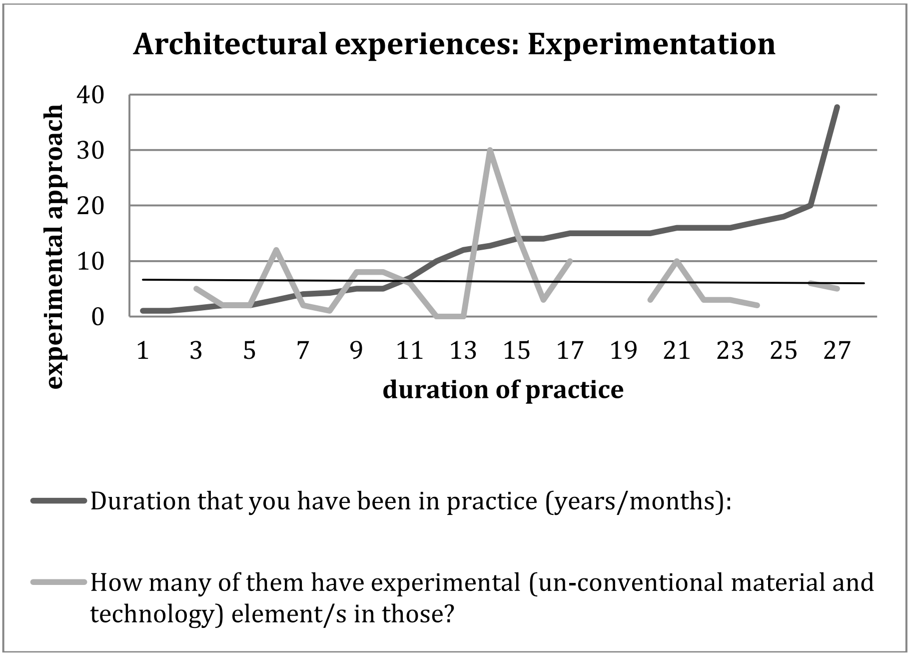

Figure 4: Architectural Experience vs. Experimentation
Source: Author based on questionnaire survey

The statistical analysis of the data collected from the architects show that frequency of experimentation decreasing with the duration of the practice (figure 4). The reasoning behind this was proved by the image survey also. Both shows that architects makes their own palette of materials and technology. Hence the experimentation limits up to making that palette. There after it is more of an applying the same palette in every design.

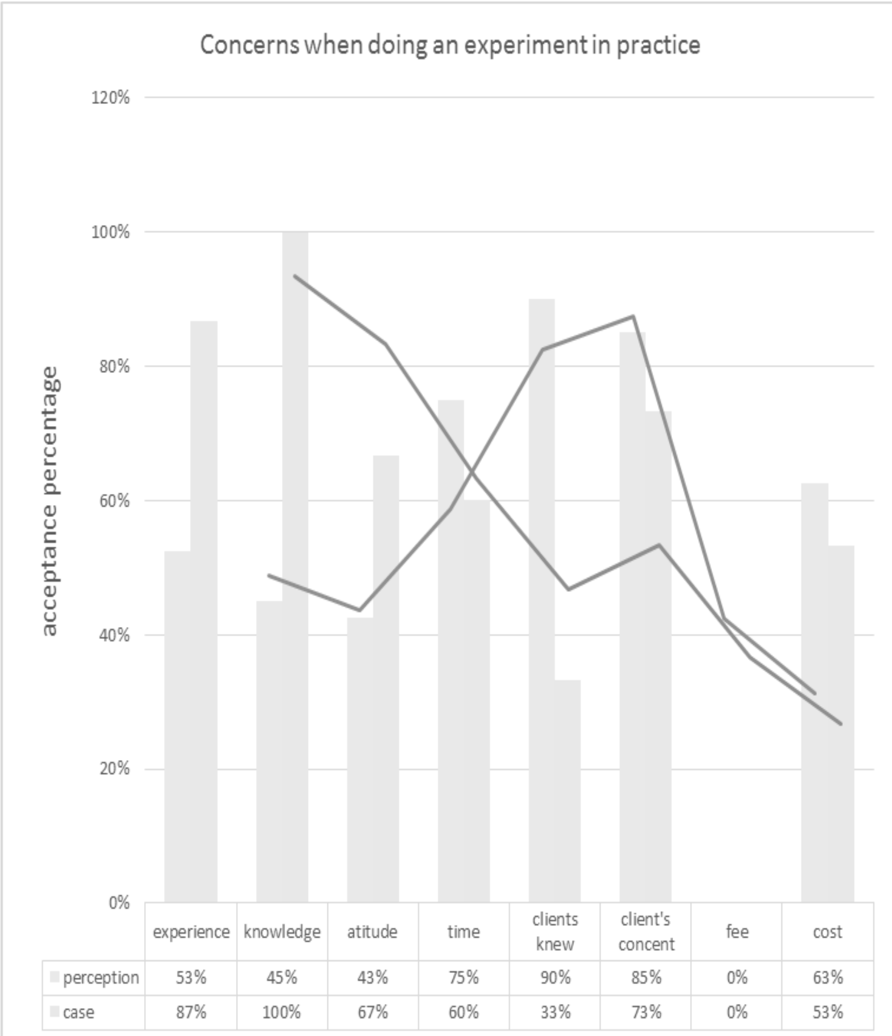

Figure 5: Experimentation concerns
Source: Author

With finding the key 'limitation' to experiment in architecture the sta-tistical analysis shows the actual factors of experiment in architecture compared to the perception of the architects (figure 5).

This clarifies that the knowledge and architects' attitude are the main factors of experiment in architecture. Architects should have material and technological knowledge in order to carry out experimentation and also they should be willing to explore experimentation with the practice (figure 6).

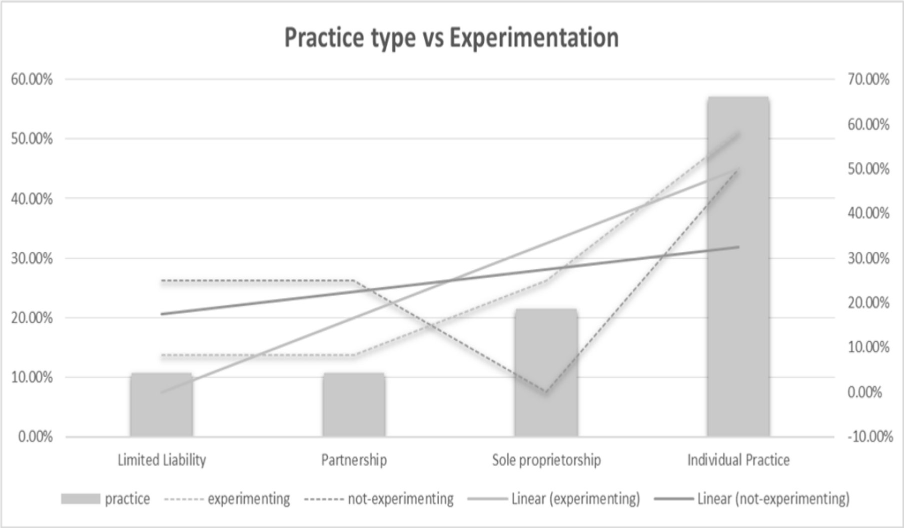

Figure 6: Practice type vs. Experimentation
Source: Author

9. Conclusions

The research findings answered key research questions and reviewed the effect on the architects Plan of Work against experiment mode of architecture. The final analysis of the study clearly showed that majority of surveyed architects believed that they 'did experiment' in practice. This was clearly reflected with the questionnaire survey findings where 83% of architects claimed that they do experiment and only 17 % claimed that did not experiment. This finding was based on their own perception of their work practice.

From the case studies, two out of three architects (67%) stated that they were experimenting and the remaining architect (33%) claimed that whatever he did, he did not consider that as experiment.

Therefore, in conclusion, it can be noted that on contrary to the claim in the hypotheses, 'that architects do not experiment' majority of architects believed that they did experiment in materials and technology.

The analysis of the image survey, carried out on the published projects however revealed that majority of architects continued to operate within conventional use of materials and Technologies confirming the claim that made by the research question. However, it can be concluded that image survey was carried out with limitations as compared that of questionnaire survey and the case study survey.

From the questionnaire survey findings it can be concluded that majority of architects believed that experimenting was beneficial to the practitioners and to the profession. The majority who took the questionnaire survey indicated that cost and time as the key challenges and factors that discouraged experimentation. However, this finding was comprehensively disputed by the case study interviews. Those architects concluded that 'cost' was key determinant to engage in experimentation and the extension of time was not as critical as perceived. The gains on cost effectiveness seemed have off set the difficulties of time extensions incurred due to experiment.

The findings of the case studies indicated the considerable changes and variations to the standard, Architects Plan of Work, in relation to experimenting. However, most of these variations in architects extended scope and engagement occurred within the conventional building programme. The case study survey justified that extended involvement as an essential feature to the success of any experimental intervention although it was not supplemented with additional professional fee. It may be concluded that architects were aware of these facts from the inception of the projects and they continued to engage in experimenting without any monetary reward.

The findings of the study further indicated that experiment in architecture might be encouraged where cost limitations are critical. The experimental case studies justified this fact and established that greater cost benefits can be achieved with experiments, although these projects may require additional time to complete.

The case studies gave valuable insight to salient factors specific to experiment. These findings indicated that, for successful experimenting and to encourage experimenting, certain simple methods can bring positive outcomes. The study findings are concluded with the following list of ten key propositions to achieve a successful approach to experiment in architecture;

1. Develop a plan of work and a fee scale that can facilitate experiment in architecture
2. Carry out background studies
3. Keep the records
4. Before implementation, discuss ideas with the engineer and the builder
5. Educate the client about what you are going to do as 'experiment'
6. Pre-plan alternatives in case of an un-successful experiment

7. Pre-think about the maintenance process
8. Educate the client about the maintenance
9. Get feedback from the client
10. Execute the improvements immediately

Acknowledgements

The authors like to acknowledge the valuable contribution made by the Chartered Architects and other personnel who participated in the field survey, interviews and case studies in the research.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 78–91. ©

TRANSACTION COSTS OF GREEN OFFICE BUILDING CONSTRUCTION IN SRI LANKA

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Abstract
Although the concept of Green Building is popular in other countries, it is not yet so in Sri Lanka as no clear identification of the transaction cost of green buildings has so far been made. Given the expanding scope of construction of office buildings in Sri Lanka, it has become important to differentiate between the transactions costs of green buildings from those of conventional buildings. Hence this research is aimed at studying the transaction costs of green office buildings in Sri Lanka. A literature synthesis was carried out to learn about the green building concept and the benefits of green buildings. Identification of the transaction cost components was done through three preliminary interviews and two case studies conducted through semi structured interviews that were aimed at comparing the cost components of each building type with those of the other type. The findings revealed that the transaction costs of green buildings in Sri Lanka relates to costs incurred for preliminary studies, managing the designs, gaining knowledge on green certified material, technical advice, documentation and commissioning for LEED certificates and quality checking by obtaining the services of green consultants. Hence, the state agencies need to ensure that green material is available at discounted prices, take steps to present awards to professionals involved in green building and conduct seminars for the benefit of these professionals. It is also recommended that the Green Building Council should lower its commissioning fees to encourage the developers to obtain green certificates so that the concept of Green Building in Sri Lanka is promoted.

Keywords. *Cost Components; Green Building, Office Building, Transaction Cost*

1. Introduction

Construction activities are an integral part of a country's national economy and industrial development (Khan, 2008). The rapid growth of the world's population and rapid urbanization lead to a higher consumption of the world's limited resources (Kats, 2003). The construction industry has a responsibility to utilize environmental resources in an ecologically sustainable manner (Fernando, 2012) since the buildings are responsible for more than 40 percent of the global energy used, and as much as one third of global greenhouse gas emissions, in both developed and developing countries (United Nations Environment Programme, 2009).

Green buildings consist of environmentally sustainable building elements, which can deliver benefits to society by saving environmental resources (Urbecon, 2008). Despite the merits of green buildings as far as the owners, occupants, society at large, and environment are concerned (Baird, 2010). They have a higher initial capital cost compared to that of traditional buildings (Johnson, 2000; Kat, 2003). The Transaction Cost (TC) is referred to in terms of risk, time delay, uncertainty, and information search, setting up cost etc. (Qian, Chan & Khalid, 2015) and also in terms of increased architectural and engineering (A&E) design time, modeling costs and time necessary to integrate sustainable building practices into projects (Kats, 2003).Even though the design of green buildings is critical in terms of cost components (Richard, 2008), if integrative design techniques are properly employed, TC of green buildings should become less than that of conventional buildings (Rehm & Ade, 2013). Additionally, Malin (2000) has argued that considering the life cycle cost advantage, a higher initial cost which is associated with certain types of green material will not be an expense. Hydes and Creech (2000) have studied the use of green building as the reuse of building material and equipment can be considered as more beneficial.

According to data made available by the Central Bank reports, the construction of office buildings is on the increase in Sri Lanka. Thus, a successful investigation on transaction costs incorporated with Green office building construction would lead to introduce new trends in construction industry. Therefore, a study to identify and analyse transaction costs of green buildings against conventional buildings in Sri Lanka has become necessary in order to fill the gap in literature and to face the demands of the construction industry which if expanded can rapidly boost the country's economy.

2. Concept of Green Building

The construction industry has a negative impact on the environment in a number of ways; i.e from excessive consumption of resources to the pollution of the surrounding environment (Ding, 2008). According to Kates (2003), human activities cause greenhouse gas emissions and global warming to increase whereas Tatari and Kucukvar (2011) have agreed with the fact that the buildings are one of the biggest contributors to greenhouse gas emissions being responsible for 38% of all CO_2 emissions. In order to reduce or eliminate the impact on human health and the natural environment and increase the efficiency of use of energy, water and other resources, the movement of green (sustainable) building was found , which is expected to enhance the enjoyment of life of the occupants of green buildings (Richard, 2008).

For the purpose of enhancing the quality of green building construction by measuring its performance, a transparent evaluation process has also been established, which is called a 'Rating system' (Cole, 1999). The Leadership in Energy and Environmental Design (LEED) has been launched which encourages the adoption of sustainable green building and development practices. The Green Building Council of Sri Lanka (GBCSL) is uniquely supported by both the industry and government institutions across the country (GBCSL, 2011) which is quite similar to LEED.

After comparing with the conventional buildings, Kats (2003) has argued that green buildings are more efficient in terms of using resources whereas Richard (2003) has positively criticized that they are environmentally responsible and resource efficient throughout their life-cycles commencing from their siting to design, construction, operation, maintenance, renovation and deconstruction. Thus, green building has now become a leading mode of sustainable development in this century which has the ability for balancing long-term economic, environmental and social health. (Ali & Al Nsairat, 2009).

3. Transaction Costs in green buildings

The actual cost of a construction project comprises of not only production costs but also transaction costs (Li, Arditi, & Wang, 2012). Production costs consist of direct expenses related to the building such as the costs related to material, equipment and construction labor whereas transaction costs consist of indirect expenses related to the building. Transaction costs relate to the cost of resources used to create and use a policy through defining, establishing, maintaining and transferring property rights (McCann (2005)). Moreover, Coggan, Whitten, and Bennett (2010) have mentioned that the transaction costs typically occur in the form of goods and services, travel costs, labour and time expended in a transaction whereas Alexia and Valerie (2008) have argued that they consist of all additional expenses related to a construction project such as the fees paid to the architect, engineer , consultant and the government, taxes, costs of financing and interest. Transaction costs are incorporated into the costs incurred at the pre contract stage (cost for carrying out market research, exploring financial opportunities, conducting a feasibility study, organizing bidding or negotiation and managing the designs) and post contract stage (costs for carrying out the administration of the contract, change orders and claims, resolving of disputes and managing incentives) in construction projects. The transaction cost as a percentage of the total construction cost varies according to the procurement arrangements of a particular construction project (Whittington, 2008).

For this study, transaction cost is defined as the all the indirect cost which are incorporated in pre-contract stage as well as in post contract stage in a construction project i.e. cost for preliminary studies, designing costs, bidding costs, extra legal costs, administrative costs after contract, resolving disputes, inspection costs etc.

Green building transaction costs are higher than those of conventional buildings due to incremental costs associated with the process that has to be followed for obtaining a green building rating (Rehm & Ade, 2013) which involves additional consulting services , use of new technologies, processing of green certificates and risks connected with the innovative designs used (especially inexperienced contractors) (Alexia & Valerie, 2008). For instance, Langdon (2007) has analysed the Australian Green Star rating system by comparing the cost of the green and that of non-green buildings to estimate the cost premium where the green building has had a 3-5% premium with respect to their conventional counterparts. Likewise, Kats (2006) has found that the green design provided 1-2% additional cost with Packard Foundation (2002) indicating a 21% premium for LEED Platinum rated buildings.

4.0 Research Problem

Many international and local researches have been based on costs and benefits of green buildings, especially, their initial costs and the resulting benefits. This research was carried out on green office buildings in Sri Lanka since Colombo and other areas have a high demand for office buildings, even though their cost of maintenance is high. Brain (2003) has stated that if office buildings could be designed to reduce costs (especially their maintenance costs) and provide healthy and attractive buildings, tenants would be quite pleased with them as they were never before. Because of the reluctance to adopt new technologies and unwillingness to take financial risks, ‘Green technology’ is still a concept that is new when compared to conventional building construction. (Shirajiv, 2012).

As far as the literature gap and the industry gap are concerned, in Sri Lanka, a clear demarcation has not yet been identified between transaction cost of green office buildings and that of conventional buildings. Therefore, identifying and analysing the transaction costs of Green builsings vs. conventional buildings will have a significant effect on the research on innovative methods of reducing the cost of green building construction in Sri Lanka.

5. Research Aim and Objectives

The aim of the research study is to identify and analyse transaction costs of green buildings against conventional buildings in Sri Lanka. The objectives of the research study are as follows:

- To identify the Green building concept and its benefits
- To identify the components of transaction costs of Green buildings and conventional buildings
- To identify the transaction costs of Green buildings and conventional buildings
- To investigate the transaction costs in Green building vs. Conventional buildings

The study was conducted among professionals involved in the design, construction, and maintenance of at least one green building in Sri Lanka. To enhance the accuracy, both green and conventional office buildings having similar conditions and situated in Colombo region were considered.

7. Research Methodology

The mixed method was adopted to undertake the research study while case studies were the research approach. Initially, an extensive literature survey and three preliminary unstructured expert interviews were carried out to understand the concept of green buildings and the benefits of the green buildings (objective 1) and the components of the transaction cost of both green and conventional buildings (objective 2).To identify the transaction costs of green and conventional buildings (objective 3), four case studies were done. Semi structured interviews were used for data collection and content analysis was the data analysis technique where the Nvivo 10 software was the analysis tool. The final objective; investigating the difference of transaction costs in Green buildings vs. conventional buildings was achieved through analysing the cost information attained from semi-structured interviews and document review.

8. Research Findings

Research findings are discussed under three main headings (green buildings vs. conventional buildings), i.e identification of the transaction cost components, identification of the transaction costs and investigation the difference of transaction costs in Green buildings vs. conventional buildings.

8.1. IDENTIFICATION OF TRANSACTION COST COMPONENTS; GREEN OFFICE BUILDINGS VS. CONVENTIONAL BUILDINGS

The objective of this Section is to identify the transaction cost components of both green and conventional office buildings and the validation of the findings of the literature review. Three unstructured interviews were conducted for this purpose and Table 1 presents the profiles of the interviewees.

Table 1: Respondents' details of preliminary survey interviews

Profession	Position	Years of experience
Engineer	Project Manager	25 years
Quantity surveyor	General Manager	20 years
Engineer	Mechanical Engineer	7 years

The applicable transaction cost factors for both the pre-contract stage and the post contract stage were compared with the support of the experts. It was found that some cost components are similar while some others are higher for green buildings. Some factors were ignored as they were not applicable. The identified cost components are shown in Table 5 and those components were used to compare the transaction costs in Green office buildings against conventional buildings.

8.2. IDENTIFICATION OF TRANSACTION COSTS; GREEN OFFICE BUILDINGS VS. CONVENTIONAL BUILDINGS

The objective of this Section is to identify the transaction costs of both green and conventional office buildings. Four case studies were done to enable an in-depth investigation and Table 2 and 3 present respectively the details of the buildings and the details of the respondents.

Table 2: Brief details of the cases

Description	Green building (Part I)	Conventional building (Part I)	Green building (Part II)	Conventional building (Part II)
	CASE A1	**CASE A2**	**CASE B1**	**CASE B2**
Employer	Bank	Bank	Office	Office
Duration	1.5 Years	2 years	3 years	2 years
Contract sum	132 Million	150 Million	390 Million	340 Million
Number of	2 stories	3 stories	3 stories	4 stories
Completed	2012	2009	2009	2012
Floor area	10,000 sq. ft.	13,000 sq. ft.	100,000 sq. ft.	90,000 sq. ft.

Procurement method	Measure and pay	Measure and pay	Measure and pay	Measure and pay

Table 3: Details of respondents

	Designation	Profession	Years of experience
	Bank building		
Respondent 1	Chartered Architect	Consultant	25
Respondent 2	Sustainable Engineer	Green consultant	10
Respondent 3	Civil engineer	Client	25
	Office building		
Respondent 4	Chartered Architect	Consultant	20
Respondent 5	Sustainable Engineer	Green consultant	10
Respondent 6	Civil Engineer	Client	15

This study was mainly focused on comparing green buildings with conventional buildings. The green building in Case A1 was compared with the conventional building in Case A2 as was the case with the buildings in Case B1 and Case B2. The case analysis was carried in two steps: the first step to analyse the cost components based on the responses of the respondents and the second step to make the actual cost comparison using data obtained from the case studies.

8.2.1 Transaction Cost Components Comparison; Green vs. Conventional

Experts were asked to compare the transaction costs considering two stages; pre-contract stage and post contract stage. The identified factors (Refer table 5) through preliminary interviews was the basis of the comparison. Finally, it has to be accepted that the transaction cost of green buildings is higher than that of conventional buildings.

8.2.2 Actual Transaction Cost Comparison; Green vs. Conventional

For the actual comparison, cost data was used gathered from semi-structured interviews and the Table 5 gives the comparison of transaction costs for Case A1 and Case A2 as well as for Case B1 and Case B2. The highlighted sub-categories are for the incremental costs of green buildings under both scenarios. Meanwhile, Table 4 shows the most significant cost items for the increments of the transaction costs of green buildings which are feasibility study, preliminary estimation, sustainable design, cost for designing time, modelling cost, preparing tender document, drawing up a contract, gaining knowledge of materials and production, technical costs, commissioning and documentation required for LEED certification, checking the quality of work at post contract stage as well as conducting inspection and preparing list of defects.

8.3 INVESTIGATION OF DIFFERENCE OF TRANSACTION COSTS IN GREEN BUILDINGS VS. CONVENTIONAL BUILDINGS

As shown in Table 4, the green coloured items are the incremental transaction costs whereas the yellow coloured items are the most significantly incremented transaction cost components. The reason for deducting the bidding cost of green buildings is the increment of the transaction cost due to commissioning for LEED certification and consultancy fees. However the bidding cost of green buildings is comparatively higher when compared with that of conventional buildings. The reason for the fluctuation of 'Gaining knowledge of materials and production' in Case B1 is because of its BMS system. On the whole, according to Table 4, green buildings have a higher percentage of transaction costs compared to conventional buildings which are significantly affected by the process required for commissioning for LEED certificate and its required documentation. However, the main intention of the client is to reduce the cost. When comparing the costs during pre-contract and post contract stages, cost for managing the designs of green buildings was more than what was required. It is an additional cost that was incurred due to lack of familiarity with green building construction. Thus with more and more green buildings being construct ed and with more familiarity gained with their technologies, there will be a reduction of the transaction cost of green buildings.

Table 4: Cost comparison for significant cost items

Stage	Most significant cost item	Case A1	Case A2	Case B1	Case B2
Pre-Contract Stage	Preliminary studies	20.94%	20%	20.57 %	20%
	Managing Design	19.91%	10%	14%	10%
	Bidding cost	17.16%	25%	20.15%	25%
	Gaining knowledge of materials and production	4.8%	5%	5.94%	5%
	Acquiring and processing information	4.8%	5%	4.88%	5%
	Technical	2.95%	2%	3.65%	2%
	Commissioning required for LEED	3.90%	-	2.44%	-
	The documentation for LEED	1.72%	-	2.12%	-
Post Contract Stage	Check the quality of work	7.04%	10 %	8.17%	10 %
	Carrying inspection and preparing list of defects	1.78%	1.50%	1.68%	1.50%
Total Transaction costs		9.71%	5.5%	7.20%	5.5%

9.0 Conclusion and recommendations

The negative impact of green buildings is less on the environment and these buildings have benefits in terms of environmental, economic and social factors. At present, there is a high demand in Sri Lanka for office buildings, especially in Colombo. Therefore it becomes necessary to identify the transaction cost of green office buildings.

The preliminary study, managing cost, bidding cost, drawing up of a contract, value engineering, geotechnical testing, environmental studies, acquiring and processing of information, modelling costs, gaining knowledge of materials and production and external costs have been identified as the transaction cost components in the pre-contract stage of a green building construction, whereas the administering of the contract, checking the quality of work, administering change orders and claims, resolving disputes, handing over and issuing of the final certification, and carrying out inspections and preparing a list of defects are the cost components identified as related to the post contract stage.

From the in-depth analysis of the four case studies, it was revealed that the transaction cost component of green office buildings is higher when compared to that of conventional buildings.

Table 5: Actual Transaction Cost Comparison

Stage		Green Building	Conventional Building	Green Building	Conventional Building
		Part I		Part II	
		Case A1	Case A2	Case B1	Case B2
Pre-Contract Stage	**Contract sum**	132,000,000.00	150,000,000.00	370,000,000.00	340,000,000.00
	Total Transaction Cost	12,820,000.00	8,250,000.00	26,650,000.00	18,700,000.00
	Preliminary Studies	2,684,000.00	1,650,000.00	5,482,500.00	3,740,000.00
	Feasibility Study	1,254,000.00	618,750.00	2,091,250.00	1,402,500.00
	Preliminary Design	1,034,000.00	618,750.00	2,373,750.00	1,402,500.00
	Preliminary Estimation	396,000.00	412,500.00	1,017,500.00	935,000.00
	Managing Design	*2,552,000.00*	825,000.00	3,730,000.00	1,870,000.00
	Sustainable Design	1,786,400.00	577,500.00	1,424,500.00	1,309,000.00
	Architectural and Engineering (A&E) Design Time	382,800.00	123,750.00	305,250.00	280,500.00
	Modelling Costs	382,800.00	123,750.00	305,250.00	280,500.00
	Bidding Cost	2,200,000.00	2,062,500.00	5,370,000.00	4,675,000.00
	Preparing a Tender Document	1,012,000.00	825,000.00	2,317,500.00	1,870,000.00
	Estimating	792,000.00	825,000.00	2,035,000.00	1,870,000.00
	Local Authority Approval	396,000.00	412,500.00	1,017,500.00	935,000.00
	Drawing up a contract	*616,000.00*	412,500.00	1,017,500.00	935,000.00
	Accepting Bids and Making an Award	369,600.00	247,500.00	610,500.00	561,000.00
	Concluding Contracts	246,400.00	165,000.00	407,000.00	374,000.00
	Gaining Knowledge of Material and Production	*616,000.00*	412,500.00	1,582,500.00	*935,000.00*
	Environmental Studies	*616,000.00*	412,500.00	1,300,000.00	935,000.00
	Acquiring and Processing of Information	616,000.00	412,500.00	1,300,000.00	935,000.00
	External Costs	*1,336,000.00*	412,500.00	2,797,500.00	935,000.00

	Legal	118,800.00	123,750.00	305,250.00	280,500.00
	Technical	497,200.00	288,750.00	1,277,250.00	654,500.00
	Commissioning required for LEED	500,000.00	-	650,000.00	-
	Documentation for LEED	220,000.00	-	565,000.00	-
Post Contract Stage	**Total Post Contract Transaction Cost**	**2,200,000.00**	**2,062,500.00**	**5,370,000.00**	**4,675,000.00**
	Administering of the Contract	792,000.00	825,000.00	2,035,000.00	1,870,000.00
	Check the quality of work	902,000.00	825,000.00	2,176,250.00	1,870,000.00
	Administering of Change Orders and Claims	79,200.00	82,500.00	203,500.00	187,000.00
	Resolving of Disputes	39,600.00	41,250.00	101,750.00	93,500.00
	Handing Over and Issuing of Final Certification	158,400.00	165,000.00	407,000.00	374,000.00
	Conducting Inspections and Preparing the List of Defects	228,800.00	123,750.00	446,500.00	280,500.00

The most significant reasons for this are the process that has to be followed for the commissioning required for LEED certificate and its required documentation. The lack of familiarity with green building construction is also a reason for the increment of the transaction cost. It can be recommended that becoming familiar with the green concept by stakeholders of the construction industry and increasing the rate of green building construction would reduce the transaction costs of green buildings. Most importantly, reducing the cost of Green Certification would provide considerable relief to clients in the industry. Furthermore, regulatory bodies are invited to increase the affordability of green material by minimizing the taxes imposed on the imported material. It will be rewarding to the professionals who are involved in the construction of green buildings, if they could be recognized officially. Organizing of seminars to promote the green concept among the younger generation will also add a value to the industry.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8thInternational Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 92–104. ©

CONSIDERATION OF RUNNING COSTS: CONVENTIONAL BUILDINGS VS. GREEN BUILDINGS

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Abstract
'Green Buildings' aim at the efficient use of energy, water and material resources while reducing the impact of the buildings on human health and environment. Green Building reduces the Running Costs (RC) required for the operation and periodic maintenance of a building throughout its life cycles thereby providing significant financial benefits. In Sri Lanka, green buildings are being increasingly constructed, and the lack of understanding about the Life Cycle Costs (LCC) of buildings has resulted in several misconceptions and these contradict the research findings on RC of green buildings. Therefore, this study is aimed at identifying the savings from RC that can be obtained from green buildings, compared to conventional buildings. The research problem was approached through case studies, semi-structured interviews and a document survey. The findings were analysed using content analysis. It was revealed that the RC would vary depending on the function of the building, and that this cost is always less when compared with that of conventional buildings mainly due to the 78% saving on energy consumption cost. Furthermore, sustainable features in the building contribute to reducing energy cost during the running period. Consequently, it is essential to make the stakeholders aware of the RC of green buildings, to encourage them to move towards sustainable development.

Keywords. *Cost Components; Green Building; Life Cycle Cost (LCC); Office Building; Running Cost (RC).*

1. Introduction

Green building has been in the forefront of sustainable development since the dawn of the 21st century as it balances long-term economic, environmental and social health (Ali & Al Nsairat, 2009). Even though , it initally has higher capital costs when compared to conventional buildings, green buildings ultimately generate a pool of financial and environmental benefits such as reduced energy and water consumption, low Running Cost (RC), improved productivity and health. According to Forster, Carter, Banfill, and Kayan (2011), the building maintenance and operation is well known internationally as an essential mechanism for retaining the cultural heritage and protecting the capital associated with the building fabric.

Meanwhile, RC being the cost required for the annual operation and periodic maintenance of a building during its entire economic life span, the proper design and the selection of materials for building construction would result in lower RCs (Krstić & Marenjak, 2012; Marszal & Heiselberg, 2011; Nalewaik & Venters, 2008). In Sri Lanka, the entry barrier for green buildings is higher than that for conventional buildings in terms of the need for a new design, new technology and lack of understanding about the cost of green buildings (Chan, Qian, & Lam, 2009; Barnes, 2012). Moreover, SGS Economics and Planning Pty Ltd (2008) has highlighted that developer's focus on initial costs, rather than LCC. Even though, a critical problem arises in this regard according to Johnston & Newton (2004), green buildings bring a wealth of practical and psychological advantages while improving ventilation, unsealing hard surfaces, sustaining wildlife and providing shelter and insulation. Jayantha and Man (2013) have emphasized that the cost of constructing green buildings which is 2-4 % higher than that of conventional buildings due to their higher initial capital costs, is balanced in the long-run by their lower RC during the entire life span of a property.

Therefore the arguments generate a clear platform for considering the RC of green buildings through research carried out in the construction industry. Consequently, this research aims at identifying the savings of RC of green buildings compared to that of conventional buildings while identifying the green building concept and LCC, comparing the significant cost components during the running periods of the two types of buildings and ultimately at analyzing the reasons for the difference in costs between the costs of the two types of buildings throughout their lifecycles.

2. Concept of Green Building

Sustainable development facilitates quality of life and thereby allows people to live in a healthy environment with improved social, economic and environmental conditions for both the present and the future generations (Ortiz, Castells, & Sonnemann, 2009; Berardi, 2013). Kubba (2012) has stressed that the concept of green building has emerged with the essential purpose of improving the conventional design and construction practices to ensure sustainability. The Green Building Council of Australia defines the concept of green building as the building design, construction and operational phases which significantly reduce the negative impact of development on the environment and occupants while increasing social equity, cultural and heritage issues, traditions, human health, and social infrastructure (SGS Economics and Planning Pty.Ltd, 2008; Kubba, 2012).

Hence green building rating system has become the background for assessing building environmental performance and integrating sustainable development into construction processes (GBCSL, 2011). Thereby, GBCSL (2011) has introduced the GREENSL® rating system as an assessment tool to provide a guideline for green building construction. Further Kats (2003) has also elaborated that it provides several benefits to occupants such as, lower RCs, higher returns on investments, healthy interior spaces for occupants, better aesthetic appearance etc.

3. Benefits of Green Buildings

SGS Economics and Planning Pty. Ltd (2008) and Wilhelm (2005) have stressed that the financial, social and environmental benefits that green buildings provide make them more comfortable than conventional buildings. Some of the significant financial benefits that accrue are the savings on RCs which can be used as a marketing tool for potential clients and tenants (Gottfried, 1996; SGS Economics and Planning Pty. Ltd 2008). Apart from that Kats (2003) has stressed that green buildings produce 20% cost savings over the life of the buildings.

On the other hand, Durmus-Pedini and Ashuri (2010) have stated that their environmental benefits include the reduction of the impacts of natural resource consumption, minimising of the negative impact on the environment; conservation of water and energy; prevention of noise, air, water, soil and light pollution and provision of healthier environments. Meanwhile its social benefits include the improvement of employee health and productivity, satisfaction of occupants, indoor environment quality, thermal conditions, and the preservation of water resources foe future generation (Fernando, 2012; Tatari & Kucukvar, 2011). In Sri Lanka, Jayalath (2010) and Bombugala and Atputharajah (2010) have witnessed that in the last few years the concept of green buildings has made considerable growth providing energy efficient buildings.

4. Life Cycle cost

life cycle cost (lcc) is defined as the ‘total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value' (pelzeter, 2007, s. 117). the author considers the period of lcc not only during the economic life-span but also during the entire period of existence of a building. lcc is especially useful when selecting better project alternatives in fulfilling the performance requirements. according to marszal and heiselberg (2011), the investment cost / initial cost of construction is defined as the sum of the planning cost, designing cost, construction cost including material cost, equipment cost, labour cost for all the works necessary for the construction process and other services required for building operation while rc includes the cost of maintenance and operation during the life span of the building.

5. Running Cost

RCs mainly consider and carefully account for the cost of annual operation and periodic maintenance during the entire economic life span of a building, and replacement of equipment after its service life (Forster & Kayan, 2009). The findings of Wang, Zmeureanu and Rivard (2005) have revealed that maintenance is usually required during the operational stage while transportation is an activity associated with most other stages and El-Haram and Horner (2002) have divided maintenance into two types as shown in

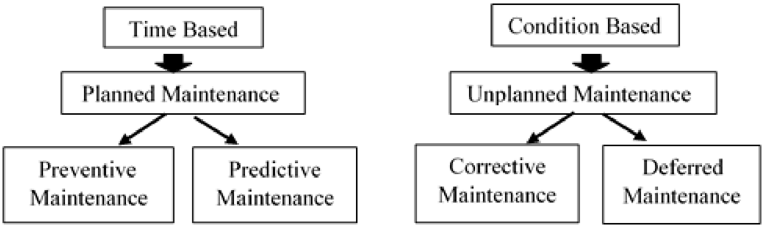

Figure 1, Types of maintenance

On the other hand, Aye et.al (2000) have stated that the operation of the energy supply system is associated with the running of the building systems such as heating and ventilation, air conditioning, lighting and power and vertical transportation. Therefore the cost involved in operating services is called the operation cost (Marszal & Heiselberg, 2011). Operation costs include costs of managing the built environment including administrative support services (Al-Khatam, 2003). The classification is improved in Table 1 where the RC components have been identified as direct and indirect costs separately.

Table 1, Classification of RCs Separately as Direct and Indirect Costs

Direct Cost (Material, Labour, Equipment)	**Indirect Cost (Administration)**
Main structure, Internal construction, Finishes and fittings, Services(mechanical, plumbing, electrical), Decoration, External work, Sustainable features, Energy Cost and other utilities cost	Staff cost, Planning cost, Training cost, Profit, Insurance, Taxes, Experts cost (consulting cost), Opportunity cost

Source (Maintenance Practice Committee, 1975; Brown & Robertson, 1990; Levitt, 2009; seeley, 1987)

5.1. RUNNING COST OF GREEN BUILDINGS

Properly designed green buildings incur reduced RCs related to heating, cooling, lighting and ventilation, water consumption and proper maintenance (ITU, 2012). Moreover, Nalewaik and Venters (2008) have identified the design of the building, material selection and the site construction as factors affecting RCs and also the fact that between 70% - 85 % of the building RCs can be influenced during the design stage.

5.1.1. Running Cost of Conventional Buildings Vs. Green Buildings

RCs of both buildings cover the cost of energy related to heating, cooling, electricity, gas and water supplies, maintenance work, repair or replacement of equipment, and other related soft costs (Nalewaik & Venters, 2008). In green buildings, energy consumed during the running stage of the building is reduced while conventional buildings consume large quantities of material and human resources (Local governments in Alameda County, 2009). Therefore Barnes (2012) has suggested that if the building is built in accordance with the LEED guidelines, it will become more efficient as far as the occupants are concerned. Meanwhile Fowler and Rauch (2008) have stressed that the conventional buildings do not use natural resources for lighting, air conditioning, electricity and material but that they only use artificial systems while green buildings use natural resources for these systems, i.e solar panels for electricity consumption which reduces the cost of the electricity used, green roof and glazed windows for the cooling system and LEDs for lighting system which consume lower energy. This has been clearly justified by the findings of Kats (2003) and Gottfried (1996) which indicate that green buildings are 28% more efficient than conventional buildings and that they generate 2% of their power requirements at -site from solar.

6. Importance of RC in Green Buildings

Improper maintenance and operation of the green buildings lead to unnecessary energy consumption, poor indoor air quality and environmental damage (Wu, 2010). Furthermore the RC of a green building plays a vital role since life span of a green building will depend on its quality (Seo & Hwang, 2001). According to SGS Economics and Planning Pty.Ltd (2008) and Ryghaug and Sorensen (2009), the lack of understanding about the LCCs of buildings leads the focus to be mainly on the initial cost of the green building rather than on LCC. However, the effective maintenance and operation of the building facilitate long-term returns on investment through the reduced RC of green building construction (Barnes, 2012). Yet, the RC of green buildings is an under researched area in the construction industry in Sri Lanka which has to be thoroughly investigated if a productive outcome is to be obtained.

7. Research Methodology

In this research, the qualitative research approach which is appropriate for gathering and analysing data for the study of a contemporary phenomenon in its natural context, was followed. Four case studies were conducted using a document survey and semi structured interviews and cross case analysis was done using the data collected from six semi structured interviews done under the case studies. The collected data was analysed using both content analysis and statistical data analysis. Thus the findings were geared towards achieving the ultimate outcome by identifying the saving of RC of green buildings compared to that of conventional buildings

8. Research Findings and Data Analysis

Prior to analyzing the research findings in detail, the pilot survey was conducted by interview with four people of green building experts. The details of the respondents, are given in Table 2.

Table 2, Detail of Respondents in Pilot Survey

Profession	Position	Years of experience
Engineer	Project manager	25 years
Quantity Surveyor	General manager	20 years
Engineer	Mechanical engineer	7 years
Facilities Manager	Senior manager	20 years

The findings exposed significant cost components in building construction in Sri Lanka as shown in Table 3. Thereafter green and conventional buildings were compared in terms of each identified cost element and special reasons behind the increment of cost in green buildings in each cost component were highlighted.

Table 3, Identified components of Direct and Indirect Costs

Direct Cost		
Cost Components	**Cost Comparison**	**Special reasons behind the increment of cost in green buildings**
Main Structure Frame, External walls, Roof structure, Roof covering, Roof lights and glazing, Gutters and rainwater pipes, Windows, External doors and glazing	More in green buildings	• Roof Structure- Due to roof plantation cleaning • Roof covering/ Gutters and rainwater pipes - Due to rain water collection, adequate cleaning system required • Roof lights and glazing- To get the day light regularly, want to clean the high efficiency glazes • External doors and glazing- To reduce the heat, use heat proof stickers
Internal construction Staircase, Floors, Partition walls, Internal doors including glazing	More in green buildings	• Staircase- To maintain salvage timber stair case additional manpower required
Finishes and fittings Ceiling finishes, Wall finishes, Floor finishes, Ironmongery	Same or sometime more in green buildings	• Ceiling & Wall finishes- Maintenance cost is high due to the green certified materials • Floor finishes- Extra cost for maintaining green certified carpet floor
Plumbing and sanitary fittings Cold and hot water supply pipe, valve, Sanitary fittings, Disposal pipe	Same or sometime more in green buildings	• Sanitary fittings- using efficiency fittings (E.g- sensor taps)
Mechanical services, heating and ventilating Lift, AC, Chiller, Fire, Elevator	Same as conventional buildings	• Chiller- Use of energy efficiency chiller
Electrical services Wiring, Main switch board and meter, Appliances and fittings, Lighting protection, Other electrical equipment like fax	Same as conventional buildings	• Appliances and fittings- Use of energy efficiency lamps
Sustainable features PV panel, Solar tubes, Eco roof, Storm water recycling equipment, LED lights	More in green buildings	• Generally only green building have this features • Eco roof- Due to maintenance of roof plantation cost is high • LED lights- use of energy efficiency lamps are high • Storm water recycling equipment -Additional cost for cleaning those equipment
Indirect cost		
Staff facilities, Security staff, CCTV operation	Same as conventional buildings	• Same Cost
Planning or inception cost, Operator, Operational manual	More in green buildings	• Involvement of expertise in maintenance period
Energy audit	Additional in green buildings	• Generally only green building have this features

8.1. DATA ANALYSIS – SEMI STRUCTURED INTERVIEWS

Subsequently, a cross case analysis was done by selecting a green building and a conventional building, to compare its RCs in terms of the previously identified cost components. The details of the four cases are shown briefly in Table 4.

Table 4, Details of Cases

	Case A - Bank Buildings		**Case B - Office Buildings**	
	Green Building (Case A1)	**Conventional Building (Case A2)**	**Green Building (Case B1)**	**Conventional Building (Case B2)**
Employer	Bank	Bank	Office	Office
Project duration	2009-2012	2009-2011	2006-2009	2010-2012
Contract sum	132 Million	150 Million	390 Million	340 Million
Number of stories	2 storey	3 storey	3 storey	4 storey
Gross floor area	10, 000 sq.ft	13,000 sq.ft	100,000 sq.ft	90,000 sq.ft
Procurement method	Measure and Pay	Measure and Pay	Measure and Pay	Measure and Pay
Running period until 2014	2 years	3 years	5 years	2 years

The analysis was conducted for the cost components and cost savings of RC. The cost components were divided in to two categories as direct and indirect costs. In the main structure, differences and similarities of the cost components have been identified and the respondents have stated that the RC for the frame structure, external walls and windows are same for both conventional and green buildings while RC of the roof coverings of green buildings is higher than that of the conventional buildings. Meanwhile, the majority of the respondents have indicated that the RCs for gutters and rain water pipes are higher in green buildings. Even though only one respondent has stated that "*there is a small difference in cost from that of a conventional building because there is door glazing which needs heat proof stickers*", all the other respondents have stated that the cost is same for external doors and glazing in both types of buildings. In the meantime when building appearance mainly depends on the finishes and fittings, the majority of the respondents have indicated that the RC components of the wall, ceiling and floor finishes are same for both buildings. However, one respondent has said that "*the indoor environmental heat in a conventional building is higher than that in a green building thus the cost of finishing of a conventional building will be more than that of a green building making the maintenance cost of a conventional building to be higher than that of a green buildings*".

As the bottom line lies in the internal construction, the RC of finishes and fittings cannot be predicted. Apart from that sustainable features such as PV panels, solar tubes, eco roof LED lights and storm water recycling equipment play a significant role in green Buildings and their RCs are higher compared to those of conventional buildings. With regard to water consumption, the cost is less in green buildings whereas the RC remains same for both types of buildings in respect of fuel consumption. In considering the indirect cost component of RC, respondents argued that the cost of staff facilities is high in green buildings as it is the educated people who are involved in running them. Under the planning and inception cost one respondent has highlighted that, "*there is a little difference because in green buildings we have to provide an energy simulation plan and with that we have to submit additional documentation making the cost high*". On the other hand, the majority of the respondents have stated that the RC of the building management system can vary because of the building services. Hence the analysis has revealed the possibility of having a realistic platform on which the RC components of the green and conventional buildings could be discussed thoroughly in terms of their direct and indirect costs.

8.2. DATA ANALYSIS – DOCUMENT REVIEW

For the analysis done under the document review, all data related to the cost components of the running period were collected from documents prepared in 2013. Table 5 gives the RC details of labour, material and equipment (including cleaning, maintenance repairing) of different buildings.

Table 5, RC data of each Cases

Cost components	Case A1	Case A2	Case B1	Case B2
DIRECT COST				
Main structure	21,299.00	12,835.00	300,000.00	280,000.00
Internal construction	8,520.00	7,333.00	162,000.00	160,000.00
Finishes and fittings	42,600.00	11,920.00	600,000.00	260,000.00
Plumbing and sanitary fittings	63,899.00	18,339.00	900,000.00	400,000.00
Mechanical services, heating and ventilating	266,400.00	324,922.00	1,500,000.00	340,000.00
Electrical services	19,170.00	9,252.00	270,000.00	195,000.00
External works	480,000.00	153,600.00	960,000.00	668,000.00
Internal and external decoration	17,040.00	16,506.00	540,000.00	360,000.00
Sustainable features	506,940.00	917.00	2,784,600.00	20,000.00
Energy consumption	1,939,788.00	9,739,600.00	4,302,800.00	19,134,461.00
others	78,000.00	18,000.00	145,000.00	25,000.00
Total cost	**3,443,656.00**	**10,313,224.00**	**12,464,400.00**	**21,842,461.00**
INDIRECT COST				
Administration	6,010,000.00	3,605,000.00	10,825,000.00	7,220,000.00
BMS	-	-	1,800,000.00	900,000.00
Other outsource	3,060,000.00	3,294,666.00	410,000.00	525,000.00
Documentation	200,000.00	100,000.00	350,000.00	200,000.00
Total cost	**9,270,000.00**	**6,999,666.00**	**13,385,000.00**	**8,845,000.00**

The main RC varies for only two cost components in the four cases. The RC of the roof covering of Case A1 (green building) is 55% higher than that of Case A2. Similarly, Case B1 has a 31% higher cost than Case B2. Case A uses storm water recycling equipment for purifying the water. Similarly, the RC for gutters and rain water pipes is higher in green buildings. Thus, in the main structure, the RC is more in green buildings than in conventional buildings. In respect of ceiling, wall and floor finishes , the RCs are high for green buildings and Case A1 has nearly a 73% higher cost than Case A2. Similarly in Case B1 it is 68% higher than in Case B2. Even though the gross floor area matters for some extent, the cost is not saved here during the running period of green buildings.

Ultimately in each case, green buildings are not capable of saving the RC component during the running period. In contrary to this in the analysis of the direct cost components of energy consumption related to fuel, electricity and water it is found that nearly 78% of the RC of green buildings is saved compared to that of conventional buildings and in Case A1 this is 66% and in Case B1 it is 42%. On the other hand, the indirect cost of RC is 24% higher in Case A1 than in Case A2. Similarly, in Case B, the RC of green buildings is 33% higher than in conventional buildings. Thus, in green buildings there is no saving from the RCs of indirect cost components. Eventually there is no saving of direct and indirect cost components and therefore the total RC in green buildings is less than in conventional buildings as shown in Table 6.

Table 6, Total Running Cost (RC)

Cost Components	Case A		Case B	
	Case A1	Case A2	Case B1	Case B2
Direct cost	3,443,656.00	10,313,224.00	12,464,400.00	21,842,461.00
Indirect cost	9,270,000.00	6,999,666.00	13,385,000.00	8,845,000.00
Total cost	12,713,656.00	17,312,890.00	25,849,400.00	30,687,461.00

Table 6 clearly depicts the total RC including both direct and indirect RC components of selected cases during a one year running period. The findings elaborated that in the green buildings of Case A, there is a 26% saving of RC of a conventional building during a one year running period. Similarly, in Case B1 there is a total saving of 15% from that of Case B2. Noticeably, the RC savings comes from direct cost components whereas indirect cost components add costs to green buildings.

According to the table the indirect RC is 24% higher in case A1 than case A2. Similarly, in Case B1, the RC of green building is 33% higher than conventional building. Thus, there is no running cost saving during the running period when the indirect cost is considered. In green buildings, there is a saving of nearly 66% in the direct cost components of Section A buildings whereas for Section B buildings the cost saving is only 42%. However, RC of indirect cost components in green buildings is higher than those of conventional buildings. i.e. it is nearly 24% in Section A buildings and 33% in Section B buildings. Thus, the saving in costs is higher than the addition of costs during the running period of green buildings and this saving is only related to energy consumption.

Further, it has been automatically stressed that the cost savings are only from the energy consumption charges during the life cycle and ultimately the results highlighted that, in green buildings the saving of RC is a considerable benefits for the building owner.

5. Conclusions

Green buildings provide environmental, economic and social benefits as they are designed for a healthier environment to live in and work while reducing any negative impacts on the environment. However, the lack of knowledge on the cost of green building is a significant barrier in its implementation. In Sri Lanka, the lack of knowledge and projects based on green concept have already made the authorities to investigate the RC components and its savings. Under the savings of the RC, the contribution of the direct and indirect cost components is significant. When it is compared between the green and conventional buildings, the overall RC saving in the green buildings is heavily determined by the energy saving mechanism, while all the other maintenance and operational activities add cost to green buildings.

Although green buildings use more sustainable features to reduce energy cost during their running periods, in respect of maintenance there is an additional cost identified as expertise are involved during the running period in supervising labour and maintaining documentation. This indicates the necessity for an in depth analysis in generalizing the different situations when investigating the RC. Ultimately a thorough understanding of the RC leads to effective maintenance and operation of the buildings during their running periods, securing a long-term return on investment in the green building construction industry in Sri Lanka.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 105–117. ©

DRUG CRIME AND URBAN ACTIVITY PATTERN: THE LOCATIONAL CHOICE OF DRUG CRIME IN RELATION TO STREET TYPE AND LAND USE.

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Abstract
Crime like drug dealing in public places of cities is a widespread phenomenon. This paper reports on the findings from the case study on illegal drug crime in one of the prime locations of Narayanganj City Corporation. Physical location of 216 incidents of illegal drug dealing is analyzed here with respect to spatial configuration of streets and corresponding land use. Main focus is to test the hypothesis supported by the Crime Pattern theory that drug dealing is more likely to happen in areas which are near streets or places that triggers a flow of good number of people at a regular basis. Basic tool used in this paper is Space Syntax methodology. Integration (HH), control and weighted optimal local choice levels of streets at reported locations are considered while using the space syntax methodology. Aim of the paper is to identify the spatial attribute of drug crime locations for helping urban planners, designers and crime control authorities to identify crime zones easily for acting proactively rather than reactive. Results shows, street accessibility, proximity to specific land use, the number of intersections that need to be crossed to reach a street at a local level has a significant effect on location choice of drug dealing. Rational choices (to movement) of streets and mixed-use residential areas with close proximity to poorly integrated streets show more vulnerability for becoming selling point of drugs. Also the streets having drug crime record show an inverse relation between streets control value and weighted choice value at local level. These results indicate that spatial attributes while explored can help to control the potential crimes in cities and create a responsive environment in social terms.

Keywords. *Drug crime, Crime pattern theory, Street network, Rational choice, Space syntax*

1. Introduction: Drug dealing and urban economic dynamics

Drug related crimes are alarmingly high in Bangladesh for the past few years which are evident from the crime records of recent year by

Bangladesh police (BP). Among 51832 recorded cases of 2014, 42510 cases were drug dealing crime (BP, 2015). 1990's Narcotics Act of Bangladesh provides list of drugs considered as Narcotis and also indicates the allowable range for a person to carry those drugs. Most common drugs used in Bangladesh are stimulants among which Yaba is sold the most (BP FIR records). Report published by The Daily Star on June 26, 2015 refers, according to the police and other sources, the number of addicted people in Bangladesh are more than six million, spending over Tk 700 million (70 crore) every day on illegal narcotics (yearly US$ 533 per person) is nearly half of per-capita income of Bangladesh(US$ 1,314 in 2015). But this cost will be more if we consider the cost of the damage related with drug problems.

2. Crime pattern theory and mechanism of crime

Crime pattern theory, a spatial theory of crime, focuses on crime as a complex event that requires not only the socio economic or physical or mental condition of offender, but also context or place as a requirement for its occurrence. This theory assumes the existence of motivated offenders and tries to understand their decision processes and actions within the context of the other elements of the criminal event. It is closely related with rational choice and routine activity theory and this theory promotes that there is a stronger geographic reasoning within the thought process of committing crime. In reference to P.L. Brantingham and P.J. Brantingham's paper on Crime Pattern Theory (2008) some key points are:

a) Criminals go through a sequence of daily activity and cross some routes at regular basis and take decision of committing crimes.
b) Usually criminals do not function individually; they always try to be at groups of friends or family.
c) Criminals commit crime finding triggering event within their daily routes.
d) There is a limited range for every individual's daily activity, these comprise of work place, markets, schools, mosques, hospitals and nodes between them.
e) Criminals have a similar spatial typo movement like a law abiding person.
f) Possible targets or victims usually have passive or active activity space that shares the boundary of the offender and the happening of crime depends on the will of the offender.

g) Within the built urban form, crime generators are created by high flows of people through and to nodal activity points.

According to Rational Choice Theory (Cornish and Clarke,1987), which is the base of crime pattern theory, a motivated offender will commit crime if it is profitable, useful or enjoyable, and if they think they can get away with it (Ratcliff J., 2005).

2.1 Locational choice for drug crime

In general high value products, not frequently purchased are sold at large places accessible for all. In contrast, products of daily needs are sold at local markets with very short travel time. Though drugs are illegal, but they are the commodity of frequent daily needs. Drug dealers also do not select their business location at a random basis, rather they might take a rational decision in selecting their business palace (Eck, 1995 & Rengert, 2005). Their aim is to attract potential customers and supply products to make profit. To fix the location of the stores, retailer focuses on finding an accessible location, which will have a flow movement of potential customers (Rengert, 1996). In addition the drug dealers have another condition staying safe and unnoticed. Some possible locations of drug dealings are transport interchange (Brantingham and Brantingham, 1995) areas near to pawn shops or squatter type colony (Anderson, 1999), shopping centers (Eck, 1995), high schools (Roncek and Lobosco,1983), Bars (Roncek and Lobosco,1991), train links, highways (Eck,1994) and vacant homes (Rengert et al.,2005) .

Charls Booth's study on spatial pattern of poverty, (Booth, 1889-93), explains, the distribution of prosperity to poverty pattern follows a sequence of square and avenue to thoroughfare, road, street, alley, court, yard to dead end rookery and slum. It is also noted that physical boundaries, such as railways lines had an effect on isolating areas and creating a barrier between the people of those areas and the city life (Laura Vaughan, Ilaria Geddes). From Booth's study it is clear that poor settlement or squatter type colony grow at areas beside a highly integrated street with large urban block which is not accessible from every side, but from one side and also that might be a dead end road. Drug dealers might be attracted for these streets which have urban blocks having squatter type colony (Anderson, 1999) with difficult accessibility at close proximity to integrated streets.

Drug retailer's attraction towards close proximity to integrated streets can be explained by Habermas's Theory of Communicative action, which indicates a border concept of rationality that focuses on social interaction (Byron Miller). In his paper of Collective action and rational Choice, Byron miller, indicates that communicative form of action coordination are colonized by systematic forms of action coordination, places become less significant as a base for community but more important at corporate location and investment decision. On the other hand Spatial Interaction theory(Retail Geography, Jhon Dawson) suggests that, consumers doesn't get very interested to buy things from the nearest available location, but locations with other attractions like institution or other urban attractions works as a gravitational force for retailing (Law of Retail Gravitation, Reilly, 1931). Drug dealing at inter-urban context also works as a local retail activity, as the consumer gets their product in small amount from an agent on locality basis.

The systematic crime control model predicts that informal surveillance of a space reduces street crime (Paul E. Bellair, 2006). Inversely, streets which enjoy less informal surveillance are more prone to crime. Some scholars also think that some legal land uses may also have an effect on drug dealer's locational choice (Eck, 1995 & Rengert, 2005). For example , drug dealing can be found at places which generate a large flow of people at a routine basis, like public places, schools, hospitals, under construction infrastructure, hotels etc. These locational choices are also supported by Spatial Interaction theory (Retail Geography, Jhon Dawson). To attract drug dealers, these places need to have a low level of control (Eck and Wartell, 1996), so that the safety of dealers does not come to a cost.

The above theories supporting probable locational choice for drug retailing can be summaries as - Urban areas having low informal surveillance, near public facility or mixed use development that supports economy of local level and placed nearby of poor settlement are more vulnerable for Drug Retailing.

3. Methodology : Space Syntax as a tool of spatial analysis

pace syntax is a method for analysing the relation between spaces and the use of that space. Major references of Space Syntax theory are the books by

Hillier and Hanson (1984). This methodology has been widely used for analysing city structures. In Space syntax, the spaces are considered as voids (streets, squares, rooms, Field, etc.) between buildings, walls, fences and other obstructions that restrain (pedestrian) traffic and the visual field. Among several methods for analysing a city via space syntax methodology a very common way to do is preparing an axial map of respective city for further analysis. An Axial map in space syntax denotes the least number of straight lines covering all spaces where no line between any two of its points crosses the perimeter (convex space) of a layout and their connections.

Hillier's theory of Natural movement (1993) states, the distribution of the built form, which generate and attract movement in an area, will be determined by the grid configuration itself. This theory indicates, the integrated streets points at an integration core has a great possibility of becoming the commercial hub of town. Integrated streets attracts public facilities and mixed use development at a close proximity. Public facilities and mixed use development creates to movement at a street highly integrated streets of a city are denotes a through movement. According to space syntax theories, integration is a static global measure. Integration of a street, shows the average depth of a street or axial line to all other streets or axial lines in the system. The streets of a city can be ranked from the most integrated to the most segregated via integration value obtained from Integration [HH] analysis. Again depth of a street means between two axial lines, the least number of syntactic steps in a graph that are needed to reach one from the other. In terms of space syntax method the spatial choice value with weight factor (local, R=3) denotes to movements at a local basis considering probable land use and is a local measure. Weighted choice value (R=3) indicates possible presence of local public facility like, schools, mosque, hospitals and mixed use development. A street has a strong weighted choice value at local level (R=3) when many of the shortest paths, connecting immediate streets to alternative streets of a city, passes through it. This measure can also be described as optimum rational choice at local level. Again, informal surveillance in space syntax means the control value of streets. Control value is a dynamic local measure of city streets. It measures the degree to which a space controls access to its immediate streets (axial lines) taking into account the number of alternative connections that each of these streets has.

The present study tries to identify a common locational logic behind topological location choice for drug dealing in the urban context. The study concentrates more on the street network connections and land use. From the support of the available theory, it is predicted that, a place within the spatial network which is situated close proximity to a highly integrated or accessible street, having nearby difficult accessible urban blocks with poor squatter type settlement, with land use which attracts to movement of people, but poor in control measure and ranges within the local level choice route of people will have a great potential for locating drug dealers. Present study is formed around one dependable variable and other four independent variables. Dependable variable is drug crime data that has been collected from local Police Authority of study area. Independent variables are global Integration [HH] of spatial network, land use and poor settlement data, optimum rational choice at local level and control value of spatial network of the study area.

4. Case study

Narayanganj, the most crime prone zone of Bangladesh has a record of 3932 crimes during the year of 2014 among which 1605 are drug related crimes (S.P. office, Narayanganj). At 2011, Narayanganj received the status of City Corporation and got a larger administrative area consisting of old Narayanganj municipality, most of the part of Siddhirganj municipality and some part of Kadam Rasul municipality at the east side of Shitalakkha River. This study only considers the old Narayanganj municipality part. New part of the city is under development project for infrastructure construction. As this study uses space syntax methodology for finding logical relation of drug crime with spatial network, a city with ongoing infrastructure construction might give mislead results. To avoid complications only the Narayanganj pourasava part has been analyzed. For preparing drug crime pinned map, all of the drug related cases of 2014 were analysed and plotted on the old Narayanganj municipality map (2010) at respective location (Fig: 1). Numbers at Fig: 1(b) are showing current ward number of Narayanganj City Corporation. The administrative zone and police judiciary zone differs in the way that administrative zone mainly serve the purpose of electoral boundary and police judiciary zone serve the purpose of surveillance. Narayanganj city corporation (NCC) is divided under 3 police surveillance zone. These are Narayanganj Sadar, Siddhirganj and Bandar. Old Narayanganj municipality is mostly under Narayanganj Sadar, but some of its part has gone under the surveillance of Siddhirganj. To avoid complication of data management regarding to Siddhirganj (as most part of this zone is out of old Narayangaj municipality area) this study only considers drug crime data from Narayanganj sadar and also the judiciary zone under this police station. Narayanganj Sadar is divided into 3 police stations each consisting of 4 police Bit (patrolling area), which are Chashara, Tanbazar and Shitalakkha police station. Police bits are shown with dashed lines at Fig: 1(a).

Figure 1:(a) Drug Crime Data (2014 -2015) of Narayanganj Sadar Thana (b) Merged Map of land use and poor settlement, Integration [HH] and drug crime data of Narayanganj Municipality (2010)

Among the 353 recorded crimes under Narayanganj Sadar at the year of 2014, drug related crimes are 216. Each crime incidents recorded information regarding the date and time of crime, location of the arrest with address, police bit of the location, number of accused person, the type, quantity and value (in BDT) of the drug that has been found from the offender. Fig:1 shows all these 216 crime with black dots at respective locations with nearby land use. In all cases the offender was found retailer and the value amount of recovered drug ranged approximately from BDT 1,500/= to 24,000/=. Although in most cases Yabba was found, in some cases Marijuana was also recovered from the offender. Fig: 1 indicates a clear pattern of drug retailing hot spots. These are – Baburail, Bhuiya Para, Chashara near Don Chember, College Golachipa Road, Eshakha road, Golachipa, Neyamati road at Tanbazar, Naya para near Shasuja road, Naya para near Bhuiya para, Shahsuja road at Paik Para, Samsujdoja road at Chashara, S. M. Mahel road at Tanbazar.

5. Spatial analysis and Discussion

For this study, only the old municipality part of Narayanganj(2010) has been taken for space syntax analysis. At Fig.1, current street network of previous Narayanganj Municipality are shown. This parts of Narayanganj City Corporation has been analyzed for finding the most integrated streets at global scale and its relation with land use, optimum choice and control value of the drug crime hot spots with the help of space syntax method. Numbers has been used for denoting land use and alphabets has been used for indicating economic levels of the settlement. Land use codes are, 1=commercial, 2=cultivated land, 3=industrial, 4=mixed use residential area, 5=park, 6=public facility, 7=residential area, 8= restricted area, 9= road/railway, 10= water bodies. Settlement codes are, A=extreme poor settlement, B=very poor settlement, C=moderately poor settlement, D= marginally poor settlement, E=poor settlement. Fig: 1(b), shows the drug crime plotting of year 2014-2015 on land use and economic condition map. Table: 1, refers to the obtained values from space syntax and land use analysis of independent variables at drug crime hot spots.

Table 5: Comparative analysis of values obtained from Space Syntax methodology for the drug crime hot spots

Name of Steet , Ward number of City Corporation	Police Bit Number	Ref	Choice [Choice Wgt][Norm] R3	Connectivity	Control	Integration [HH]	Axial Line Length	Land use	Economic Condition of Local Residents
Baburail, 16	Tanbazar police station, Bit no. 4	1386	0.194	2	1	0.515	41.837	4	A
Baburail, 16	Tanbazar police station, Bit no. 4	1460	0.260	3	1.033	0.480	68.558	4	A
Baburail, 16	Tanbazar police station, Bit no. 4	1516	0.311	3	1.033	0.480	95.287	4	A

Bhuiya para, 17	Shitalakkha Police Station, Bit No. 3	1506	0.407	3	1.25	0.506	130.337	4	A
Bhuiya para, 17	Shitalakkha Police Station, Bit No. 3	1524	0.325	5	1.158	0.558	142.403	4	A
Chashara, Near Don Chember, 12	Chashara Police station, Bit no. 2	793	0.281	2	0.583	0.494	79.518	4	A
Name of Steet , Ward number of City Corporation	Police Bit Number	Ref	Choice [Choice Wgt][Norm] R3	Connectivity	Control	Integration [HH]	Axial Line Length	Land use	Economic Condition of Local Residents
College Golachipa Road, 13	Chashara Police station, Bit no. 1	1278	0.394	2	0.533	0.514	83.979	6	C
Eshakha Road, 11	Chashara Police Station, Bit No. 3	353	0.095	3	0.535	0.568	120.677	4	A
GolaChipa, 16	Chashara Police station, Bit no. 1	1537	0.231	5	1.7	0.428	114.959	6	C
Neyamati Road, Tanbazar, 15	Tanbazar police station, Bit no. 2	75	0.259	2	1	0.401	90.236	4	A
Naya Para, near Sahsuja Road, 17	Shitalakkha Police Station, Bit No. 3	1419	0.373	3	0.976	0.462	82.726	4	A
Naya Para Road, near Bhuiya Para, 17	Shitalakkha Police Station, Bit No. 3	1433	0.379	2	0.666	0.483	85.354	4	A
Naya Para Road, near Bhuiya Para, 17	Shitalakkha Police Station, Bit No. 3	1433	0.379	2	0.666	0.483	85.354	4	A
Shahsuja Road, Paik Para, 17	Shitalakkha Police Station, Bit No. 3	1396	0.427	7	2.226	0.447	128.623	4	A
Shamsujdoja Road, Chashara, 12	Chashara Police Station, Bit No. 3	1113	0.321	4	0.983	0.519	89.972	4	A
S.M. Mahel Road, Tanbazar, 15	Tanbazar police station, Bit no. 1	52	0.349	4	1.166	0.468	46.352	4	A
S.M. Mahel Road, Tanbazar, 15	Tanbazar police station, Bit no. 1	63	0.229	3	1.333	0.421	204.337	4	A
Average Value	N/A	N/A	0.111	2.96	1	0.427	81.462	N/A	N/A

Minimum Value	N/A	N/A	0	1	0.056	0.169	4.546	N/A	N/A
Maximum Value	N/A	N/A	0.489	24	4.901	0.701	1772.46	N/A	N/A

For better understanding the relation among Integration [HH], Control and Weighted choice value a comparative analysis is shown at Chart:1. To ease graphical presentation the maximum value of Integration [HH], Control and Weighted choice has been equalized to a same scale, which is 1.

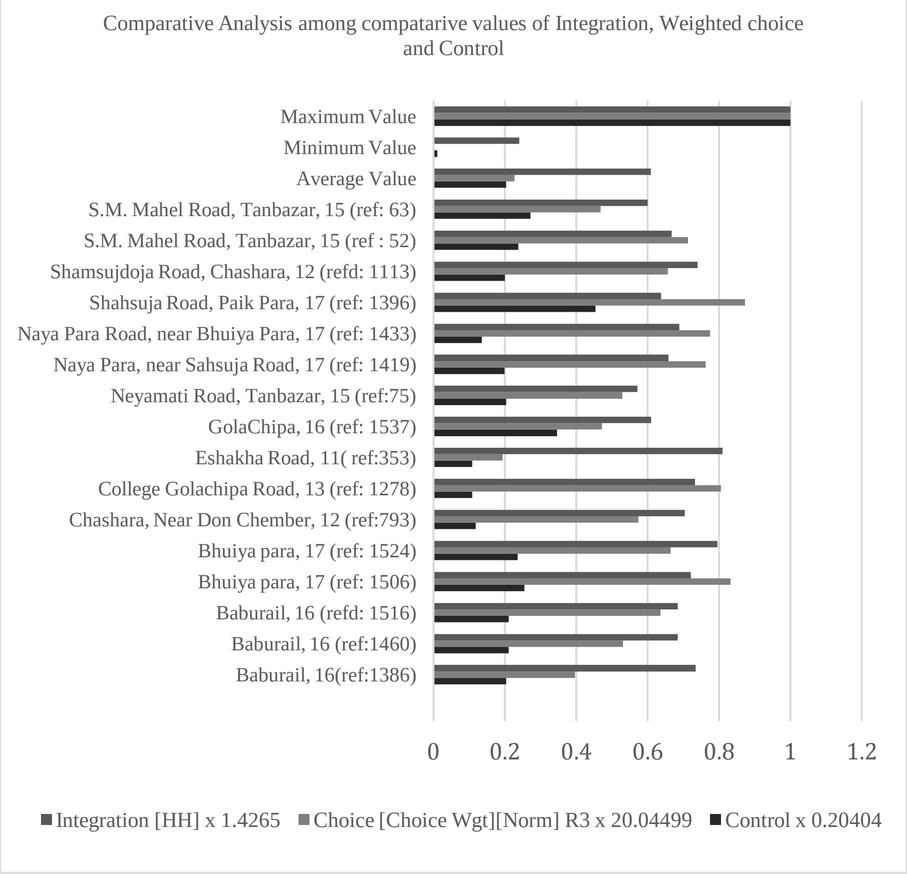

Chart 1: Comparative Analysis among comparative values of Integration, Weighted choice and Control

Chart: 1 shows that none of the drug crime hot spots coincides with highly integrated streets, rather resides at streets having near average integration value.This indication supports the idea of Crime Pattern Theory, that not the through movement, but the to movement (rational Choice) is necessary for happening a crime incident. Chashara was the central commercial core of previous Narayanganj municipality. Current land use map shows the area as a mixed of both commercial and residential land use. Most of these mixed use buildings have commercial use at ground floor and residential or other uses at upper floor. Fig: 2, indicates drug crime might have some relation with land use having residential zone with extreme poor settlement and mixed use development. Again, Table:1, shows, all drug crime hot spots has either mixed use or public facility as land use at respective streets. In case of economic condition of the settlement, from table:1, it is seen that drug crime hot spots have either extreme poor or moderately poor settlement at nearby streets. Fig: 3 shows Integration [HH] map(R=n), Weighted choice map and Control map of previous Narayanganj municipality.

Figure 3: a. Integration[HH] map(R=n), b. Weighted Choice Map(R=3), c. Control map; ?Color range: Red to Blue (high value at red and lowest at blue)

Chart: 1, and Fig: 3(b), supports that all drug crime hot spots at previous Narayanganj Municipality happened at streets with near average and lower side of the control value of case study area. Table:1 shows these control value ranges from .05 to 1.7. But not all of those streets which have a lower or near average control value coincides with drug crime hot spots. This observation indicates not only control value of street network, but also there might be some other attributes which has a positive influence for making a street suitable for Drug crime. Again, Chart:1 indicates hot spots for drug crime are located on the streets where Choice value (local with weight) is above average. This indication supports, Law of Retail Gravitation theory. Table:1, shows weighted optimum local choice value of hot drug crime spots ranges from 0.4 to 0.2. Here in this case the highest optimum local choice value (weight) is 0.489 and average value is 0.11.

Analyzing all the dependent and independent variables, it can be assumed that Streets having mixed use or public facility with nearby poor settlement of previous Narayanganj municipality look vulnerable for drug crime. Again analyzing the control and weighted optimum local choice value of the Municipality Streets, it is found that drug crime hot spots tends to have an average or below average control value with high or near average weighted choice value at local level. Compiling all these observation, it can be stated that, Drug Crime at Narayanganj Municipality happens on those streets with mixed use or public facility having a nearby urban block with higher density of people (poor informal settlement always have a higher density), difficult accessibility and has a higher above average local weighted optimum choice value with a lower (near average or below average) control value.

6. CONCLUSION

Locational choice of retailing drugs doesn't depend on single factor. Here in this paper, the problem of identifying probable hot spots of drug crime has been looked thoroughly on the spatial point of view. There might be other perspective as well. In search of definite spatial parameters which might have an influence on drug crime, this paper formed around a case study of Previous Narayanganj municipality. Further research is needed to find out more spatial attributes for drug crime hotspots. Not only Narayanganj City Corporation but similar type of study can be done on all the urban areas of Bangladesh. Results from existing situations will give a direction for better protection against drug crime not only at current cities but also for future urbanized areas. This paper shows that analysis of spatial parameters like integration, control and weighted choice value can indicate probable drug crime spots, which matches with real-life situations. City planners and urban designers can use this dimension of spatial analysis to find out potential drug crime spots having above average or near average integration [HH], lower range control and higher range of weighted choice values, at design phase and act necessarily. Also, analyzing integration, control and weighted choice value of new urban areas, law enforcing agency could be able to act as a proactively to secure vulnerable areas, by taking measures for controlling drug crime.

Acknowledgements

I would like to thank Md. Azim-Ul- Ahsan, Senior Assistant Superintendent of Bangladesh Police, A (Narayanganj) Circle, Narayanganj District, RAJUK and UPPR project of LGED for providing necessary data to prepare this paper. This paper was developed as a term paper under M.Arch program of Bangladesh University of Engineering and Technology for Urban Morphology (ARCH 6403) course.

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ANALYSIS ON PROCUREMENT SYSTEMS FOR ALTERATION BUILDING PROJECTS IN SRI LANKA

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Abstract
Alteration building is an emerging concept with growing interest in Sri Lankan construction industry pertaining to building renovation and building refurbishment to get effective and efficient out come to their existing buildings. Any additional work, removal work or changes in the external parts of the building structure as well as any modification works of surface texture, architectural details or materials can be regarded as building alteration works. Success of this concept depends on many factors, where the procurement is one of that. It has been identified that the selection of an appropriate procurement method could reduce construction project costs by an average of 5 percent. Thus, this study was conducted to identify the strengths and weaknesses of procurement systems used for building alteration projects and determine the suitable procurement system. Three alteration building projects were selected for in-depth analysis of procurement systems and SWOT analysis were utilised. Findings revealed that the traditional procurement method as the most suitable procurement system for building alteration projects in Sri Lanka. Reduce conflicts, providing high quality output, cost saving, profitable for both contractor and the client were the strengths and unsecured client's initial price and increase completion time were the weaknesses of said procurement system.

Keywords. *Building alteration* - *Building projects* - *Construction industry* - *Procurement systems*

1. Introduction

The construction industry, undeniably a unique environment and by definition is a creative concept is one of the backbones of any country's economy (Ratnasabapathy & Rameezdeen, 2007). No single project is the same as another and the diversity breeds novelty and innovative problem solving at the practical level. Even though with its magnificent characteristics, it has been criticized for its adversarial culture and lack of performance (Kaka *et al*., 2008). Construction Industry engages in a variety of building sites including building renovation, efurbishment and new constructions.

Alteration means the physical changes such as additions, removals and modifications to a building or plans as a permanent work not physically expanding the existing property (Barron's Real Estate Dictionary [BRED], 2008). United States Access Board (2010) has defined alterations as an amendment in a building or facility that affects or could affect the operation of a building or facility or portion thereof, while National Institute of Health (2012) has construed it as any upgrading or amendment to an functioning property to permit its sustained or more efficient use within its designated reason (Renovation), or for use of a diverse reason or function (Alteration). The common goal of alteration projects is to achieve the facilities standards of new projects in existing works. Renovation designs must gratify the immediate residence needs and anticipate other future changes. As they are altered, building systems should become more flexible and adaptable to varying occupancy requests (US General Services Administration, 2015). Accordingly, alteration projects are categorized at three fundamental scales: refurbishment of an area inside a building; major renovation of an entire structure; and upgrade/ restoration of historic structures.

Consuming a building for a long time period create problems of social and economy. Building owners suffer a lack of income due to long-term vacant building and high vacancy rates create a negative attitude of investors about market conditions. Occupants living in older buildings with a life time of more than 35 years are more likely to undertake a major renovation on their homes as depreciation becomes a major issue when they are going to sell their own buildings (Nair, Gustavsson, & Mahapatra, 2010). Therefore, both owners and investors tend to implement alteration concept in their projects (Remoy & Wilkinson, 2012). "Now, the trend of alteration on an existing stock has become more and more important. This should provide an opportunity to enhance the social, economic and environmental performance of the property and community as required in many sustainable development concepts" (Isnin, Ramli, Hashim, & Ali, 2012, p.02).

Projects can be defined as a combination of activities which are placed along with specified objectives and limited resources (Bakar, A.H.A. et al. 2011). Thus performance of the project is measured in terms of time, cost and quality evaluating the importance of secondary factors such as budget availability, client satisfaction, proper project management, procurement type and several other unnamed factors (Alias, Zawawi, Khalid, Aris & NM, 2014). Among them selection of the suitable procurement system is critical for project success (Kumaraswamy & Dissanayaka, 1998). It has been estimated that the selection of an appropriate procurement method could reduce construction project costs by an average of 5% (Alhazmi & McCaffer, 2000). Griffith (2007) have identified the key considerations focusing on obtaining better value in procurement in alteration buildings, which are the function of building estate, financial relationship to the major business, location and the client's activities. Various researches have been conducted on identification of most suitable procurement methods for different types of constructions except alteration buildings. Turner (1997), Peek (2006), Singh (1990), Hashim,Yuet, Yin, Hooi, Heng& Lee (2006) have discussed how the procurement system is affected in general construction works.

Previous researches have revealed that price certainty, responsibility, risk avoidance, price completion, quality level, complexity, controllable variation and time as the main factors to be concerned when selecting a procurement method which can vary according to the nature of the project, executing time, role of the client and other important criteria (Najeeb, 2005). Even though researches have been conducted regarding other types of constructions, less literature is available relating to building alteration where none has discussed about analysis of procurement system for the building alteration projects. Therefore, this research intends to identify "what is the behaviour of procurement systems of the building alteration projects in Sri Lanka?" which is a visible gap prevailing in sustainable construction industry.

2. Building Alteration

Building alteration works can be defined as any additional work, removal work or changes in the external parts of the building structure as well as any modification works of surface texture, architectural details or materials (Isnin *et al*.,2012). Accordingly, refurbishment of an area inside a building; major renovation of an entire structure; and upgrade/ restoration of historic structures are the three fundamental scales of building alterations (US General Services Administration, 2015).

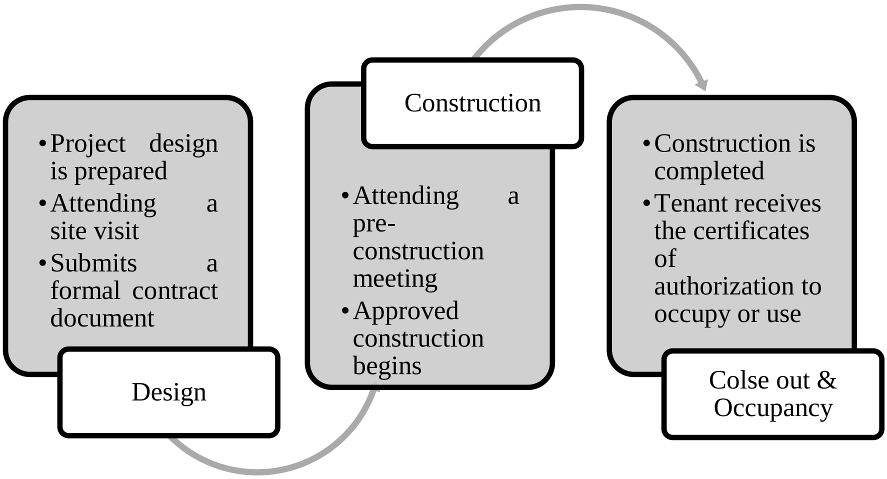
Alteration design should satisfy the initial occupancy needs and also anticipate additional future changes. Alteration model should be more flexible and the aim of the alteration should be to convince the new requirements within the parameters and constraints of the existing systems (Carol, Chan & Daniel, 2011). According to The Port Authority of New York & New Jersey (2013), to add comfort and enhance value of the building is one governing reason for building alterations. Building owners are changing internal parts to increase the comfort of living and increase the value of money. Due to development of the world and attitudes of people, nowadays most of the historic buildings are tend to change by the building owners. Due to lack of spaces in urban areas, people alter their existing buildings to get new look and value for the buildings.

Alteration building works can be classified under two main categories, as major alteration and minor alteration. Under major alterations, Type 1 and Type 2 are the main sub categories while alteration Type 3 is the main category under minor alteration section (The Port Authority of New York & New Jersey, 2013).

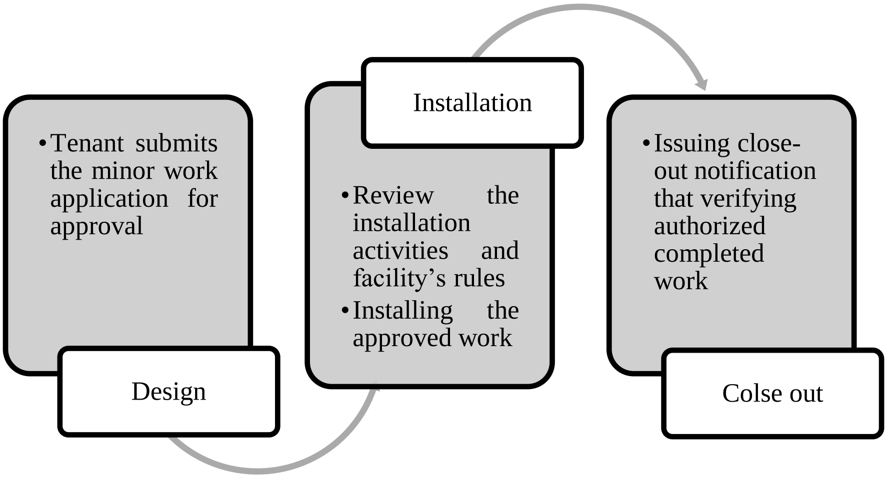
Alteration Type 1 • Commonly use when there is a change in maximum number of occupancy, changes the occupancy or use group of a space or changes the description of a space. Examples- Converting from commercial to residential, interior conversion of the building or a space within a building due to a building addition. Required approval of registered architect or licensed engineer.
Alteration Type 2 • Commonly use in renovation of commercial tenants and it will not change the building use, exits or type of occupancy. • Does not change the use or occupancy of the building but requires several types of work, such as plumbing and construction. Required approval of registered architect or licensed engineer.
Alteration Type 3 Doesn’t require detailed plans and professionals. Examples- Curb cut, Constructing fence

Most of the alteration works in Sri Lanka are not very complex. Therefore the proper alteration process is not regularly using in alteration works. However, in complex alteration works, as it is engaging with more planning works and complies with law, a proper procedure should be followed to ensure safety. Different alteration processes have been identified for both major alterations and minor alterations separately (The Port Authority of New York & New Jersey, 2013).

Major alteration process has been discussed as following stages.



Minor alteration process has been explained in following stages.



Thus it is significant that major alteration process differs from minor alteration process from the initial step itself. No formal contract is prepared for minor works only application is submitted for approval. Moreover alteration process as a whole totally differs from normal construction which has 11 different steps according to RIBA plan of work 2007.

In order to govern the alteration process effectively, procurement is acting a critical role in construction projects. Each project is having special characteristics and it is a must to treat the project considering appropriate procurement systems which expose the attainment of the project objectives (Hashim, Yuet Li, Chu Yin, Hooi, Heng & Yong, 2006). Suitable procurement system will always provide a good chance to get project success from the start and toward the end of any kind of construction works. The importance of the procurement system is to determine the degree and the relationship between the clients, designers and other project participants in each and every stages of the project (Alhazmil *et al*., 2000).

Different kinds of procurement systems have been involved in different levels of performances. Procurement has been developed due to several reasons, such as enhancement of complexity and magnitude, crossing national and natural barriers, innovative modalities. "These present prospective clients with many possible procurement paths within the complex network of potential arrangements for procuring design, construction, and management and financial services" (Kumaraswamy *et al*., 1998, p.224).

Significant changes in the technical and the economic conditions have been occurred in construction industry in recent past developing new procurement systems causing changes in clients' basic requirements and other identified factors by the researchers in the past for successful completion of a project (Jayasena, 2009). However those factors have not been addressed with respect to the alteration building constructions.

3. Methodology

The aim of this study was to identify the behaviour of procurement system for alteration building projects in Sri Lanka. Case study approach was selected as the appropriate methodology to this study. Multiple cases have been selected to provide multiple sources of evidence and potential replication of findings. The unit of analysis of this research was building alteration projects. Three cases have been selected for analysis with Alteration Types 1 and 2 which are major alteration works which is the limitation of the research.

Semi-structured interviews were carried out among related professionals based on their past experience to formulate solutions to understand the behaviour of procurement systems in selected building alteration projects.

Table 1: Cases Profile

Type	Case A	Case B	Case C
Alteration type	Alteration Type 2	Alteration Type 1	Alteration Type 1
Project cost (Rs)	56 Million	65 Million	80 Million
Project duration	15 days	6 months	8 months

Table 1: Experts Interviewee Profile

Case	Reference	Area of expert
A	CA1	Project executive (Refurbishment)
B	CB1	Project QS
C	CC1	Project QS

Qualitative cross case analysis was used for data analysis to understand the behaviour of Procurement systems for alteration building projects. The process of cross-case analysis is the comparison of commonalities and difference in the events, activities and processes that are the units of analysis in case studies (Samia & Robert, 2008).

Factors influencing the successful completion of the projects were identified and later strengths and weaknesses of each case were recognised and compared with each other and analysed the behaviour of procurement systems in the building alteration projects in Sri Lanka. Even though previous researchers have identified cost plus fee as the better procurement system for small building works, as it has not been specified to alteration building projects and due to difficulty in finding projects with a considerable budget and cost details following cost plus fee as procurement system this research has selected projects with traditional measure and pay procurement method.

4. Findings

Data collected through semi structured interviews revealed that it is essential to have a proper procurement system in alteration building projects to improve good quality works and to take new ideas on-board while maintaining good relationship with different stakeholders.

Having a proper procurement system creates a good relationship between all the parties involved to the contract. A party may demotivate if the procurement selection risk is more towards their side. It will directly affect to the quality of the work. In this research all the three selected cases have used Traditional Measure and Pay procurement system. According to the

interviewees Traditional Measure and Pay procurement system is the most commonly used procurement system in building alteration projects in Sri Lankan context. Contractors are willing to select this system on their projects due to higher variations involvement in alteration works. When compared to Traditional Lump-sum or integrated procurement systems, contractors are allowed for more variations in Traditional Measure and Pay procurement system and that has been the major reason for selection of that type in building alteration projects frequently by contractors. However, it is impossible to use Traditional Measure and Pay procurement system in all times. Alteration works consider parts in item wise, and therefore several parts could not be measured easily. It is the main difficulty in adopting Traditional Measure and Pay procurement system in those kinds of projects.
Some projects have involved with a large number of demolition works and some items that could not measure easily and for that kind of projects it is better to integrate Traditional Lump-sum or integrated procurement systems, rather than adopting Traditional Measure and Pay procurement system.

Literature reveals (Ratnasabapathy et al., 2006), that the Traditional Measure and Pay procurement system is the commonly used procurement system for construction works in Sri Lanka which was supported by the findings of the research.

Identification of factors that are affecting the procurement process in a particular project is a crucial aspect. Figure 3 displays the factors affecting selection of procurement system and the level of influence in selected three projects.

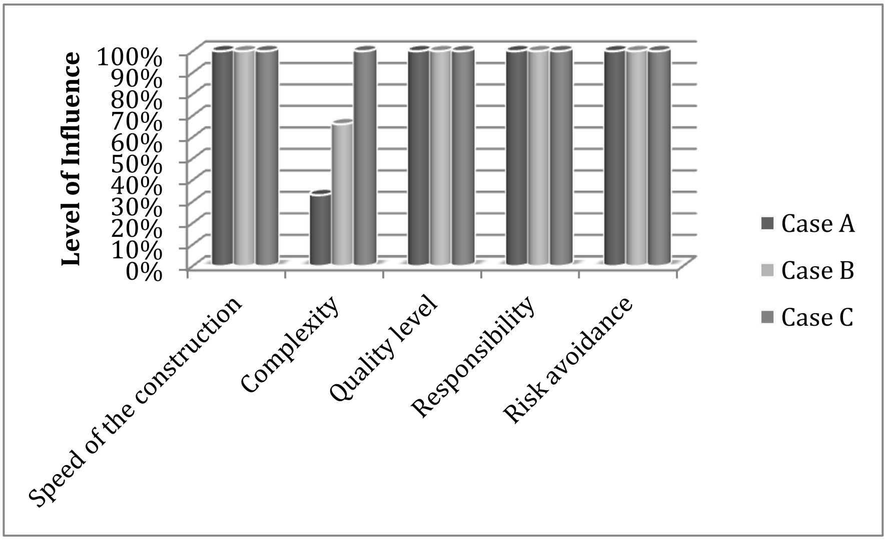


Figure 3: Factors affecting selection of procurement system and level of influence

According to Figure 3, affected factors in all three cases are almost same to the identified factors in literature. According to the three cases, above mentioned factors were common to the alteration projects as well.

In all three selected cases were concerning the speed of the construction in procurement selection. Alteration building projects normally engage with less time duration compared to new construction works. However, even the speed of the construction is a concerning factor in alterations, all three cases were used Traditional Measure and Pay procurement system which is not suited for a speedy construction. Quality work and less allocation for extension of time were the client's main requirements of all three cases.
The main reason for complexity on alteration building projects is due to modern techniques and modifications to the existing buildings. The modern architecture is used in alterations to provide a good aesthetical appearance to the building. Most of the times existing structure is not changing in the alteration projects, only the additions, removals and modification works are affecting in alteration process. However, case C uses Traditional Measure and Pay procurement system even it was a complex project. The main reason for the above cause is that, cost might increase if it is a Managing Contract procurement system which is more suitable for complex nature. But as client is always concerning the project cost engaging in Traditional Measure and Pay procurement system is a better solution for even a complex project.

Quality of the work is a highly affected factor in alteration building works. Further, one of the most important aspects is to identify client's requirements when selecting a procurement system for the project. Provision of dominating client in alteration building projects is relatively higher than the other constructions. Therefore, quality level is a critical factor when selecting the procurement systems in a project. Quality level is a governing factor especially in alteration building projects. The client's expectation in alteration projects is to increase clients' income or the profit by increasing demand for the existing building. Through the findings of the three cases, factors which were included in the literature synthesis were also proved further.

In any kind of construction project, responsibility should be taken regarding all stakeholders who are involving in the contract. In early stages onwards contractors are involving in decision making process in alteration building projects. Responsibility can be shared in reasonable provisions by involving contractor in the early stage of the contract. In alteration works, it is important to engage with different parties to both design and construction works separately. Therefore the both parties are responsible for their works and it will help to complete the work successfully. Through the findings of the three cases, factors which were included in the literature synthesis were proved further.

Mitigating conflicts when selecting the procurement system for an alteration project is always a plus point which directly affects for completing the project effectively. When it comes to alteration works, it is always good to have less conflict procurement method in the contract. Through the findings of the three cases, it was identified that alteration building projects prefer Traditional Measure and Pay procurement system.

From the initial stage onwards every party who are involving to the contact, have to face different kinds of disputes and arguments. Minimum disputes leads to a good quality effective outcome for the client. Case A is not a complex project and therefore, possibility of having large number of disputes in that kind of low complex project is very low. When compares to Case A, Case B is a kind of complex project. One of a main reason to follow Measure and Pay in their project was to minimize disputes while engage in construction. Traditional Measure and Pay procurement system is a flexible method when compared to Traditional Lump Sum and other procurement methods. Alteration works always difficult to predict quantities and therefore, selection of Traditional Lump Sum is a considerable risk for the contractor. In case B, consultant and the contractor have completed the work in a friendly manner. All the three cases were concerned about the quality of work while Case A was a restaurant project and Case B was converted to a shopping complex. Therefore, good aesthetic appearance was expected by the client.

Quality of the work was a governing factor in case A. In Traditional Measure and Pay procurement system, client was directly involved to the design stage and the designs were required to fulfil client’s requirements. Project cost is an important factor that all the clients are concerning in a particular project. In above three cases client has used competitive tendering to select the contractor on their projects. Selecting the lowest bidding price was an advantage to the client. When it compares with integrated arrangement, most of time contractors are selected through negotiations. Therefore, the client has to agree the contractor’s price and that price is not the lowest when it compares to competitive tendering price in Traditional Measure and Pay procurement system.

In the contractor’s perspective, selecting Traditional Measure and Pay procurement system is a profitable approach when it compared with other procurement types. The reason is possibility of misjudging the quality in alteration building works due to high involvement of variations and extra works.

After analysing the three cases, the following advantages can be zoom out in using a Traditional Measure and Pay procurement system in building alteration projects in Sri Lanka;

- Very less in arising conflicts
- Providing high quality out put
- Cost saving method
- Profitable for both contractor and the client

However, while having advantages of the Traditional Measure and Pay procurement system, there were few drawbacks affecting this system as well. By analysing all the cases, the major drawback is in adopting for Traditional Measure and Pay procurement system is, the client's initial price is not secured. In alteration works, variation cost and the extra work cost is significantly higher than when it compares to other construction types. In Traditional Measure and Pay procurement system, the contractor aware that he is paid for the work which has been carried out. When considering other disadvantages, time consumption for the completion of work is higher in the Traditional Measure and Pay procurement system comparatively to other procurement systems. Design and the construction are not overlapping in Traditional Measure and Pay procurement system. Construction works initiates when the design is finalized. Therefore, the completion time is higher in the Traditional Measure and Pay procurement system because the designing time and the construction time are acting separately. After analysing the three cases together the following disadvantages can be obtained in using a Traditional Measure and Pay procurement system in building alteration projects in Sri Lanka;

- Client's initial price is not secured
- Time for completion is high

Thus it has been identified that behaviour of alteration building projects differ based on the procurement systems used.

5. Discussion

In alteration projects, client's expectation is mainly focused to the quality of the works. The reason is client is altering the existing building to have a better earning with his owned property. Therefore, the quality of the work needs to be increased. Additionally, client is always preferred for cost saving methods to make full use of his financial commitment. Furthermore, not only the client, but also the contractor expects profit in the works and they prefer minimum risk affecting contracts on their side. Always the final output is more efficient when the conflicts are getting lower in parties who involve to the contract. If a procurement system could satisfy those factors, even the high completion time and the unsecured client's initial price would be a useful system for an alteration building project. According to professionals' opinions and the analysis of the strengths and weaknesses of three cases, it can be concluded that the behaviour of alteration projects differ depending on the procurement systems used for building alteration projects in Sri Lanka.

6. Conclusions

Building alteration is a new concept for Sri Lankan construction industry. Unlike other construction works, studies were very less regarding the alteration constructions. In all kinds of construction works it is important to select a proper procurement system in those projects. In selecting those procurement methods, various factors were affecting in selection process of the suitable procurement methods. In this research, it has been identified that speed, complexity, quality Level, responsibility, risk avoidance and price completion were the most affected factors when selection a procurement system in a general construction project.

According to the selected cases, Traditional Measure and Pay procurement system was the commonly used procurement system in building alteration projects in Sri Lanka and the reasons for the selection is very less conflicts, high quality output, cost saving and profitable for both contractor and the client. Some drawbacks also have been identified as client's initial price is not secured and time for completion is high. Suitable procurement system was finally identified by critically compared strengths and weaknesses of the procurement systems that were used in selected cases. By analysing and comparing the selected three cases and according to the literature, it can be recognised that behaviour of alteration projects differ depending on the type of procurement system selected for the project.

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LEADING THE PROJECT TEAM IN CONSTRUCTION PROJECTS THROUGH TEAM DEVELOPMENT STAGES

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Abstract
The importance of teams in construction is an issue of international relevance. For example, several influencing government reports in UK have highlighted this. However, effective teams cannot be created at a stroke, and, they need to be managed effectively to foster successful teamwork and team performance. Construction project management literature is heavily targeted on offering tools and techniques to manage a project to achieve the set project goals. However, it is very superficial on detailing how the construction project team should be led towards the project goals. Drawing on case studies conducted in Sri Lankan construction industry, this paper reports on how project managers lead construction project teams when they go through forming, storming, norming and performing stages. The findings revealed that due to the independent nature of construction project team and mostly the construction project managers acting on behalf of the client rather than the project leader, their leadership role deviated from a general project leader. More case studies are required to compare and contest these findings in different settings. However, since the findings were quite similar across the three case studies, which had different procurement arrangements (separated and design and Build) and different types of clients (public and private), it is expected similar trend would be observed in other construction projects.

Keywords. *Project Teams, Project Management, Leadership Roles, Team Development*

1. Introduction

The concept of "teamwork" is very much related to construction settings and is an issue of international relevance. Many of the problems with regard to construction projects could be overcome by better team working and collaborative arrangements. According to Constructing Excellence (2004, p4) “construction is a collaborative activity – only by pooling the knowledge and experience of many people can buildings meet the needs of today, let alone tomorrow.” Thus, teamwork in construction is not a choice but a necessity.

Since construction work requires team efforts, leadership should have great impact on the performance of construction work (Odusami et al, 2003). As stated by Cornick and Mather (1999), stirring all project team members to perform to the best of their ability and even more importantly inspiring them to co-operate as and when it is necessary is a major key to success in the management of a construction project. To this end, the project manager has a distinctive role as a leader, since he is liable to drive the whole project team towards its aims and objectives with the use of limited resources supplied to him (Toor and Ofori, 2008). This research study aims to identify how construction project managers (CPMs) lead their team across various team development stages.

2. Literature Synthesis

To be an effective leader, the project manager of a construction project should adapt a style of behavior according to the given situation to meet the needs of the followers as well as the task environment. According to Hersey and Blanchard (1982), as all followers are unique individuals, the manager must treat them accordingly in a given situation in order to be a successful leader, which is the basic argument in situational leadership. Situational leadership stresses that leadership is composed of both directive and supportive leadership roles and each of them has to be applied appropriately in a given situation. Northouse (2007) further described that, directive role helps group members to accomplish goals by giving directions, establishing goals and method of evaluation, setting time lines, defining roles and showing how the goals are to be achieved. . Directive roles are often with one way communication. Supportive roles help group members to feel comfortable about themselves, their coworkers and the situation. Supportive roles involve two way communication. In Meyer’s (2014) research on competencies of a successful project leader, they found communication as the most important competency.

Muller and Turner (2010) indicate that leadership style should change at different stages of a construction project life. They argue that the nature of the work to be undertaken within each work stage will determine the leadership style most appropriate at arriving at the best outcome. On the other hand, Walker (1996) suggests two distinctive styles required by the leader at the start and towards the end of a construction project. At the early stages of a project, the manager has to weld together the range of professional specialists involved in the project and lead them in balancing the conflicting objectives, which demands them to adopt a human relations-oriented style of leadership. Once the proposed solution has been defined, the process of developing the solution into working documents becomes a much more structured process, a more task-oriented leadership style is adopted by them. However, more studies are required to identify leadership role of a CPM during different development phases.

Construction project teams, similar to general teams, go through various team development phases with slight deviations (Senaratne and Hapuarachchi, 2009; Senaratne and Samaraweera, 2015). The team development stages as described by the Tuckman (1965) comprise of four phases as; Forming, Storming, Norming and Performing. The forming stage is when a group of people first comes together and members are primarily seeking for structure (orientation), guidance, and a safe environment. The storming stage is when individuals begin to challenge differences, especially as they relate to power and decision-making. The norming stage is when they accept rules, or norms of behavior and show the desire for group cohesion or consensus. The performing stage is where the members begin to relate more deeply to each other and to the group's purpose and task. The research findings of Senaratne and Hapuarachchi (2009) confirmed that construction project teams follow this linear sequence when they develop as teams. However, they found that this is affected when new team members enter into the project or when major changes occur in the scope of the work. Hence, these different stages in team development call for different leadership roles to suit a given situation in each of these stages.

When considering the construction project team development process, it is apparent that the team members have different behaviour patterns in each stage (Senaratne and Hapuarachchi, 2009). This requires a leader to adopt different leadership roles to cater the different leadership requirements in each stage of the team development process. As depicted in Table 1, a rational could be developed to identify the leadership role of the project manager; as either a high/low directive role or a high/low supportive role, using a generic study of Sheard and Kakabadse (2004) on leadership roles with the observable behaviours identified from a study of Senaratne and Hapuarachchi (2009) on construction project team development. Literature that describes leadership styles across the team development phases too proposes different styles that should be adopted at each phase. For example, Cornick and Mather (1999) propose in forming , storming, norming and preforming stages of the construction project team, the leadership style that the team leader should adopt are 'directing', 'coaching', 'supporting' and 'delegating' respectively (see Table 1). Kasapoglu (2011) propose, most of the research on the construction industry's leadership styles has shown that most employed style is the supportive. However, there is less understanding on how leadership styles of a project leader changes across the project phases.

Table 1 - Predicted leadership role of CPM

Stage	**Observable behaviours of the construction project team members** Source: Adopted from Senaratne and Hapuarachchi (2009)	**Rational for the selection of the required leadership role for the construction project manager (CPM)** Source: Adopted from Sheard and Kakabadse (2004)	**Predicted leadership role**
Forming	• Attempts to define tasks, processes and how it will be decided • Politeness • Orienting with others personally	• Leader should provide structure and clear direction to his team members • Leader is not required to provide a high supportive role since team members show a behaviour trying to orient with others personally and being polite in their behaviour	High-directive Low-supportive ***Directing Style***
Storming	• Arguing among members • Differences in points of view and • personal style • Lack of progress • Establishment of unrealistic goals • Concern over excessive work	• Guide team members towards team goals • Improve work progress • Leader should help team members to achieve the team goal • Should address interpersonal issues and utilize interpersonal skills to address sensitive issues • Guide team members towards consensus • Teach conflict resolution methods	High-directive High-supportive ***Coaching Style***
Norming	• Agreeing of processes and procedures • Attempts to make consensus decisions • Focus and energy on tasks • Setting and achieving task milestones • Shared problem solving • Developing routines • Comfort with relationships • Effective conflict resolution skills	• As the team shows success in setting and achieving the task milestones, the leader would need providing a Low-directive role • Leader should assist the team members to build strong relationships and agreeing on norms and standard behaviours • confront sensitive interpersonal issues • Focus on the effective utilization of interpersonal skills • Reinforce the strengths of each team member	Low-directive High-supportive ***Supporting Style***

Performin g	• Functioning fully as team • Clear and interdependent roles • Ability of the team members to organize • themselves • Flexibility and well-functioning individually • Better understanding of each other's strengths and weaknesses and insights into group processes	• Provide little direction and decisions since the team seems to work with full autonomy • Low amounts of two way communication • Only giving positive reinforcement and support	Low-directive Low-supportive ***Delegating Style***

Hence, case studies were conducted to explore this phenomenon as explained next.

3. Research Method

Deep insight into a phenomenon could be obtained by using the case study research approach. Yin (2003) describes that case studies are preferred to study real-life social contexts as the findings are interpreted based on the views and experiences of the case study actors. As Eisenhardt (1989) advocates case study is a powerful research methodology that enables to build novel theoretical versions based on theoretical generalisation.

In view of the facts cited above, three construction projects were selected as case studies as detailed in Table 2. Yin (2003) depicts that external validity of a research can be increased by improving the ability of generalizing the findings beyond the immediate case study. This is mainly achieved while designing the research. Thus, different procurement arrangements and different types of clients were considered under the case selection of this research, to allow the findings to be extended to a wider range of projects improving external validity of the research.

Data collection was mainly done by conducting semi-structured interviews with the project managers of the selected projects and with other three key participants of each project team including architect, client and the contractor. Data analysis was done through code-based content analysis using the N-vivo computer software. The findings are discussed in the subsequent section.

Table 2- Details of the selected cases

Project	**Project A**	**Project B**	**Project C**
Type	A government hospital	A private Institute	A government building refurbishment
Project Cost (Rs.)	215 millions	100 millions	1000 millions
Project Duration	32 months	18 months	14 months
Procurement Method	Traditional method	Traditional method	Design and Build method
Client	NGO	Private-Client	Government-Client
Nature of the team	Project manager and other consultants from the same private organisation and the contractor from a different private organisations	Architects, structural consultant and contractor from different private organisations and project manager and other consultants from a single private organisation	Whole project team from a government organisation with internal divisions for consultancy, architectural and construction

4. Research Findings

The case analysis carried out on the current roles of leadership revealed that some of the leadership roles provided by the CPM are not in line with the identified roles at the literature review stage. Table 3 provides a summary of the leadership roles as verified through the empirical findings. Key findings of each phase are further described in this section.

Table 3 - Existing leadership roles of CPM across the team development process

Stage	**Directive Role**	**Supportive Role**	**Revealed leadership role**
Forming	• Providing structure and clear task direction • Active involvement • Not showing how goals are to be achieved • Not making many decisions by the project manager • Not adopting one-way communication	• Not allowing time to get to know each other • Not breaking interpersonal barriers within the team • Creating an atmosphere of confidence and optimism	Moderate-directive Moderate-supportive ***More Directing Style***

Storming (Just after forming stage or arrival of a new team member)	• Get members to assume more task responsibility • Fair amount of clarifying and explaining • Active involvement • Leader consults but make final decision	• Offer support and praise	High-directive Low-supportive ***Directing Style***
Storming (Issues giving rise to interpersonal conflicts)	• Get members to assume more task responsibility • Fair amount of clarifying and explaining • Active involvement • Leader consults but make final decision	• Offer support and praise • Acknowledge conflict • Guide others towards consensus • Teach conflict resolution methods	High-directive High-supportive ***Coaching Style***
Norming	• Allow for less structure • Promote discussions • Ask for contribution from all team members • Encourage the team members in decision making	• Giving feedback and support • Collaboration • Continues to build strong relationship	Low-directive High-supportive ***Supporting Style***
Performing	• Observing • Inquiring • Leader sets goals and team accomplishes • Provide direction and decisions	• Give positive reinforcement and support • Providing two-way communication	Moderate-directive Moderate-supportive ***More Directing Style***

4.1. FORMING

All the three project managers and majority of the subordinates agreed that 'providing structure and clear task direction' to the team members was mostly undertaken, while the leader 'had an active involvement' at the forming stage. However, project managers were only involved in 'making the overall targets' and the subordinates themselves were given the freedom to prepare their individual goals. Rather than one-way communication, 'two-way communication' was more prevalent even at this forming stage. Generally, project managers declared that they 'did not get the opportunity to make many decisions' due to independent team members. Hence, it is observed that instead of a high-directive role 'a moderate-directive role of leadership' is appropriate at the forming stage of construction project teams.

With regard to the supportive role, majority of the interviewees agreed that project managers 'did not require allowing time to get to know each other' and 'did not require breaking interpersonal barriers within the team'. In addition, all of them have tried their best to 'create an atmosphere of confidence and optimism'. This was supported by the two-way communication maintained by the leader and team members. Therefore, it is apparent that a CPM provides a ‘moderate supportive role’ during the forming stage.

Hence, the CPM seems to be adopting a more ‘directing style’. It is very much similar to the ‘authoritative style’ of leadership, where the leader takes a “come with me” approach stating the overall goal but gives people the freedom to choose their own means of achieving it. But the influence of the client and the architect seem pushed the project manager to act more a role of a coordinator avoiding him giving a high task direction.

4.2. STORMING STAGE

The storming stage, which comes just after the forming stage or which comes with the arrival of the new team members has not been very much apparent externally from the team members to the project managers. Rather, case studies revealed that certain unsolved technical issues led to a storming stage that required CPM involvement. This was evident within the team of the project C, where the senior management has had a conflict over selecting a suitable procurement method, which ultimately has resulted in the whole project team polarizing into two groups. Therefore, the project manager seems acting different leadership roles in each type of storming situations.

Generally, all the three project managers have ‘got their members to assume more task responsibility’. Further, they all have provided ‘a fair amount of clarifying and explaining’ and have ‘involved actively’ within the team providing the direction. Further, all the three project managers have ‘consulted and made the final decisions’ in a storming situation, but at varied levels. However, when the storming stage has occurred due to a technical, business or social matter only the project manager had made the final decision after consulting others. Therefore, when considering the directive-roles provided by the CPM in all storming stages, it is apparent that they provide a ‘high-directive role’.

It was found that during certain storming situations, in particular, during interpersonal conflicts arising out of technical, business or social problems, all the project managers have ‘acknowledged conflicts’ and have provided the roles like ‘offering praise and support, guiding the team members towards consensus’ and ‘teaching conflict resolution methods’. But, there was no requirement for them to engage in ‘conflict resolution’, as most other storming situations were not that severe or apparent. Therefore, it is observed that the CPM provides a ‘low-supportive role’ during the storming stage which occurs just after a forming stage or with the arrival of new team members and provides a 'high-supportive role' in storming stages which occur due to issues giving rise to interpersonal conflicts.

Overall, as most of the members in a construction project team consist of professionals, they require only a working relationship to work as a team unlike a general project team where team members look for personal relationships to work as a team. Moreover, in project teams from government organisation are further governed by rigid hierarchical procedures in case of conflict situations. Therefore, a typical CPM has a less-supportive and a high-directive role in the storming stage which shows a nature of a 'directing style' of leadership again. However, during the storming stage which occurs by various issues giving rise to personal conflicts, the CPM offers a high-supportive role reflecting a 'coaching style' of leadership.

4.3. NORMING STAGE

When analysing the directive role in norming stage of the construction project team development process, all the three project managers and majority of the subordinates stated that project managers 'asked for contribution from all team members' and 'encouraged the team members in making decisions' and also 'promoted discussions' which is of 'low-directive role' as required at this stage.

With regard to the supportive role of the project manager in norming stage, project managers 'gave feedback and support' to their team members and there had been 'collaboration' and helped all the team members in 'building up strong relationship' with each other to a great extent which are all seem to be 'high-supportive roles' of leadership as required at this stage.

Therefore, a typical CPM seems adopting a 'supporting style' of leadership during the norming stage. However, in project teams where all the members are from different organisations have a restriction for them to have a close relationship. Nevertheless, it does not seem having a strong effect on building up norms among members and building up the relationship, as most of the project teams have weekly meetings which facilitate them building-up norms.

4.4. PERFORMING STAGE

Case studies revealed that at the performing stage, the project managers adopted the roles of 'leader setting goals where the team is accomplishing them' together with 'observing and inquiring' mainly which are in line with a less-directive role of leadership. But, all of them declared that they 'could not still avoid providing direction and decisions.' Therefore, it could be argued that the CPM offers a 'moderate directive role' in performing stage.

It is further observed that all the project managers have provided 'positive reinforcement and support to their team members' throughout the performing stage which is in line with a less-supportive role of leadership, but contrary to that all the leaders were still 'unable avoid two-way communication between leader and the members', which is a high supportive role. Therefore, it could be argued that the CPM offers a 'moderate supportive role' of leadership at the performing stage.

Such a directive role still at the performing stage has to be adopted by a typical CPM due to the contractual nature of a construction project where he has to administer and protect the contractual obligations of client and the contractor and prevent other consultants attempting to breach any obligations agreed upon. Unlike the manufacturing industry and most of the other industries which produce typical products, the projects in construction industry hold a complex nature and most problems require having a customised approach to solve it. Mostly, the contract period and the contract sum become fixed in construction projects and CPM needs to coordinate the team through regular meetings until the project completion. This avoids them to adopt a low-supportive role and forces them to continue a more directive style towards team performing stage.

5. Conclusions

The case studies findings indicated that leadership roles required for a CPM deviated from the predicted roles for each team development phase based on construction team behavior at each stage.

In forming stage, the CPM adopted a moderate directive role and supportive role of leadership, which is different to what was expected by a leader at a forming stage (high directive and low supportive role). These deviations were mainly due to working with the same level members in the team who are all regarded as experts in their own field.

Three different kinds of storming stages were identified in a construction project team as; the storming stage that begins just after the forming stage, storming stage occurring at the arrival of new team members and the storming stage that occurs due to various issues giving rise to interpersonal conflicts. The CPM adopts a high-directive role and a low supportive role in his leadership in the first two storming stages due to the professional nature of the team members who consider maintaining working relationships rather than personal relationships. During the third storming stage, which occurs due to interpersonal issues, it was noted that the CPM has to deviate his leadership role to high-directive and high-supportive.

With regard to the norming stage, the CPM adopts a low-directive role and a high-supportive role where he demonstrates a leadership very much similar to the required leadership at this norming stage. During the performing stage, the CPM demonstrates a moderate directive and supportive role, which is rather different to what is expected at such a stage. The reasons identified were mainly due to CPM acting more on behalf of the client.

Overall, the findings of this study are important to realize how CPMs lead their project teams. More importantly, it shows that due to the independent nature of construction project team and mostly the CPM acting on behalf of the client rather than the project leader, the leadership role deviated from a general project leader. More case studies are required to compare and contest these findings in different setting. However, since the findings were quite similar across the three case studies, which had different procurement arrangements (separated and design and Build) and different types of clients (public and private), it is expected similar trend would be observed in other construction projects.

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Rajapaksha.U, et al (eds), 2015, “Making built environments responsive”*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 143–157. ©

ARCHITECTURAL EVALUATION OF HISTORIC SITES THROUGH SITE SURVEYS IN NINGBO CHINA

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Abstract
The preservation and renovation of historic buildings have aroused the public concern in the city of Ningbo, one of the most economically active regions in the south-eastern coast of China. The municipal government of Ningbo has targeted over 2,000 historic sites and been working on creating the database of these sites including building layouts and locations. The research team from the University of Nottingham Ningbo China, in collaboration with the government, had been working on the site survey and follow-up evaluation of a total of 44 historic sites. This study summarizes the site survey results of these historic sites, including building type, structure and construction materials, repair status, historic and architectural values, and present usage. Apart from the follow-up survey data, the research team also conducted further investigation on the retrofitting of a selected case building. Building information modelling, the newly emerged digital technology, was adopted to visualize the case building. The architectural evaluation motivates the exploration of maintaining the historical value and original character meanwhile improving the existing condition of these historic sites. Modern visualization technologies would be a potential tool on modelling the architectural, structural, and building service systems of existing buildings.

Keywords. *Historic buildings, conservation, building survey, building information modelling, visualization.*

1. Introduction of conservation of historic buildings

Under the pressures of a rapid and unprecedented development and urbanization, traditional housing in China has been under a constant threat. Entire neighbourhoods and villages have been demolished making place for contemporary housing aiming to increasing land efficiency and improving the living standard. However, this often results in loss of embodied energy, urban diversity and cultural identity. Although the conservation movement has helped to preserve some traditional housing, the need for old buildings to meet modern standards of comfort and environmental performance remains a potential economic deterrent to conservation (Phillips and Ding, 2011)

1.1. INTERNATIONAL EXPERIENCE

Conservation of historic heritage has a long history, initially focusing on the repair and amending of buildings and other artefacts for their maintenance and aesthetic quality. The Venice Charter for the Conservation and Restoration of Monuments and Sites, a code of professional standards issued by the 2nd International Congress of Architects and Technicians of Historic Monuments, has been viewed ever since as a fundamental document reflecting the internationally accepted philosophy for protection of architectural heritage, and restoration architects throughout the world have been using it as a guide for their work (ICOMOS, 1964).

In the United States of America, Weeks et al (1995) in their guidelines issued by the Department of the Interior define the following treatment approaches to architectural conservation:

- Preservation "places a high premium on the retention of all historic fabric through conservation, maintenance and repair."
- Rehabilitation "emphasizes the retention and repair of historic materials, but more latitude is provided for replacement."
- Restoration "focuses on the retention of materials from the most significant time in a property's history, while permitting the removal of materials from other periods."

1.2. CONSERVATION OF HISTORIC BUILDINGS IN CHINA

Since the establishment of the People's Republic of China, China has effectively conserved many heritage sites that were in danger of being completely lost and, at the same time, has developed conservation theories and guidelines according to national conditions. The Law of the People's Republic of China on the Protection of Cultural Relics as well as interrelated laws and regulations define the legal framework for conservation practice. The Principles for the Conservation of Heritage Sites issued by China ICOMOS (2004) set the professional guidelines on the basis of these laws and regulations, while drawing upon the 1964 International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter).

The case of Xiao He Zhi Jie (Little River Street), located in Hangzhou, China, bears some similarities to this research project. The case is described in Table 1.

Table 1. Xiao He Zhi Jie project outline description. (Source from Wu et al, 2010 and Phillips and Ding, 2011)

Location	Hangzhou City, located on the Xitang River, close to the intersection with the Beijing-Hangzhou Grand Canal)
Residents	120 households with 450 residents, many of them being retired employees
Situation before the renovation	High population density, outdated or no basic sanitation facilities, illegal construction, poor aesthetic condition, lack of neighborhood vitality and other common problems
Age of Buildings	Built in the late 19^{th} -20^{th} century.
Building Type	One or two-storey residential building of stone construction.
Construction	Hard stone and pole framing structures.
Building Category	Historic
Renovation Construction	Original construction retained where possible, some of the houses had to be rebuilt, using masonry walls and stucco.

According to Phillips and Ding (2011), old buildings in China are generally classified into one of three categories depending on their cultural significance: heritage, intermediate, and historic buildings. For heritage buildings, conservation will be undertaken only with original materials, and the original function of the building will be conserved wherever possible; intermediate buildings can be conserved for a different use from the original, although original materials will generally still be used in conservation works; the conservation of historic buildings can involve both a change of use and the introduction of new materials (Phillips and Ding, 2011). Similar to the case of Xiao He Zhi Jie buildings, targeted buildings for site survey in this research were also classified in the historic category.

This research conducted in the University of Nottingham Ningbo China (UNNC) started from site survey of historic sites in Qiu'ai, a suburban town of Ningbo, followed by data analysis of totally 44 surveyed historic sites. A case building was further explored using Building Information Modelling (BIM) to achieve the 3D visualization which led to discussions on future research.

2. Site survey of historic sites in Ningbo China

In the autumn of 2014, the City Architectural and Planning Bureau of Ningbo (CAPBN) contracted with UNNC on the site survey and database update of historic sites in Qiu'ai Town. Originally 54 historic buildings or infrastructure sites (e.g. bridges) were targeted from the documented database. The survey work for each targeted historic site was led by one team consisting of one academic staff and three or four students within the Architectural and Environmental Engineering (ABE) department of UNNC. Each survey team was equipped with necessary tools such as laser measurement, scales, and cameras.

The survey report and database required by CAPBN included the building type (e.g., residential, public building such as temple), evaluation of building values (i.e., historic and cultural value, architectural style, construction quality, status of damage), and other general information such as ownership, floor area, and gross floor area, etc.). Each item of building values was divided into A, B, C, and D, with A being the best or least damage, and D being the worst or most seriously damaged. The evaluation criteria for building values were peer-discussed with counterpart researchers in Ningbo and CAPBN to maintain the consistency among different survey teams. An example of the building evaluation according to site survey work is displayed in Table 2.

Table 2. An example of the building value evaluation based on site survey

Photographs*		**Description**
		A residential house consisting of identical units, built in The Qing Dynasty (from 1636—1912), partly renovated after 1912, is representative of the residential house over a century ago, with certain historic values. The historic value was evaluated as in Category C.
		This building was designed in the courtyard style, with tight layout, consisting of the hall, and flats on both sides as well as the centre as displayed in Figure 1. The architectural style was evaluated as B.
		The courtyard, front door, and roof were mostly well maintained. The wood beam, column, and their joints were built with traditional features. The construction quality was evaluated as B.

		Apparent cracking occurs in the north side of the internal walls. Some wood columns have decayed with weak connections to the concrete support. The status of damage was evaluated as C, damaged at certain level.

*: Only part of photographs is included in Table 1 for demonstration purpose. More photos were taken during the site survey to assist in building value evaluations.

Before the start of each site survey within the rural villages of Qiu’ai town in Ningbo, usually the local contact would be assigned by the CAPBN to assist the UNNC team to find the target sites. The survey team would also identify the target site in the local map. The site tasks of the UNNC survey team were allocated, with the academic staff being the manager communicating with the local contact to collect information such as the site history and existing usage or living condition, one student assistant taking site photos, two or three students collaborating to conduct the site survey with the assistance of the laser measurement tool. The survey team measured the external layout of each site, as well as the internal partition elements such as walls, and other structural elements such as columns. For buildings, window/door locations and sizes were also surveyed. The 2D drawings were generated by Computer Aided Design (CAD) afterwards according to the site survey results. Figure 1 displays the CAD plan drawing of the example building described in Table2. The CAD drawings (only in 2D plan views) for each surveyed site became part of the database provided to CAPBN as one project deliverable.

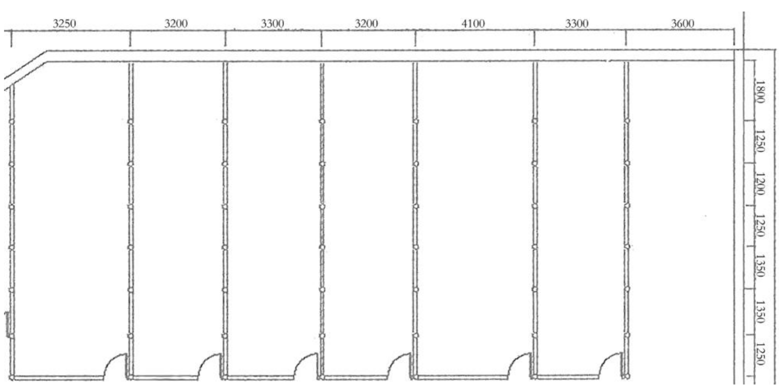
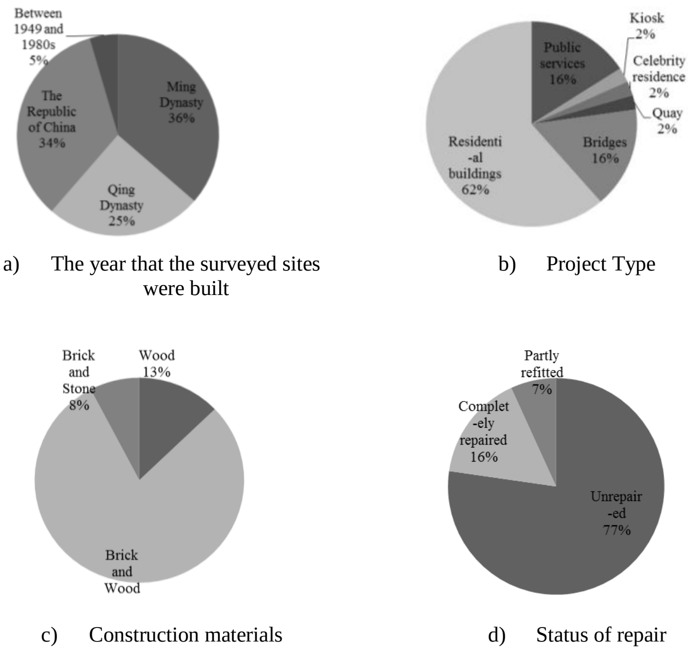


Figure 1. CAD drawing of the building’s plan view according to the site survey

By the end of May 2015, in total 44 historic sites within 17 villages of Qiu’ai Town were visited during this period. Another ten targeted buildings had been demolished due to various reasons including providing spaces for new building construction, new railway, new pavement, or land under the new development plan. The site survey report is summarized statistically in Figure 2.



a) The year that the surveyed sites were built

b) Project Type

c) Construction materials

d) Status of repair

Note: the year that buildings were constructed could only be identified within a certain historic period: Ming Dynasty (between 1368 and 1644), Qing Dynasty (between 1636 and 1912), The Republic of China (between 1912 and 1949), and People's Republic of China (after 1949).

Figure 2. Statistical report of the building survey

The statistical analysis of the surveyed historic sites displayed in Figure 2 includes the year that the building or infrastructure project was constructed, the status of repair, original construction materials used, and the type of projects. The majority (95%) of the sites surveyed were built before 1949, and 61% of sites were built over a century ago. The majority (80%) of surveyed sites were buildings, including residential buildings, public services buildings such as temple, celebrity residence, leaving the remaining 20% being infrastructure sites including bridges, kiosk, and quay. Wood and brick were the most frequently used construction materials among these surveyed buildings, accounting for almost 80% of the survey sample. Only 16% of sites had been completely repaired. Figure 3 provides an example showing the status of repair of a single residential unit displayed in Figure 1.

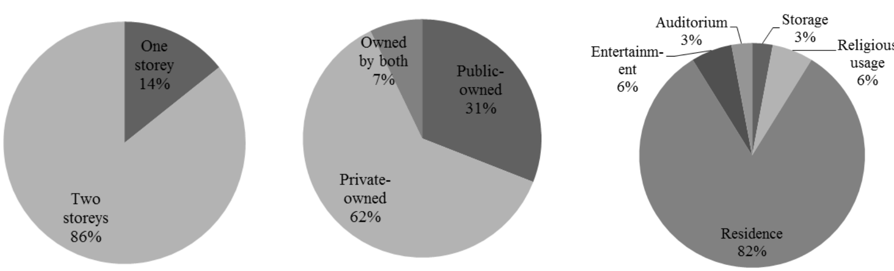
The original weakened wood structure had been replaced with modern reinforced concrete materials.

a) Replacement of the original wood column with reinforced concrete structure

b) Replacement of the original wooden panel wall with masonry / concrete

Figure 3. An example showing the repair status of a surveyed historic building

Apart from the statistical summary of the survey sample in Figure 2, the usage and ownership related data was also one of the research deliverables. Based on the site survey information collected, further data summary is provided in Figure 4 displaying the buildings' storey, type of current ownership, and the current usage.



a) Buildings' number of storeys

b) Current ownership

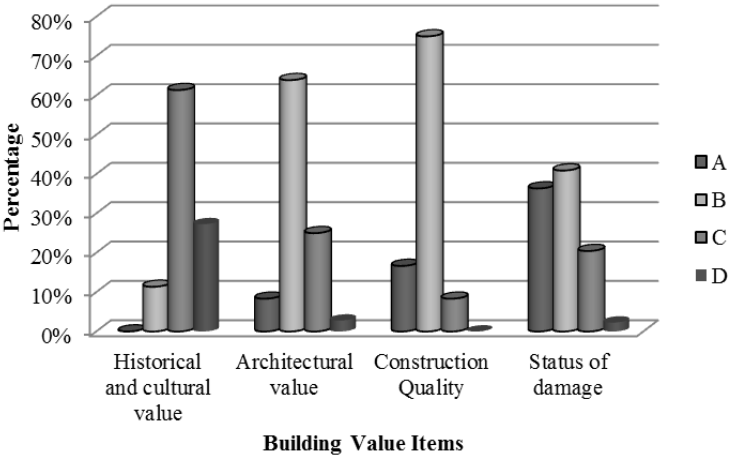
c) Status of current usage

Note: the data sample of storey number and current usage excluded bridges, kiosk, and quay. But the type of ownership was analysed within the whole sample of 44 sites.

Figure 4. Further data summary of the surveyed buildings

Most buildings in this survey were constructed in the two-storey type, and over 80% of them had been used for residential purposes providing the living spaces for lower-income families. For example, each single residential unit of the residential community shown in Figure 1 was rented to a family consisting of two to three residents.

The evaluation of surveyed sites categorized by four different levels was analysed in Figure 5.

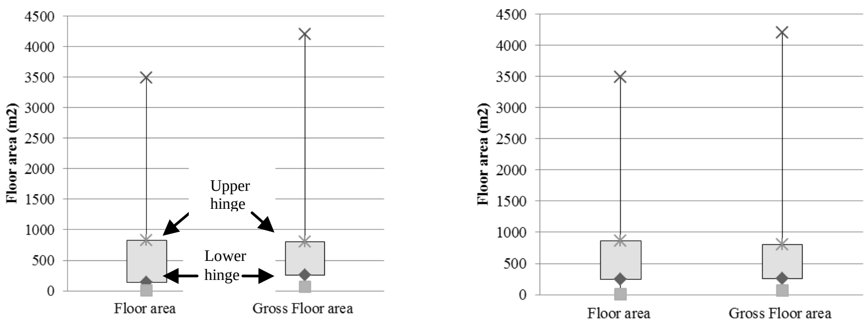


Note: for evaluation of the historic and cultural value and status of damage, all the 44 surveyed sites were included. For the evaluations of architectural and construction quality, only the 35 buildings were included for the data analysis.

Figure 5. Statistical summary of buildings' evaluation results

Apart from Table 2 describing the categorization of an example surveyed site's evaluation results, images for different categories in Figure 5 were further added in the appendix. The majority of the surveyed sites were categorized as B or C level in terms of historic and cultural value, and architectural value. Over 70% of the surveyed sites were found falling into the category of B in terms of construction quality. Only 36% of the surveyed sites were found with the minimum level of damage, and over 60% of surveyed sites were in the Levels B or C considering their damage status. Noticing that most surveyed buildings were being used as residential flats, there should be concerns raised on renovating the existing buildings for the safety and comfort living conditions for residents. Some of the surveyed residential buildings were found with inappropriate window orientations or lacking shading devices in the summer, which resulted in high indoor temperature in the summer and low solar gain with high humidity in the winter.

Further statistical analysis was conducted as part of the research project deliverables to summarize the sizes of the surveyed buildings or infrastructures. Floor areas and gross floor areas were the two measurements of project sizes. The data is analysed in Figure 6 using box plots, which conveys the data information regarding surveyed site size distribution in terms of the minimum, first quartile, median, third quartile, and maximum values of floor areas and gross floor areas.



a) Box plot of data including all surveyed sites

b) Box plot of data excluding bridges, kiosk, and quays

Note: the data sample of floor area covers the whole sample of the 44 surveyed sites, but the data analysis of gross floor area (i.e., total floor area of all storeys) only included the 35 buildings.

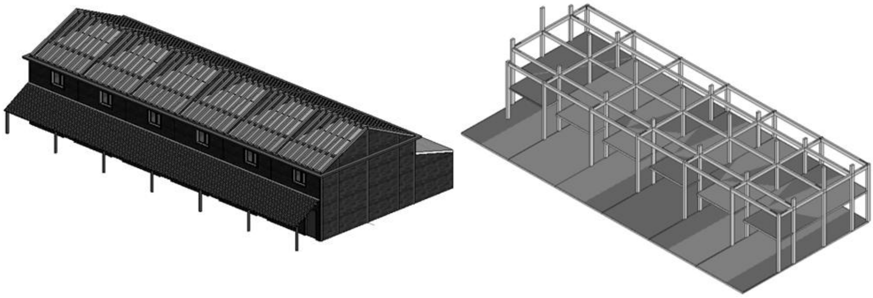
Figure 6. Box plot of surveyed buildings' floor areas

The upper and lower hinges in Figure 6 show the first and third quartiles of the data sample. The centreline between the upper and lower hinges indicates the median value of site sizes. It can be read from Figure 6 that the median values of project size with all 44 sites included were 304 m^2 and 489 m^2 respectively for floor areas and gross floor areas. When the infrastructure projects were excluded, these median values for the 35 buildings became 427 m^2 and 489 m^2 respectively. The minimum values in both Figure 6-a) and Figure 6-b) were the same at 7 $m^2$and 60 m^2 respectively. It can be found from Figure 6 that in both cases, whether the floor area data of infrastructure sites were included or not, the floor area and gross floor areas were highly skewed from the normal distribution due to the large sizes of some sites with maximum values of areas at 3491 m^2 and 4204 m^2 respectively.

3. Case study of a historic building

As the continued work from historic site survey and data collection which ended in May 2015, BIM technology was adopted in visualizing the current building's architectural details. The residential building illustrated in Table 1 and Figure 1 had the typical architectural style within Ming and Qing dynasties of China. It fell into the category of residential usage, constructed by bricks and wood with its damages unrepaired. Based on its representativeness of its project type, construction materials, status of repair, as well as its cultural, architectural, and construction values according to

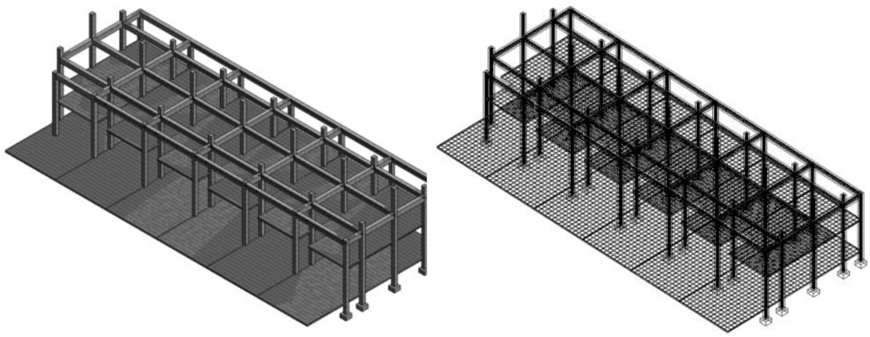
Figure 2 and Figure 5, it was selected as the BIM case study. Figure 7 visualized the building in Figure 1 by displaying the continuous six residential units in the Revit Architecture Template.



a) Visualization of the current building   b) Wood structure model

Figure 7. Visualization of the six identical residential units in the case study

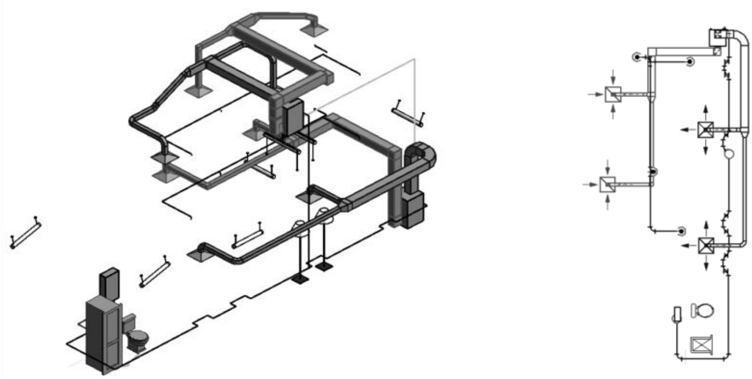
The existing residential units in Figure 7 used wood framing structure, which had been decayed and weakened. The reinforced concrete framing structure was modelled in the Revit Structure template as displayed in Figure 8.



a) Alternative plan for the structural model   b) Reinforcement details for the alternative structural model

Figure 8. Alternative plan for structural renovation

Based on the site survey work of these six residential units including the investigation of the existing building services systems, the newly proposed building service facilities were modelled in the template of Revit MEP (i.e., mechanical, electrical, and plumbing) template as displayed in Figure 9.



a) The proposed plan for building services systems for a single unit

b) Plan view of the building services in one residential unit

Figure 9. Suggested plan for the improvement of building services system within a single residential unit

The proposed building services included lighting, water supply, air conditioning, and fire sprinklers to be added to the existing residential unit. The fluorescent lamps were suggested due to the higher efficiency and energy saving potential. Apart from the existing water pipeline added in Figure 6 to supply water, fire sprinklers were suggested. The site survey revealed that the old wood building is vulnerable to fire. Fire sprinklers could be designed at working temperature of 57℃. The air conditioning system was proposed to maintain the humidity of the wood building, to prevent decomposing due to the tropical climate in Ningbo, and to improve the indoor comfort of human-beings.

4. Summaries and Discussion

The statistical analysis of the surveyed historic site sample provided the data on the current status of the reservation of historic sites in Qiu'ai Ningbo. Further suggestions would be necessary for the local government to weight between maintaining the cultural heritage and allowing spaces for new construction. It had been found from the survey that ten out of 54 original targeted historic sites had been demolished given space to new construction. Although most residential buildings had still been in use today, there were problems remaining to be solved in the near future. For example, as the data indicated, most buildings had not been repaired and could cause emergency in case of natural disaster. Even for some of the repaired structures, the reinforced concrete materials were not in harmony with the original wood construction in terms of architectural aesthetics.

Apart from the building site survey and data analysis, further study of utilizing BIM as the digital tool was conducted to visualize the current architectural and structural models, as well as the proposed improvement plan to strengthen the existing structure. The BIM work provides the learning opportunities for undergraduate students in the ABE and CE departments of UNNC in digital modelling practices. BIM would display higher potential in larger-sized building design and construction in detecting spatial conflicts. The application of BIM in a smaller building in this case study is the starting point for follow-up studies of digitalization applied in the reservation of historic buildings.

BIM, as the emerging digital tool in today's architectural, construction, and engineering industries, could be more widely adopted in the future research projects of historic buildings. The benefits of BIM application include accurate geometrical representation of building elements and better control of cost, environmental, and lifecycle data (CRC Construction Innovation, 2007). BIM enables the multidisciplinary collaboration starting from the project designs of architectural, structural, and building services. According to AIA California Council (2007), using BIM in the project criteria design stage could allow different options to be evaluated, tested, and decided. In a project using BIM, the model can be used to test "what if" scenarios (AIA California Council, 2007).

5. Conclusion

The historic site survey research project in the suburban area of Ningbo China provided the local government with updates in light of current repair status, cultural and architectural values, current usage, as well as other information such as years of history, construction materials, and floor areas. The data generated from this project would lead to further decisions on reservation, renovation, or demolition of these existing buildings. Strengthening the weakened wood structure and improving the indoor living condition would be two suggestions from this research. Apart from the data summary report as well as the 2D CAD drawings provided as the research project deliverables, this study further adopted visualization tools in BIM starting with a case study from one surveyed residential site. BIM has demonstrated its potential in visualizing the existing architecture, proposing alternative plan for renovation, and advising the improvements of building services systems.

6. Recommendations for future research

Based on the current work, the future research of historic site survey and evaluation could focus on two areas related to the 3D visualized historic building database and renovation targeting on energy efficiency:

- Apart from extending the visualized model from single residential units to cover the whole community, other historic buildings, especially those with high cultural and architectural values could be created with visualized models by adopting BIM. Therefore, the 2D CAD database could be updated with the 3D platform.
- Some of the residents in surveyed residential buildings were suffering from poor daylighting, high indoor humidity, and uncomfortable living condition due to improper ventilation. BIM could be linked to building energy analysis tools to perform renovation study of improving the energy efficiency and indoor living condition of the residents. The study of achieving the architectural renovation, structural strengthening, and energy efficiency while maintaining the cultural features of these historic buildings would motivate cross-disciplinary collaboration by adopting BIM and building analysis tools for the future study.

Acknowledgement

The authors of this study would like to acknowledge the support of City Architectural and Planning Bureau of Ningbo (CAPBN) to the University of Nottingham Ningbo China research team in completing all the site survey work of totally 44 historic buildings and infrastructure projects in Qiu'ai Town, Ningbo, China from December 2014 to May 2015.

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Appendix: Images of Different Categories in the Historic Site Evaluation

Category	**A**	**B**	**C**	**D**
Historical and Cultural Value	**N/A**			
Architectural Value				
Construction Quality				
Status of Damage				

Note: 1: No example of category A in the evaluation of historical and cultural value from the surveyed sites as indicated in Figure 5; 2: The evaluation of each site's values were based on a comprehensive review and discussion among research team members, and one single image in the appendix may not be fully representative of each category.

Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 158–172. ©

IMPROVING WORKABILITY, STRENGTH AND APPEARANCE IN INTERLOCKING BLOCKS USING GRINDED PADDY HUSK ASH

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Abstract
Road paving plays a vital aspect in urban development prospect. "Uni Natural" Interlocking blocks (Size: 220mm x 110mm x 80mm) are becoming very common in many parts of the country. With the initial field studies; it was found that the mix proportions were roughly, 1: 2: 1½: ½ {Cement: River Sand: Chips: Quarry Dust} and the water Cement ratio is around 0.4. These blocks were mainly produced with mechanical vibration. During the casting process; it was observed that, when removing off the casted blocks with the pallet board, some of the blocks break (approximately 10%) which results in a fairly rough surface. To overcome this problem it is proposed to introduce grinded paddy husk ash (GPHA) as a filler material, which is freely available in most parts of the country. In brief, different percentages of grinded paddy husk ash was added to the mixture and blocks were tested after the curing process. In addition, workability, compressive strength was also tested using the available standard tests. The best mix proportion which was obtained will help to introduce a paving block with high strength and pleasing visual properties. Since the paddy husk ash is freely available in many part of the country and the current disposal method is burning; this project will lead to an environment friendly and cost effective paving block manufacturing process.

Key words*: Road* paving*, workability, strength, appearance, best mix proportion*

Introduction

Interlocking blocks were first introduced in Holland in 1950's and became very popular all over the world. As cited in the web, NBM Media Construction Information (2009) it can be used in all countries in various conditions such as Non traffic, light traffic and Medium traffic areas, pedestrian, parking lots, traffic intersections and container yards. As cited in the web, Paver Blocks manufacturers, buyers and sellers (2012) the *Paver blocks* can absorb stress such as small earthquakes, freezes and thaws, and

slight ground erosion by shifting each tile slightly. Unlike the concrete and asphalt pavements; Interlocking concrete block pavement is an environment friendly method since the blocks can be removed and replaced by same existing materials during the pavement repair. Furthermore, since the casting and paving of the blocks being done by the automatic machineries nowadays, this can be a low labour input technology in the view of costing.
An interlocking block pavement consists of individual blocks of hand held size units laid on a thin bed of sand or dust layer, called bedding layer and edges can be restrained on either side by concrete backing. Since Sri Lanka is a developing country; the main aspect of the development is improving the road network and providing convenient mobility. Normally the roads are classified into four categories; which are ‘A’, ‘B’, ‘C’ & ‘D’ classes and Sri Lanka has two major road construction and maintaining institutions which are Road Development Authority entrusted with ‘A’ & ‘B’ class roads while Road Development Department assigned ‘C’ & ‘D’ class roads. The rural roads are maintaining by local authorities such as, Municipal Councils, Urban Councils and Divisional Councils. Nowadays, concrete roads are the most commonly practiced method in the rural areas. But in the aspects of strength properties and cost effectiveness, this method cannot be considered as most suitable for the rural roads which are experiencing low traffic flows. In such a situation; the interlocking block paving can be an effective method to satisfy the adequate requirements of the rural roads. Therefore; the interlocking blocks should have proper strength, physical and mechanical properties, shape, dimension and visual aspects to satisfy the above proposal. Therefore it’s necessary to improve these properties in a suitable level via economically feasible method.

In this platform; there was several research activities had been carried out by researchers all over the world to improve the properties of Interlocking blocks by adding admixtures or by replacing the designed materials. Ghassan Abood Habeeb and Mahmud HB (2010) have presented that grinded paddy husk ash can be replace the 20% of cement content in the concrete mixture and it showed a 10% of strength improvement. Also, in such a way Dixit N. Patel and Jayeshkumar R. Pitroda (2014) have illustrated, that the cement content can be partially replaced by foundry sand, which is the by product of metal-casting industry; can give the improvements in strength. M.C.Nataraja and Lelin Das (2014) have presented, that the improvements in water absorption by replacing the coarse aggregate using the crushed aggregates. G.Navya and J.Venkateswara Rao (2014) have presented, coconut fibre can be used to improve the water absorption and the compressive strength in interlocking blocks.

In the view of above, the GPHA was introduced as a filler material for the normal mix of the precast interlocking paving blocks since the Paddy husk is an agricultural residue, which is freely available all over the world since the rice production is booming day by day. As Dinesh Aggarwal (2013) has illustrated, though the paddy husk is using as a fuel in household and small industries in certain regions; most of the paddy husk is being disposed by burning.

Figure 1, Uni natural shape Precast Interlocking block

Figure 2, Interlocking block casting Machine

In this background, utilizing the paddy husk ash as a filler material in the production of interlocking blocks could be an environment friendly and cost effective method.

Aim and Objective

The main aim of the study was to understand how GPHA affect the properties of the paving blocks. For this purpose, followings were identified as the key objectives of the research,

- To find out how GPHA affects the workability of the paving block mix.
- To find out how the GPHA affects the quality and the strength of the finished paving block.
- To find out how GPHA affects skid resistance of the paving block.
- To find out how GPHA affects the percentage of the water absorption for the paving blocks during adverse climate conditions.
- To find the best mix proportion to introduce a paving block with high strength and pleasing visual properties.

Research Methodology

To achieve the above said objectives following methodology was adopted by adding GPHA in volume percentage (1% - 10%) to the normal mix and the workability was checked using the slump test. Then; after the casting and curing process, the standard testing methods were adopted to check the compressive strength, skid resistance, tensile splitting strength, water absorption and comparison of visual appearance for all sample types of mixtures. In addition to this, a cost comparison analysis was done for all the mixture samples.

3.1 MATERIALS USED

3.1.1 *Grinded Paddy Husk ash***:** Paddy husk ash is a combustion product of rice husk. Initially the rice husk was burnt and grinded by the ball mill and sieved to get fine Paddy husk ash. Paddy husk ash is a highly siliceous material and can be used as an admixture in concrete. The characteristic of the ash depends on the components, temperature and the time of burning. Rice husk contains nearly 20% silica, which presents in hydrated amorphous form. As Gintautas Skripkiunas, Giedrius Girskas, Jurgita Malaiskiene and Evaldas Semelis (2014) have illustrated, during the controlled temperature combustion process (below 800^{o}C), silica converts to crystobalite, which is a crystalline form of silica. Although GPHA would reduce to its average particle size and it can act as a filler material, it was the main factor which will affect the properties of the final mix.

Figure 3, Burning of Rice husk

Figure 4, Ball mill to grind the burnt husk

Figure 5, Grinded Paddy husk ash

3.1.2 *Cement***:** Three types of cement were used.
In Sri Lanka the most popular types are SLS 107 (ordinary Portland cement), SLS 1247 (Pozzolana cement- Blended Hydraulic) and SLS 1253 (Portland Limestone Cement). As cited in the web, The Difference between cement and concrete (2010) has illustrated Hydraulic cement refers to any cement that uses water to begin a chemical reaction that hardens the mixture and creates a water resistant product. This reaction is independent and it hardens even in underwater. Non-hydraulic cements to which do not harden when exposed to water. But this type is cheaper than the hydraulic cement. With this background it’s a good practice to apply these types of cement for the aforesaid mix and carry out the research in the aim of the improvements in the behavior of the interlocking block properties and the effect of mixing

GPHA. The finding can be used to identify the suitability of interlocking blocks, during several adverse climatic and loading conditions.

3.1.2.1 Ordinary Portland Cement (SLS 107) strength class 42.5N

This type of cement has been widely used for many years in general and large construction projects, ready mix preparation and in pre-cast concrete production. It is also being used in mortars and grouts. As W S S Jayamanna, Ranathunga, and Y. P. S Siriwardena (2010) have illustrated Ordinary Portland Cement is being used in the construction industry when there is no exposure to Sulphates in the soil or in ground water.

3.1.2.2 Portland Pozzolana Cement (SLS 1247) strength class 42.5N

As cited in the web, The Island (2004) has illustrated, it is manufactured either by inter grinding Portland cement clinker, pozzolanic material/slag and gypsum or by blending pozzolanic material/slag with Ordinary Portland Cement. Pozzolanic material (volcanic ash) contains natural silica in reactive form. In the presence of water, reactive silica in volcanic ash chemically react with calcium hydroxide released from ordinary Portland cement to form a stable calcium silicate, which posses binding properties like calcium silicate on ordinary Portland cement. Additional calcium silicate formation enhances the strength gain of Portland Pozzolana cement improving its long term durability under aggressive environment and also it is a low heat cement.

3.1.2.3 Portland limestone cement (SLS 1253) Strength class 42.5N.

As E.Ghiasvand, A. A. Ramezanianpour and A. M. Ramezanianpour (2013) have illustrated, Portland limestone cement consists of an intimate and uniform blend of ordinary Portland cement and limestone, and it is produced either by inter grinding Portland cement clinker, or by blending ordinary Portland cement and finely ground limestone. This is a hydraulic cement consisting of two or more inorganic constituents (at least one of which is limestone) which separately or in combination to contribute in the improvement of the properties of cement.

3.1.2.4 Standard chemical composition and physical properties of the selected cement types according to Sri Lankan Standard Institution (2011)

Table 1, Chemical composition and Physical Properties of the cements

	Description	Standard requirement for SLS 107	Standard requirement for SLS 1247	Standard requirement for SLS 1253
1	**Chemical composition**			
	Sulphur Trioxide (SO_3) %	Max : 3.00	Max : 3.50	2.5 to 3.5
	Chloride (Cl) %	Max : 0.10	Max : 0.10	Max: 0.06
	Lime Saturation Factor (LSF) %	0.88-1.02	---	---
	Limestone Content ($CaCO_3$)%	---	---	2 to 20
	Loss on ignition %	Max : 4.00	---	Max: 7.5
2	**Physical Properties**			
	Finess (Blaine) cm^2g	Min : 2250	---	Min: 3300
	Expansion soundness (Le-Chaterlier) mm Autoclave %	 Max: 10.00 Max : 0.80	 Max: 10.00 Max : 0.80	 Max : 10.00 Max : 0.80
	Time of setting (Vicat)Initial (Minutes)	Min : 60.00	Min : 30.00	95 to 150
	Compressive Strength (N/mm^2) 2 Days 28 Days	 Min : 10.00 42.5 to 62.5	 19.00 50.50	 21 to 30 45 to 65

3.1.3 *Sand*: Natural river sand was obtained and uniformly graded. The specific gravity was found to be 2.65.

3.1.4 *Quarry dust*: Quarry dust is the fine particles of rock. The specific gravity was around 1.95. Wet sieving of quarry dust through a 90 micron sieve was found to be 78% and the corresponding bulking value was 34.13%.

3.1.5 *Chips*: Graded chips were used with the nominal size of 10mm and the specific gravity was found to be as 2.73.

3.2 PREPARATION OF MIX AND CASTING

Initially the usual mix was prepared for SLS 107 cement by mixing cement, sand, chips and quarry dust in the ratio of 1:2:11/2:1/2. At the beginning of the process; cement, Sand and GPHA were mixed thoroughly. Then the quarry dust was added since its mixing ability was very low with the mix. Finally the chips were added and the mix was prepared. The allowable water cement ratio of 0.4 was maintained for all the mixes.

This procedure was repeated for SLS 1247 cement & SLS 1253 cement. During the casting process the adequate mechanical vibration was carefully handled by experienced skilled men, Because of the lack of adequate vibration, the blocks may break or start to develop cracks. During the casting, mould was filled by the mix roughly for the first time and the first vibration was applied, then again the mould was filled by the mix up to the top level of the mould then the upper mould was released and vibrated. A fully merged curing was given for the casted blocks in clean water for next 7 days.

For the testing, 3 no. of representative samples were selected from each mix, with the consideration of deviations according to Sri Lankan Standard Institution (2011) and British Standards Institute (2003).

Table 2, Permissible deviations on the work dimensions

Block Thickness (mm)	Length (mm)	Width (mm)	Thickness (mm)
< 100	$\pm$ 2	$\pm$ 2	$\pm$ 3
$\geq$ 100	$\pm$ 3	$\pm$ 3	$\pm$ 4

4 Results and observations

4.1 SLUMP TEST

Slump test was done for each mix using the slump cone. Since the interlocking block mix was considerably dry when compared to the normal concrete mix, the slump value is 0. As cited in the web, Concrete and mortars-all about slump (1997) has illustrated the normal practice 25mm of slump can be allowed for the mix.

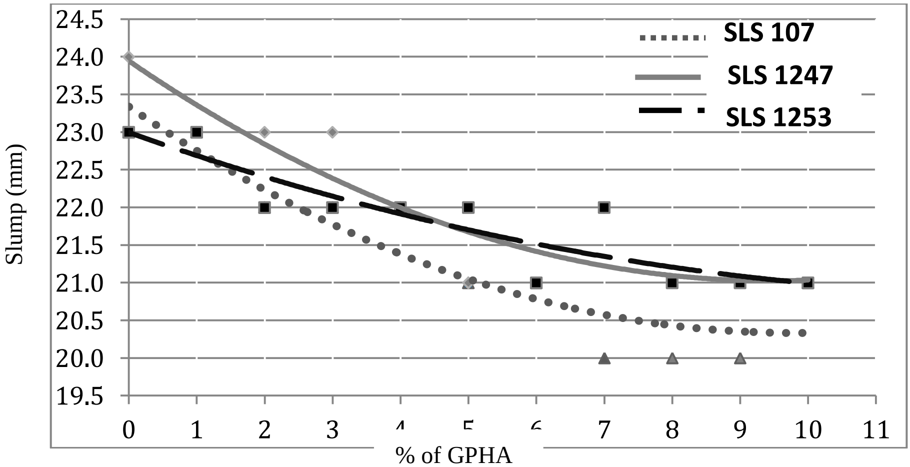

Figure 6, Slump (mm) Vs GPHA (%) graph

As per the results, with the percentage increase of GPHA all the cement types show a gradual fall in the slump value in a uniform manner. This is because; with the increment of GPHA the mix increases the water demand. Compared to the SLS 1247 and SLS 1253 cements, the SLS 107 shows lower values after 1% of GPHA mix. Here, at 0% of GPHA in SLS 1247 mix reaches the maximum value of 24.0mm and the minimum value of 20.0 mm by the 7%-9% of GPHA added SLS 107 cement. However, it can be considered that all the values of the mixes were within the allowable limit of 25mm.

4.2 COMPRESSIVE STRENGTH.

3 no. of random samples were selected from each mix and the compression test was conducted. The load was applied at a constant rate of 15± 3 N/mm^2/ minute until the block breaks. As per the Sri Lankan Standard Institution (2011) the minimum strength requirements and block thickness were defined as follows.

Table 3, Minimum strength requirements and blocks thickness

Strength Class	Average compressive strength (N/mm^2)	Individual compressive strength (N/mm^2)	Block thickness (mm)
1 (Vehicular)	50	40	80, 100
2 (Vehicular)	40	32	80, 100
3 (Vehicular)	30	25	80, 100
4 (Pedestrian)	15	12	60

According to Sri Lankan Standard Institution (2011) and British Standards Institute (2003) the compressive strength was corrected by the correction factors as follows.

Table 4: Thickness and chamfer correction factors for compressive strength

Work size thickness (mm)	Correction Factors	
	Plain Block	Chamfered Block
60	1.00	1.06
80	1.12	**1.18**
100	1.18	1.24
Blocks with chamfer of work size greater than 5 mm width.		

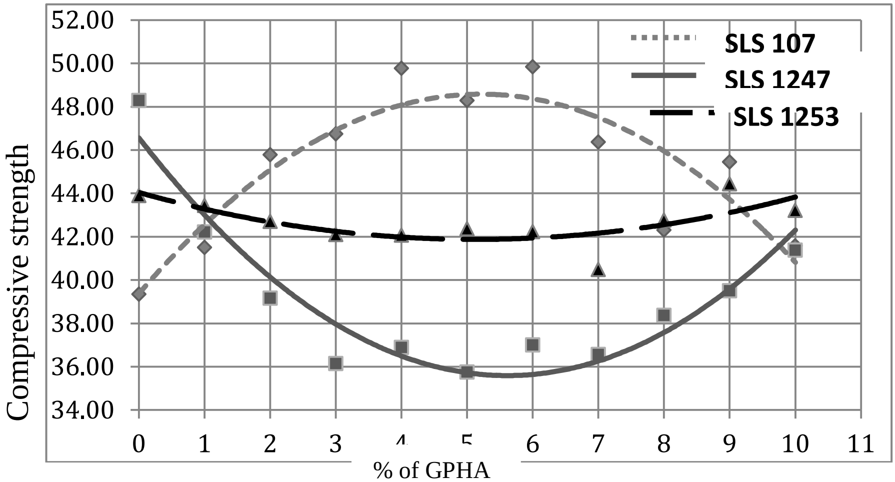

Figure 7, Compressive strength (N/mm^2) Vs GPHA (%) graph

As per the compression test results, the compressive strength of the blocks were considerably influenced by the percentage of GPHA added to each mixture. The SLS 107 cement mixture shows a good improvement in strength with the increment of GPHA and the SLS 1247 cement mixture and SLS 1253 cement mixture shows the drop. Furthermore, at the 6% GPHA SLS(107) mix shows a peak value of 49.84N/mm^2 than SLS 1247 cement and SLS 1253 cement, and all the mixes were achieved strength beyond the standard value. In SLS 1247 cement mix, it shows a peak value of 48.82 N/mm^2 in 0% GPHA and reaches a lowest value of 35.75 N/mm^2 and it shows a negative variation from 0% GPHA to 5% GPHA. In SLS 1253 cement mix; it reaches a peak value of 44.44 N/mm^2 at 9% of GPHA and it doesn't show a vast variation in the strength by adding the GPHA. Though the SLS 1247 & SLS 1253 mixes shows the drop in strength with the percentage increment of GPHA is some regions, none of the mixtures reach the lower value of 30N/mm^2 which shows the efficient improvement in adding GPHA to all the mixes.

4.3 SKID RESISTANCE.

The pendulum friction tester was used to test the skid resistance of the blocks. According to Sri Lankan Standard Institution (2011) and British Standards Institute (2003) the allowable skid resistance for interlocking blocks is $\geq$ 45.

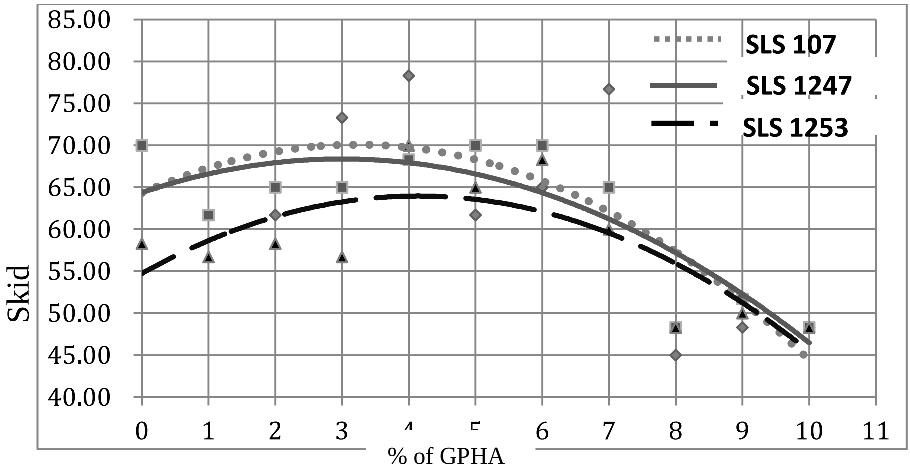

Figure 8, Skid Resistance Vs GPHA (%) graph.

As per the skid resistance test results, it shows a rise up to 4% of GPHA of all mixtures and then the values fall gradually. Further, none of the mixtures has fallen below the standard minimum value of 45. It shows though the surface smoothness was improved by adding the GPHA to the mixtures, the skid resistance values were not changed drastically. Compared to the SLS 107 and SLS 1247 cements, the SLS 1253 cement shows lower values always. At 4% of GPHA in SLS 107 mix reaches the maximum value of 78.3 and the minimum value of 45.0 was reached by the 8% of GPHA added SLS 107 cement. All the values were within the allowable limit.

4.4 TENSILE SPLITTING STRENGTH.

Splitting tensile strength was calculated according to British Standards Institute (2003). Normally tensile splitting value can be compared with the compressive strength values for the strength comparison.

The results show the positive incremental variation in the SLS 107 cement mix and it reaches a peak value of 2.47 at 10% of GPHA mix. In the SLS 1247 cement mix, it shows an increment up to 6% of GPHA and the SLS 1253 cement shows the reduction in the values within that range. Compared to the SLS 107 and SLS 1247 cements, the SLS 1253 shows a negative variation. Here at 6% of GPHA in SLS 1247 mix reaches the maximum value of 2.53 N/mm^2 and the minimum value of 1.82 N/mm^2 was reached by the 4% of GPHA added to the SLS 1253 cement.

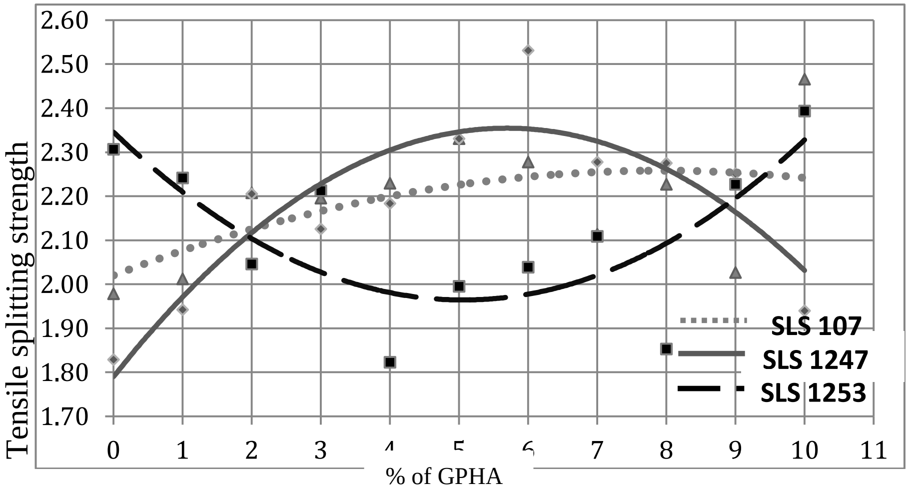

Figure 9, Tensile splitting strength (N/mm^2) Vs GPHA (%) graph

4.5 WATER ABSORPTION.

Water absorption is a measure of voids in hardened blocks which is occupied by water in saturation condition. The test was done according to Sri Lankan Standard Institution (2011) and the standard maximum allowable water absorption for the Interlocking block is $\leq$ 6%.

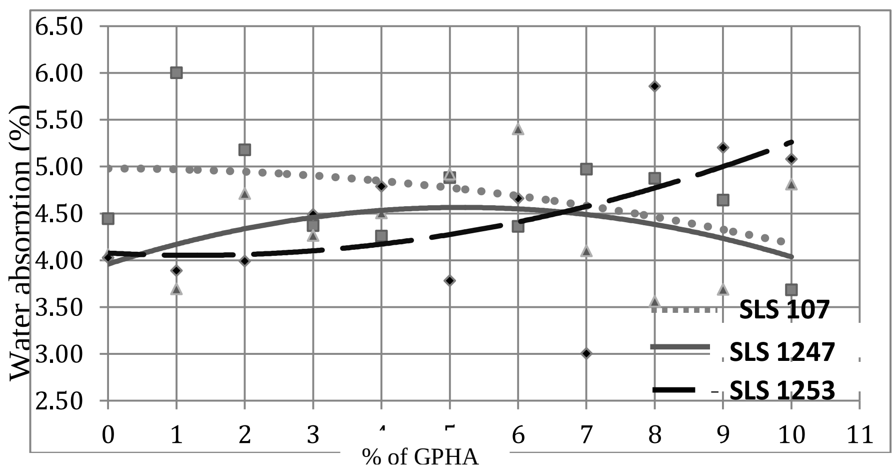

Figure 10, Water absorption (%) Vs GPHA (%) graph.

The results indicate that the water absorption values decreases with increase in the % of GPHA added for SLS 107 cement type and SLS 1247 cement type while SLS 1253 cement shows an increase in the values. At 1% of GPHA in SLS 107 mix reaches the maximum value then it drops gradually.

The minimum value of 3% was reached by the 6% GPHA added to the SLS 1253 cement. It is noticeable that, all the values were within the allowable limit.

4.6 VISUAL INSPECTION

Visual inspection was done in the natural daylight according to the British Standards Institute (2003) Annex H Method for verifying visual properties. Under this method the blocks were laid on the leveled floor in a square shape and observed from a distance of 2m for cracks and flaking. Also pleasing appearance was checked by the comparison of each block in a mixture. For easy inspection; the mixtures were named as from A0 to A10 according to the percentage of GPHA for SLS 107 Cement; accordingly, SLS 1247 cement and SLS 1253 Cement mixture samples were named as B and C.

Table 5, Visual inspection summary.

	Rough	Fairly Rough	Fairly Smooth	Very Smooth
SLS 107 (A)	A0, A1	A2,A3	A4, A5, A6	A7, A8, A9, A10
SLS 1247 (B)	B0	B1, B2, B3	B4, B5, B6, B7	B8, B9, B10
SLS 1253 (C)	C0, C1	C2, C3, C4	C5, C6, C7	C8, C9, C10

During the inspection it was noticed that beyond the 7% of the GPHA, all the mixtures give a smooth and pleasing appearance for all types of cements and there are no cracks or distresses were observed in the samples.

5.0 Cost analysis

Cost analysis for 1 Block of SLS 107 cement mix with 1% of GPHA

Cost for Paddy Husk (1%)
(Loading, Unloading & Transport 20km) = Rs. 8.00
Cost for Cement (1 Bag- 50kg) = Rs. 870.00
Cost for other Materials
(River sand, Quarry dust and Chips) = Rs. 545.42
Cost for material transport (Allow 20 km) = Rs. 250.00
Cost for Labour (4 Nos) = Rs. 600.00
Cost for Electricity (Allow) = Rs. 10.00
Cost for 1 Bag of Cement (70 No of Blocks) = Rs. 2,283.42

Cost for 1 No of Interlocking Block (1% GPHA) = Rs. 32.62
Cost for 1 No of Interlocking Block (0% GPHA) = Rs. 32.51

As per the above analysis the cost of the paddy husk for 1 Block is Rs. 0.11, and that is a 0.35% of the total production cost of 1 Block. Such a way, the production cost of 1 Block in 10% of GPHA mix will be Rs.33.65. So that the increment in the production cost is Rs.1.03 from 0% of GPHA to 10% of GPHA and it's nearly 3% compare to the production cost of 1 Block in the normal mixing proportion.

6.0 Conclusion

This research was involved in the improvement of strength and appearance in the interlocking blocks using GPHA. Overall results show a considerable improvement in the quality of the blocks by adding GPHA for all the cement types. SLS 107 cement showed a positive improvement in the strength between 0% to 5% of GPHA mix range and it has nearly a 30% of strength improvement compared to the normal mix. It also showed a fair visual appearance in that range. As the results of skid resistant values, though the values show a peak in 4% to 6% of GPHA, the values fall as expected since the voids were filled by GPHA. It is notable that none of the mixtures reached the minimum allowable limit. The tensile splitting strength can be compared with the compressive strength. SLS 107 cement and SLS 1247 cement showed the similar patterns and SLS 1247 showed a 30% of strength improvement while SLS 107 showed 12%. The water absorption variation was expected as the GPHA fill the voids. In the aspect of water absorption reduction SLS 107 and SLS 1247 showed around 20% of drop while SLS 1253 cement did not shows any. The visual property was improved in all the mixtures especially beyond 7% of GPHA as expected, because of the filling ability of the GPHA and blocks showed a considerable pleasing appearance. Since the price of the cement bags were nearly the same for all three types in Sri Lanka, adding GPHA does not affect the cost vastly. So that, it is the cheapest method to improve the strength in Interlocking Blocks. Further, this project could be an environment friendly approach for utilizing available waste materials (Paddy husk ash) in an effective way.

In conclusion, SLS 107 cement reacts more relatively to the GPHA in all the properties of the blocks. According to that, adding GPHA is an effective method to improve the strength properties of the interlocking blocks in an environment friendly approach. Though the SLS 1247 cement and SLS 1253 cement types did not reach all the objectives of the research, they showed good improvements in most of the properties and it will lead us to utilize the blocks in other appropriate places according to the various requirements.

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ANALYSING CITY AGGLOMERATION IN TERMS OF LOCAL ECONOMIC DEVELOPMENT HIERARCHY WITH THE USE OF SPACE SYNTAX

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Abstract
Pattern of urban growth is dictated by a complex interaction of place-specific factors in individual cities including geography, history, lifestyle, economies and administration. City's natural growth gradually defines its main economic centers and sub-centers according to spatial organization of its urban structure. In some cases of induced development planning, agglomeration of small towns forms a bigger city boundary for administrative operation. Narayanganj City Corporation of Bangladesh is similar to this case, which was formed by joining three municipalities in 2011. As commercial activities takes place in the most integrated part of a city, administrative agglomeration of small towns largely depends on their economic development cluster. Lack of proper agglomeration of economies among small towns may cause unplanned economic growth. Hence identifying local sub-centers can guide commercial development working as a whole. The spatial parameters of a city can evaluate functionality of economic activities within an urban structure, in accordance with hierarchical arrangement of local commercial centers. While analyzing city configuration with Space Syntax theory, movement & commercial growth within a given boundary can be predicted. This paper tries to analyze agglomeration of economic activities among three municipalities of Narayanganj working as a whole, with potential sub-centers as hierarchical city structure.

Keywords. *Agglomeration economies; hierarchical urban structure; spatial proximity; accessibility; spatial structure; space syntax theory; Narayanganj city corporation*

1. Introduction

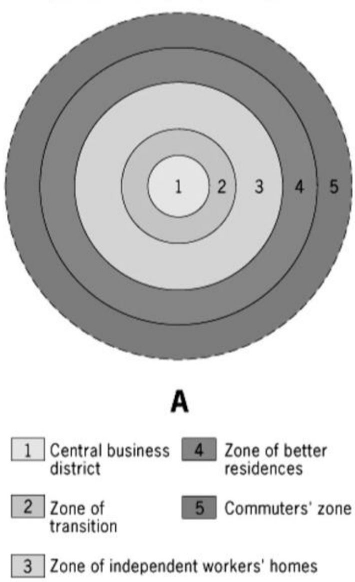
Narayanganj City Corporation has joined three municipalities naming: Shiddhiganj, Kadam-rasul and Narayanganj sadar with a total of 72.43 square kilometre including Shitalakhya River. The Narayanganj Sadar has been core centre of growth since its origin in Mughal period in this region where rail, road and waterway communications with capital city Dhaka has given great importance in its growth as a town centre. In new city boundary, various development aspects are taken into account by govt. authority such as bridge proposals over Shitalakhya River for east-west city connection, khal (water links) development projects etc. which will lead to commercial boom in this region. Proper communication, connectivity & proximity among sub-centres depict agglomeration potentials to each other. Fast commercial growth is prone to unplanned economic agglomeration without considering inherent accessibility in city grid boundary. As city configuration defines major spatial character of a space in terms of connectivity & accessibility which accentuates commercial growth, this paper tries to presume potential sub-centres as local economic hub, proximate in distance, contributing holistic economic growth within three agglomerated municipalities of City Corporation boundary.

2. Agglomeration economy & concept of 'Sub-centre'- Theoretical perspective

City centre is formed where people are concentrated conveniently for functional specialties supported by the centre (Jacobs 1970). Centres can be considered as self-organizing system sustained by socio-economic process, which are affected by spatial accessibility within city network (Narvaez, Penn & Griffiths 2014). Polycentric urban growth consequently developed over time in many cities of UK, USA, Australia, Poland & others (Haughton & Hunter 2004; Narvaez, Penn & Griffiths 2014; Saeid 2010). In decentralized city concept, a number of territorial units known as 'Sub-centres' emerges when high land value, congestion and increased transportation cost disperse population and employment density from single centre to peripheral concentrations (Davoudi 2002; Donoghue 2014). 'Concentric zone model' of Burgess (1925), which depicts city as self-organizing network possessing a single centre, breaks down into "differences of spaces that allows different centres to be identified, firstly as specialised areas and later as self-organizing local economies" (Shane 2005). The local sub-centres not only attract people for special functions like shopping or work, but also as a meeting place with interaction flows (Donoghue 2014). If sub-centres maintain economic centrality or agglomeration with the city centre, according to Salazar & Sobrino (2010) the central city take a polycentric hierarchical structure not with scattered sub-centres but rather a widened CBD. Here comes question for potential agglomeration.

Agglomeration in economies between sub-centres can be understood as a mechanism of sharing, matching and learning (Duranton & Puga 2004) where scope of common local linkages to get supply resources, population, local labour market, transport facilities and information flow is seen at ease. Spatial accessibility in terms of quantifiable distance of a space to another can modulate population movement, thus contribute to choice of functional use to that space (Narvaez, Penn & Griffiths 2014). Combining Alonso's trade-off model (1964) & Hillier's configuration theory (1999), Narvez, Penn & Griffiths found that trading between cost and access is a local process.

1a)



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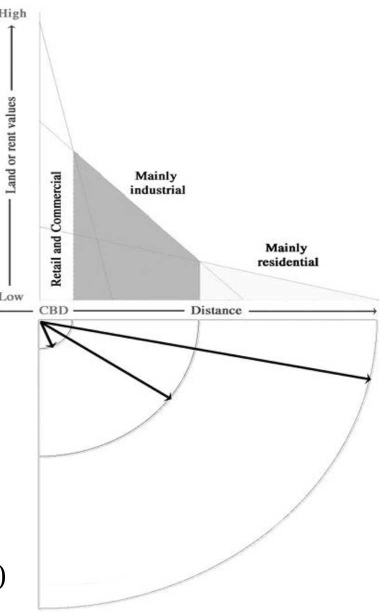
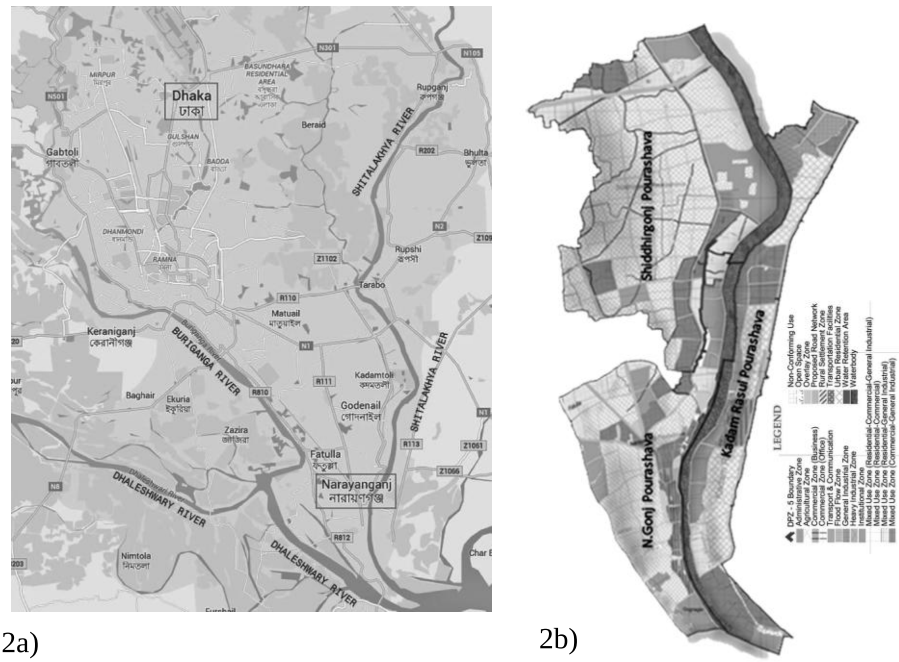


Figure 1a, Concentric Zone Model by Burgess; Figure 1b, Trade-off model by Alonso (Narvaez, Penn & Griffiths 2014)

In economic perspective, bottom-up flow of information & resources facilitates social cooperation and coordination in markets (Narvaez, Penn & Griffiths 2015). Proximity in distance among multiple local centres helps to agglomerate economic activities globally, which may form potential cluster of regional administrative boundary (Saeid 2010). Thinking reverse, within administrative boundary, efficient economy functioning depends on proximate local centres having inherent accessibility in an urban system. Proximate distance among local centres depicts global & local movement easiness in a city configuration. The ‘400 meter rule’ has been supported by extensive research in urban studies which assumes, a ‘5 minute walk’ equals roughly 400 meters distance, to basic services and local transit facilities within a neighbourhood (Mehaffy, et al. 2010).

3. Case Study- Narayanganj City

Narayanganj district is just beside south-east corner of capital city Dhaka. Geographic position of Narayanaganj and the Dhaleshwary River bent made the Shitalakhya River more feasible water rout to enter Dhaka from south.



2a) 2b)

Figure 2a, Location of Narayanganj from Dhaka (Google map 2015); Figure 2b, Narayanganj City Corporation Map showing 3 municipalities (Narayanganj City Corporation 2012)

In Mughal period, road connection to Dhaka was established and Sonakanda & Hajiganj forts were built in southern part near port to protest Magh pirates enter Dhaka through Shitalakhya River (Allen 1912). Kadam rasul dargah- a religious centre was built in eastern bank of Shitalakhya River by Mughals around which human settlements evolved. Import-exporting variety of goods like, raw foods, timber, cotton, ivory, gold, silver, wrought iron & other finished product in Narayanganj port established the region as an important commercial hub for retail market and warehouse shops. Railway connection from Narayanganj to Dhaka, established during British reign forming strong global connection. The developments took place in Narayaganj Sadar municipality, forming city's main artery- Bangabandhu (B.B) Road parallel to river. In Pakistan period, Narayaganj emerged as industrial city while Adamjee Jute Mill was established in Shiddhiganj municipality at north of Sadar. Afterwards cotton mills, garments industries became prominent at the fringe of Narayaganj Sadar municipality.

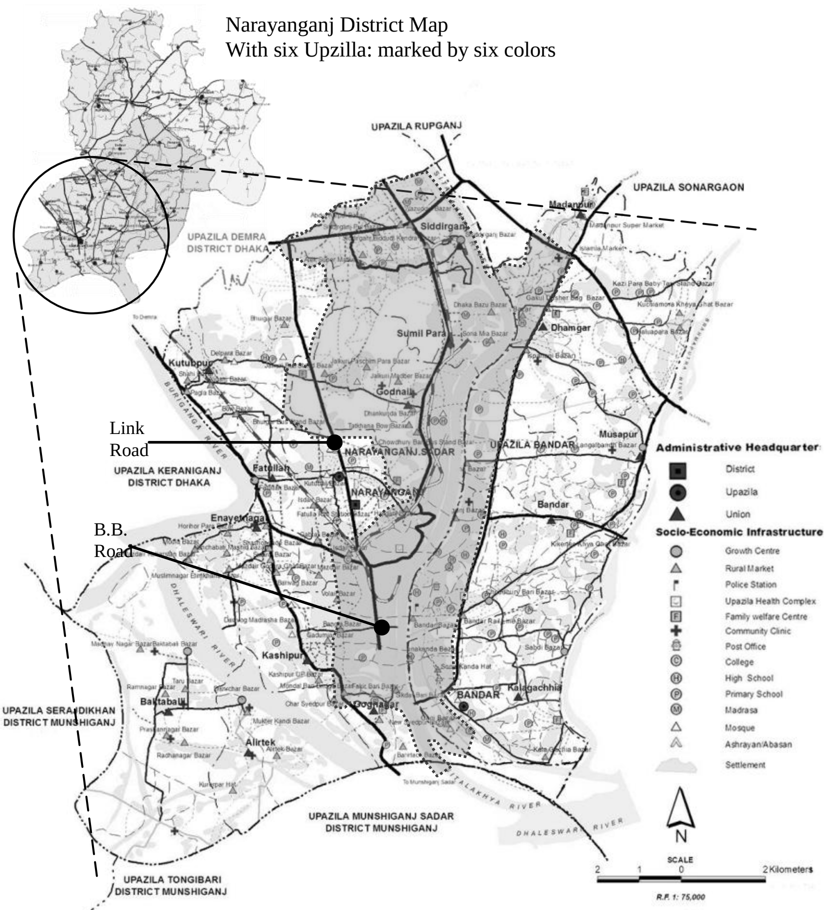


Figure 3, Narayanganj Sadar & Bandar Upazilla together high-lightened with city corporation boundary- showing Global street network and local retail markets. (LGED 2015)

In 1984 Narayanganj was upgraded to district with 6 Upazillas naming: Sadar, Bandar, Sonargaon, Araihazar & Rupganj. The Sadar and Shiddhirganj municipality belongs to Sadar Upzilla and Kadam-Rasul municipality belongs to Bandar Upazilla, which have made up Narayaganj City Corporation later (figure 3). In 2000, Dhaka-Narayanganj link road was established contributing more population movement to the town centre, making B.B. road as prominent global core in this region (figure 3). After upgrading the town to City Corporation in 2011, two bridges are proposed which will connect west to east over Shitalakhya River with Sadar & Kadam-rasul municipality on the southern part of city (Narayanganj City Corporation 2015).

4. Methodology-Space Syntax

Space syntax theory has two key propositions: the first is configuration of space is a primary determinant of probable pedestrian and vehicle movement behaviour within urban system, which is known as 'Theory of Natural movement' (Hillier et al., 1993). The second is about economic distribution which is generated as a consequence of their dependency on population movement in urban grid (Hillier 1996).

Space syntax analysis is taken as methods for measuring parameters of segment's choice and segment's metric distance to identify potential accessible local economic centres in terms of connectivity of city grid configuration within city boundary. Other broader issues in this regard i.e. land value, land use transformation, retail geography, historical or ecological effect need further research to modify the approach. This paper tries to presume hierarchical arrangement of local economic concentration which portray city's economic agglomeration in accessibility issue.

4.1. VARIABLE OF CHOICE FOR LOCAL ECONOMIC CENTRE-SEGMENT ANGULAR ANALYSIS

In segment angular analysis of road configuration, each road is considered as segment lines that create city map, where 'Segment Angular Choice' measures how many least angular paths lay between every pair of segments within a given distance (UCL Space Syntax 2015). The urban structure is considered as a system of streets, individual spaces that are visible from one end to the other without obstruction (Narvaez, Penn & Griffiths 2012). Those individual axial spaces (Penn 2001) are straight lines that represent a possible path of movement over a map of an urban settlement. The "angular segment analysis algorithm produces better correlation with observed vehicular flow than both standard axial analysis and block-distance measure" (Turner, 2007).

In socio-economic process, urban form can be understood by 'background' and 'foreground' network of urban configuration (Hillier et al., 2007). Pattern of local economic distribution can be seen by 'foreground network properties' of a city's street configuration. The street configuration is represented as a choice measure, which shows how the main arteries relate to the interconnected accessibility within the urban system. It establishes that in the highest accessible spaces, commercial and retail activities cluster more than in other areas (Hillier 1999; Narvaez, Penn & Griffiths 2012).

This foreground study of street map with segment angular analysis was executed in case of Narayanganj City Corporation to find potential areas for local economic sub-centres within the system.

4.2. VARIABLE OF METRIC DISTANCE FOR HIERARCHICAL PATTERN OF SUBCENTRES- STEP DEPTH ANALYSIS

Step depth is calculated to measure the physical distance of sub-centre potential roads from the city street origin which has highest movement concentration, namely the new core in agglomerated boundary. According to Narvaez, Penn & Griffiths (2014) distances are not only a measurement but also relatedness to urban architecture, resulting in a relation of space & economy that, economy requires proximity and proximity requires opportunity for economic activity. Metric distance captures the local patchwork properties of the network mostly with spatial differentiation (Hillier et al. 2007). In this paper, metric distances from city centre are compared among sub-centres to visualize a hierarchical accumulation in terms of movement within city corporation boundary.

5. Analysis & Discussion

5.1. PRESUME SUBCENTRE LOCATIONS

Analysing Narayaganj City Corporation street configuration into segment map, angular choice values for R=400, 500, 800, 1000, 2000 & 5000 was taken into account. From foreground & background pattern, micro-economic qualities of each municipality were clearly distinguished in the form of sub centre at a radius of 500 meters, demarked as A, B, C etc. (figure 4a). It depicts, local non-motorized transport means are more active which develop local economy in this city boundary at small radius choice.

In case of global links among the centres, it is found while R=5000 meter, the sub-centres tend to connect together regionally (figure 4b). This depicts, although single sub-centres are formed by supporting local movement, their connectivity with each other is at far. The core line of some sub-centres diminishes in global value (< top 10% of total value) starting from radius 2000m. It means urban structure of these sub-centres is clustered as ‘distant agglomeration’, functioning singular but not as a whole. Whereas in organic growth, integrated routes are originated from the core of sub-centres that connect with other sub-centres globally in whole urban structure

(Narvaez, Penn & Griffiths 2014). Hence in this case of induced town agglomeration, economic agglomeration has to develop more in terms of accessibility. It is seen that, administrative boundary agglomeration forms new urban structure that emerges new local commercial centres where global transportation and connectivity development among them may pull more budgetary concentration in planning issue.

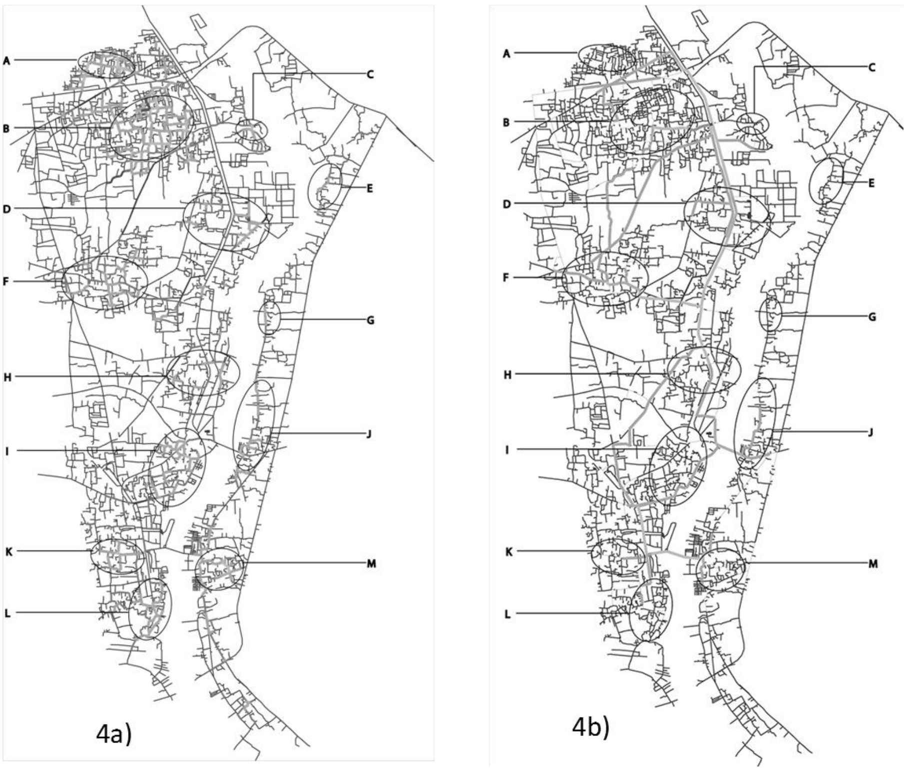


Figure 4a, segment angular choice map at R=500 m, identifying local centres within city corporation boundary; Figure 4b, segment angular choice map at R=5000 global connection of sub-centres

From the table 1, 2 & 3 below, it is seen that the sub-centres of Kadamrasul municipality are globally less connected than others. Sub-centres of Sadar municipality show fewer global integration within city boundary whereas this region used to be the main town centre in former period. This analysis indicates to new city core formation within City Corporation boundary. The sub-centres of Shiddhirganj have better choice range and integration (within top 10% value of city structure) which means new core will be more connected to this municipality.

Table 1: Sub-centre potentials in Shiddhiganj Municipality

Sub centre	Ref. no of main road	Segment Angular choice value				Segment Angular Integration value			
		R (400)	R (500)	R (1000)	R (5000)	R (400)	R (500)	R (1000)	R (5000)
		Top 10% range of Choice				***Top 10% range of Integration***			
		1273-6898	***2305-12246***	***14663-88422***	***620441-9446302***	***58.93-204.8***	***70.14-173.62***	***132.98-290.15***	***696.19-1078.74***
A	*16453*	2711	6233	65634	1332510	98.51	125.34	266.54	722.46
B	*11347*	2783	7154	71849	815150	87.60	114.63	165.16	613.35
C	*2275*	3320	6838	28913	623141	56.54	67.82	77.07	477.30
D	*16784*	5673	11723	39442	522751	66.54	68.57	131.18	734.63
F	*9446*	1324	3453	47444	1229630	51.52	68.06	137.21	535.56

Table 2: Sub-centre potentials in Kadam-Rasul Municipality

Sub centre	Ref. no of main road	Segment Angular choice value				Segment Angular Integration value			
		R (400)	R (500)	R (1000)	R (5000)	R (400)	R (500)	R (1000)	R (5000)
		Top 10% range of Choice				***Top 10% range of Integration***			
		1273-6898	***2305-12246***	***14663-88422***	***620441-9446302***	***58.93-204.8***	***70.14-173.62***	***132.98-290.15***	***696.19-1078.74***
E	*8489*	2441	3505	13843	70497	35.31	36.39	51.20	180
G	*15516*	1313	3047	13250	355105	75.18	77.60	82.08	239.56
J	*15848*	2462	4365	25755	3111750	64.57	70.94	94.94	563.42
M	*15932*	3305	6840	37840	1309750	70.86	82.15	97.41	511.29

Increasing movement by ‘area development’ in sub-centres may increase global connectivity among them. Further development of east-west connection at the north part of city may increase connectivity to Kadam-rasul municipality with Shiddhirganj municipality. Budgetary concentration in these planning aspects may have potential scope to focus on global accumulation of sub-centre economy in future.

Table 3: Sub-centre potentials in Narayanganj Sadar Municipality

Sub centre	Ref. no of main road	Segment Angular choice value				Segment Angular Integration value			
		R (400)	R (500)	R (1000)	R (5000)	R (400)	R (500)	R (1000)	R (5000)
		Top 10% range of Choice				***Top 10% range of Integration***			
		1273-6898	***2305-12246***	***14663-88422***	***620441-9446302***	***58.93-204.8***	***70.14-173.62***	***132.98-290.15***	***696.19-1078.74***
H	*15600*	1575	3357	30886	1213560	80.42	94.47	173.72	738.07
I	*8742*	3096	6130	35114	237301	60.20	67.20	92.16	566.82
K	*13913*	3252	6181	34185	1529820	74.54	85.50	147.40	661
L	*10580*	2609	5037	33248	114493	44.85	63.96	112.90	493.05

5.2. HIERARCHICAL DISTANCE FROM NEW CITY CORE

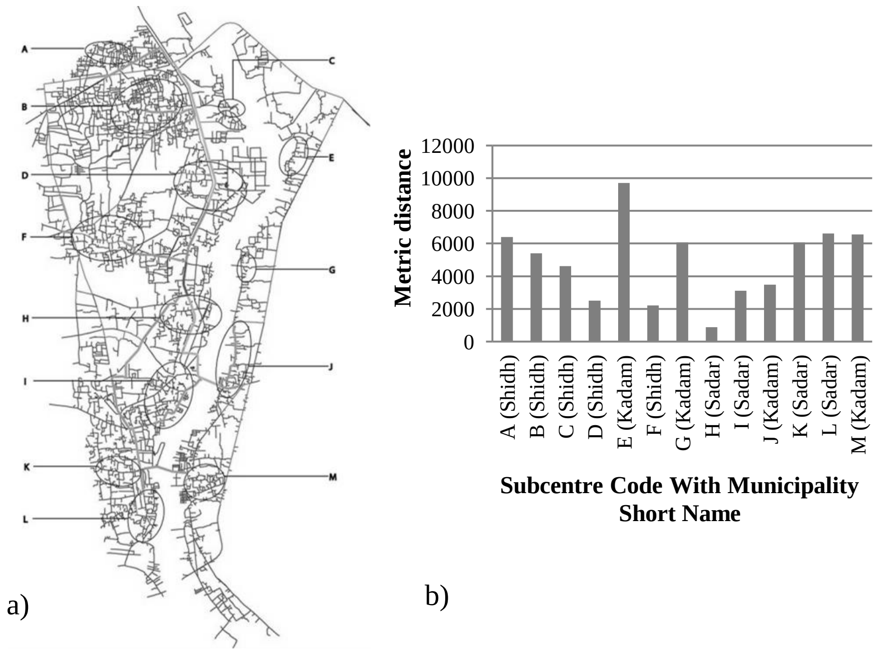


Figure 5a: Segment angular choice map at R=n, showing choice core with red line; Figure 5b: Comparative step depth distance (metric) from probable city core to sub-centres.

The probable new city core is assumed where highest value of both choice and integration core are available, theoretically this core will attract more movement and potential for central commercial growth. Hence, proximate distance from city core to sub-centres shows a hierarchical pattern for agglomeration economies in terms of accessibility.

The sub-centres which are at close proximate, located at <4000 meters to the core may agglomerate economic activities by means of local non-motorized transport system, but to agglomerate sub-centres located at >4000 meters, motorized transportation or connectivity development may be needed, which can be monitored by considering further in-depth place-specific analysis of each sub-centres.

6. Conclusion

The process of finding sub-centre locations by analysing movement within city grid configuration will help to reduce trial & error development works and utilise resources. Further research may contribute to analyse bid-rent hierarchy for detail land use pattern for each sub-centres under three municipalities to monitor overall development in newly formed Narayanganj City Corporation. Scope for using waterways as a connector within city boundary may also seek concentration for improving economic agglomeration.

As commercial strength of a city is its driving power to move on, hence other development planning should revolve around giving prime importance to it. Ease of accessibility develops communication as well as contributes to accumulate local economic forces, thereby inherent overall development. To monitor induced development, foremost scope for concentration should be local economic sector to wheel up overall growth under proper management authority, thus supervise other planning aspect in city growth.

Acknowledgement

Narayanganj City Corporation maps and data were collected from RAJUK and UPPR Project of LGED. This Paper is a research conducted as a part of credit fulfilment for M.Arch course of Urban Morphology (course code: Arch-6403) in Bangladesh University of Engineering and Technology (BUET).

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MUD-CONCRETE BLOCK CONSTRUCTION
Community centres for war victim communities in Batticaloa, Sri Lanka

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Abstract

Rejuvenating social interaction within community is an essential factor to survive together for a long time success. Designing buildings for war victim communities is challenging, thus it should be planned with great care, involving the people in the community to the design process, addressing their issues in poverty and fundamental needs through utilizing readily available materials and using locally available cost effective resources. As a new sustainable material, Mud-Concrete block (MCB) technology was introduced to build community centres for selected war victim communities in Batticaloa through ‘UN Re-settling programme’. Thus, different walling materials were introduced to build the community centers in identified areas in Batticaloa. Among those constructions, Mud concrete block (MCB) technology was identified as a highly viable solution which could use locally available soil in construction sites. This paper explores the up-to-date research process of introducing a new sustainable material to restore a war victim community within their context through community architecture.

Key words – *War victim community, Community Architecture, Sustainable material, Mud-concrete blocks (MCB)*

1. Rejuvenating social interaction through Community Architecture

Sri Lanka as a developing country which has been suffering for 26 years civil war, many communities were displaced and scattered in North and North eastern provinces. The war situation in Sri Lanka more or less destroyed thousands of lives and infrastructure of the North and East. As reported by Jayaraj (1999), Batticaloa District is in the Eastern Province (population 330,000) where 30,000 government armed personnel controlled most thoroughfares and towns while an estimated 1,500 militants operated in 'uncontrolled areas' and villages. Local population consists of Tamil (60%--largely Hindu, with minority Christian sub-populations) and Tamil–speaking ethnic Muslim (40%). As stated by Chase and Bush (2000), Batticaloa district remained in a militarized stalemate between government army and police forces, with checkpoints, security operations and underlying communal ethnic tensions, armed gangs, and severe economic contraction for a long period as well as known for high suicide rates and child recruitment to militant groups.

All these factors had shown deterioration in relation within communities and isolation of individuals. In such situation, thus the challenge is to maintain a responsive relationship with the local communities promoting dialogue about ongoing local communal tensions and offering an approach to compromise to resettle their destroyed livelihood and scattered communities. There are diverse approaches to studying resettling and empower the war victim communities of Sri Lanka relating to resources, interventions, and practice. Many studies provide appropriate intervention designs and methodology but few actually apply these interventions and evaluations in post conflict nations.

In order to empower the victim communities, rejuvenating social interaction within community is an essential factor to survive together for a long time success. Social interactions or the response of individuals to each other is a basic sociological concept, because such interaction is the elementary component of all relationships and groups that make up human community. In any community the physical environment around it, affects the human psychology for their social interaction with others. That physical environment can either enhance the interaction or discourage them. According to Rapoport(1969), "The interplay of social forces, relevance with cultural, economic, political and physical forces involving climate, location and technology will give rise to an inherent quality of the community and to the nature of the settlement."

Ray Oldenburg an American Sociologist (1989) calls these social interaction spaces as the "third places". The first being the home and the second being the work places. These third places are crucial to a community. By community living and interacting with each other allows people to discover and to gain experience by learning from others while enhancing the supporting and sharing nature of people. According to Chansomsak and Vale (n.d.) collaborative work involving all community elements and continual development are obviously keys to creating a sustainable community. The more people work together for sustainability, the more they can develop their activities and processes. Involvement in community activities also encouraged a sense of belonging and sharing and acknowledges the concept and the way to achieve sustainability under the particular conditions of the community. Also this leads individuals and institutions to strengthen belief in their ability to develop their community and be willing to take care of it. Thus the Architecture as a social art and a problem solving method, (Ching, 1979) rejuvenation of social interaction could be achieved through 'community Architecture'.

According to Wates (2000), 'Community Architecture' can be simply defined as, "architecture carried out with the active participation of the end-users". This alternative approach to the conventional architectural practice of non-participation of users can be copied back to the 1950s self-help community initiatives in the developing countries. In these self-help projects, the professionals joined hands with the people to improve their environment. As reported by Wates and Knevitt (2013), Community Architecture since then has developed in different forms around the world with a common vision, that is, public participation in decisions affecting their environments and hence their lives.

As Towers (1995) reported, 'Community Architecture' has provided alternative design and development approaches in the form of the following three priorities.

1. Save what already exists within a neighbourhood, based on the community's wishes. There should be a minimum destruction of community networks.
2. Community members be included in the design process
3. The end-users are most familiar with their needs and requirements, which is also directly related to the success of a project.

Based on these observations, Community Architecture lastly admits the participation of the community members in the decision-making and supervision of the community-based projects.

In order to rejuvenate social interaction within the immediate community, UN habitat has proposed to build prototype model of community centres in identified areas. The goal of a new community centres set in create a unique place that will unite people in a neighbourhood by providing a setting that will bring the community together, once again. The principle element that these war victim communities lack is a cultural or social bond. By providing a place where members of the community can gather together, celebrate and share their different cultures will ultimately create a new cultural and social bond within the neighbourhood and the greater community. Also by providing a place for everyday activities to take place within the community, rather than remote from its core, will allow for more social interaction. Several key objectives were considered at the beginning of design process of self-help community centre projects as follows;

- Identifying the exact Social & functional needs within the community.
- Necessity of introducing sustainable materials to reconstruct the built environment.
- Introduce strategies to use locally available materials.
- Introducing easy production process of materials.
- Challenge of building skilled labour force to possess the relevant skills in order to take advantage of the opportunities arising from improved infrastructure and other capital investment.
- Developing 'soft skills' and management and technical capabilities.
- Introducing low cost construction with highly viable solutions while keeping unique appearance.
- Possible techniques to consume less energy while maintain less impact to the environment.
- Making built environment more responsive to user community as well as nature.
- To achieve above objectives in building design process Mud-Concrete technology was introduced as a sustainable material to constructions.

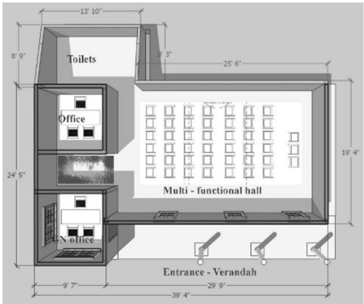


Figure 2: Plan of Community center at Batticaloa

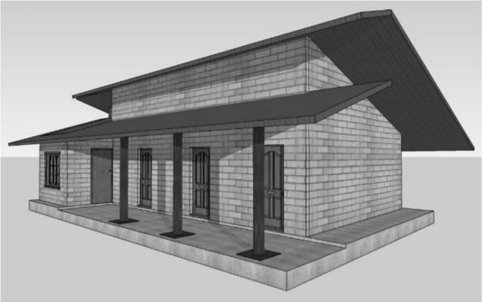


Figure 1: 3-Dimesional view of Community center at Batticaloa

2. Research through Material innovation: Mud-Concrete as a sustainable material

Selection of construction materials that have minimum environmental burdens and adoptability to local context is useful in the means of sustainable development when rebuilding the local communities through community Architecture. So, the research methodology was generated through the research process and this approach is to link the research process of inventing Mud-Concrete technology to building process and practiced through community architecture to rejuvenate the social interaction to empower the war-victim community within their context.

Mud-based construction has been very popular in ancient times, though it is not so in the present context of the industry. According to Cofireman et al. (1990) earth has been used in the construction of shelters for thousands of years and approximately 30% of the world's present population still lives in earthen structures. As Ren & Kagi (1995) presented earth is a cheap, environmentally friendly and abundantly available building material. It has been used extensively for wall construction around the world, particularly in developing countries. Several construction techniques have been practiced: dugout, earth-sheltered space, fill-in, cut-blocks, compressed earth, direct shaping, stacked earth, moulded earth, extruded earth, poured earth, straw clay, and daubed earth. These construction techniques have likely evolved through time and are still in use around the world. These earth based techniques are becoming unpopular day by day due to social believes on their strength and durability parameters , though these products got eco manufacturing process. But 'Concrete' is one of the most popular construction materials used currently, particularly due to the strength and durability factor.

Thus, the initial concept of developing Mud-Concrete is to incorporate the both strength and durability of concrete to mud-based constructions and make such constructions popular locally while ensuring indoor comfort, low cost load bearing walling system with easy construction technique which has least impact on the environment. Hence the novel concept in Mud-Concrete is that it employs a 'Concrete' made using earth/ soil. Concrete is a composite construction material made out of cement, sand, metal and water. Here, metal (coarse aggregate) governs the strength, cement acts as the binder and sand (fine aggregate) reduces the porosity and water acts as the reactor to cement. In Mud-Concrete, the intended functions of sand and metal of concrete are replaced by fraction of soil. The precise gravel percentage governs the strength of Mud-Concrete. The cement in this concrete is also used as a stabilizer in very low quantities. In this research fraction of soil has been classified as follows;

Gravel	-	sieve size 4.25mm $\leq$ gravel$\leq$ 20mm
Sand	-	sieve size 0.425mm $\leq$ sand $\leq$4.25 mm

Fine (silt and clay) - ≤ sieve size 4.25 mm

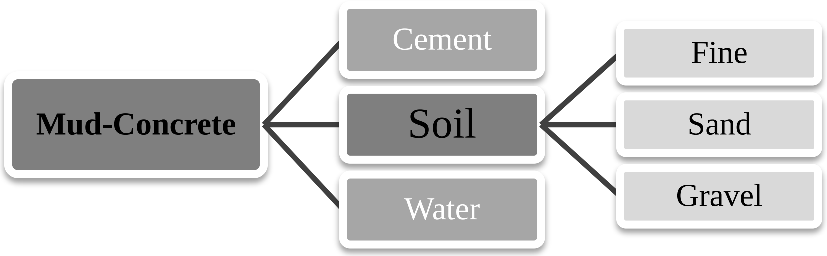


Figure 3: Composition of Mud-Concrete

The impact to the strength of mud-concrete with varied compositions of each of the above components has been studied as follows:

a. Change the fine percentage while keeping the sand and gravel constant
b. Once the optimum/ most practical fine content is known, the sand/gravel percentage was changed to find the optimum sand and gravel contents
c. Then the proposed mix was tested with different cement percentages, to optimize the required wet and dry strength of the block

According to gradual experiment process, the best mix proportions of unique Mud concrete block is achieved with minimum cement percentage and optimum water requirement which allows its self-compacting nature. Unlike conventional approaches to mud based construction, the MCB as a sensitive technology explained below significant innovative ideas which could utilize people ambitions in real world construction.

d. Soil will be slightly modified to form a concrete, which can withstand high strength and is durable.
e. The gravel acts as the strengthening agent, while clay and cement will act as the binder.
f. High water / cement ratio used will reduce strength; however, it would be regained by the proposed mix proportions.
g. The proposed water content will allow the mix to flow freely, which would create a mix that can compact itself.

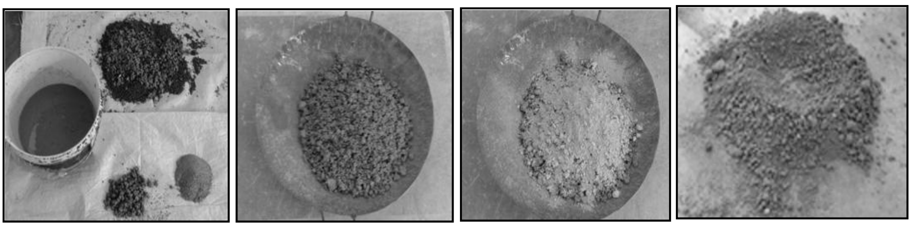
h. Excess water in the mix will create a porous structure that will later act in cooling the building through convection. This will increase the thermal comfort of the interior than other earth based constructions.
i. The porous structure and the absence of compaction will ensure aeration which would cut down heat gain due to low conductivity.
j. The extra water within the block will ensure that the block achieves its strength with time without any curing process. This will allow the block to be used as soon as it achieves the required minimum strength.
k. Since there is no burning involved, the block can be casted to any dimension, which matches the structural and architectural equipment.
l. Due to high water content and presence of clay, the block will end up with a clear and smooth surface which allows it to be used without plaster.
m. The proposed manufacturing techniques as well as the proposed proportions finally make a block that is low cost, has low embodied energy and requires lesser technical input / knowhow at the construction stage.

Day by day society's misconception on Soil based constructions is growing, because it is considered that these technologies only employ for poor who runs with low cost budget. Thus, the innovation of MCB drives people to rethink on soil based construction once again in making their built environment more responsive, while fading their doubts on strength and durability measures of soil. UN Habitat and the beneficiary community in the area was identified "Mud Concrete Block" as a cost effective technology for construction through the presentation and workshops conducted by the inventors from University of Moratuwa. Therefore, three community centres out of six were decided to construct using Mud-Concrete Blocks.

3. Research through building process: Introducing Mud-Concrete Block technology in construction of community centres

<u>Step 01: Conducting soil test</u>

Visited the selected site for constructions and soil samples were borrowed from each selected sites. Laboratory tests were conducted and all soil samples borrowed from the proposed sites were analysed at laboratory. Identify the existing proportions of available soil of selected sites. Proposed possible techniques were introduced to bring the soil up to best practical mix. According to the test results Soil: Cement mix proportion decided. (4%-8%). Then the composition of Mud concrete could be concluded as Fine (≤ sieve size 0.425mm), Sand (sieve size 0.425mm ≤ sand ≤4.25 mm), Gravel (sieve size 4.25 mm ≤ gravel≤ 20 mm), Cement (minimum of 4%) and Water (pouring stage).



Fraction of Soil: Gravel, Sand, Mud | Prepared soil samples after | Added cement | Mixture ready to add water

Figure 4: Composition of Mud-Concrete

<u>Step 02: Development of form work</u>

Form work was developed and introduced most optimum way of casting the blocks with the available resources to maintain easy manufacturing through less involvement of technology. As an initial approach form work made by 0-1” thick laminated plywood sheets. (Figure: 5) Due to the easy removal, maintain the quality of block finishes and maintain the durability of moulds ‘form work’ was developed from plywood to steel. (Figure: 6)

<u>Step 03: Taking part in the discussion of technology, people and interaction</u>

Community meetings were conducted to introduce the technology to people and maintain a responsive relationship with the local community and different Training programs/workshops were conducted to technical officers from UN habitat. Ongoing collaboration with families from the different ethnic groups and dialogue with village leaders was encouraged

Community provided labour used to manufacture Mud blocks, hence community was empowered and educated for manufacturing their own material. Within this programme skilled and unskilled labour force was identified and technology was develop to make easier and user friendly to people.

<u>Step 04: Mud-Concrete block casting and curing at site (Figure: 7)</u>

Casted block sizes were 225mm x 200mm x 150mm and required half sized blocks also casted prior to the work. According to the calculations, 2500

Mud-Concrete blocks (with added 5% wastage) were required per Community centre.

Step 05: Preparation of Mortar

During the masonry construction cement, soil and sand mortar was used. Mortar proportion was considered as cement 1: soil 3: sand 4 and it should prepared with adequate workability for facilitating the mason to fill the joints easily. The water content of the mortar is decided by achieving a good workable mix. Sieving the soil and sand from a mesh size of 6mm is essential in case of removing the coarser particles and to achieve good homogeneity of the mortar in the joints between the blocks.

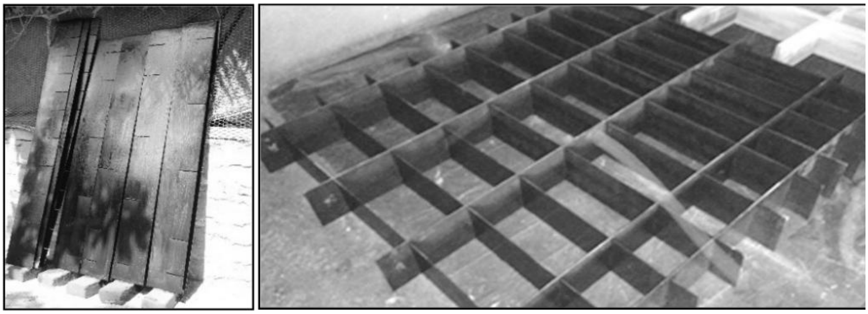
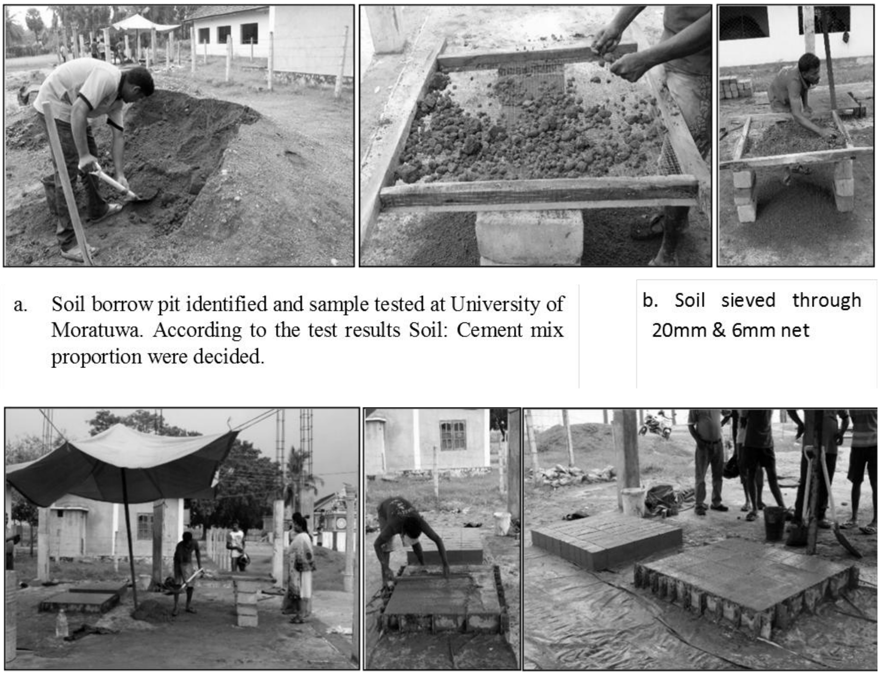


Figure 5: Development of Form work - Form work made by Steel sheets

Figure 6: Form work made by plywood



a. Soil borrow pit identified and sample tested at University of Moratuwa. According to the test results Soil: Cement mix proportion were decided.

b. Soil sieved through 20mm & 6mm net

c. Mix soil with sand and then add cement. Pour water to make the proper mixture

d. Pour mixture into the oiled mould and compact manually, let the mixture dry for approx.3 hours and remove from the mould, Let the blocks self-cure in a shady area for 5 -7 days & start wall construction

Figure 7: Mud- Concrete block Casting and curing procedure at Site

<u>Step 06: Construction of walls (Figure: 8)</u>
To control the quality of work, there was a necessity to pre-plan for controllable failures. Therefore, easy handling simple tools were introduced to levelling and aligning the mortar joints and construction of walls. Continuous monitoring and quality controlling measures were provided by inventors & technical officers during construction.

3.1 Research on cost reduction strategies of a Mud-Concrete Block through the manufacturing process

Several work studies were carried out to find the optimum construction labour/ machinery cost. Several trials were done with 1-3 moulds and found the best as to have 2 laboures at each site while sharing the production cost of 3 moulds among more than 2 sites, to gain the best cost saving for the buildings. With the careful and continuous supervision, the labour cost of a block can be reduced from LKR. 33.92 to LKR.7.21 and this will lead to an extra cost saving of Rs.60, 000.00 by having 3 laboures at the site with 2 moulds and increasing the number of cycle of casting. The calculations are based on reusing of the moulds for at least 10 sites. (Table: 2) Further, study was carried out to minimize the Material cost through optimizing added cement from 8% to 4%. (Table: 1)

Figure 8: Introduction of simple tools to maintain the labour skilfulness

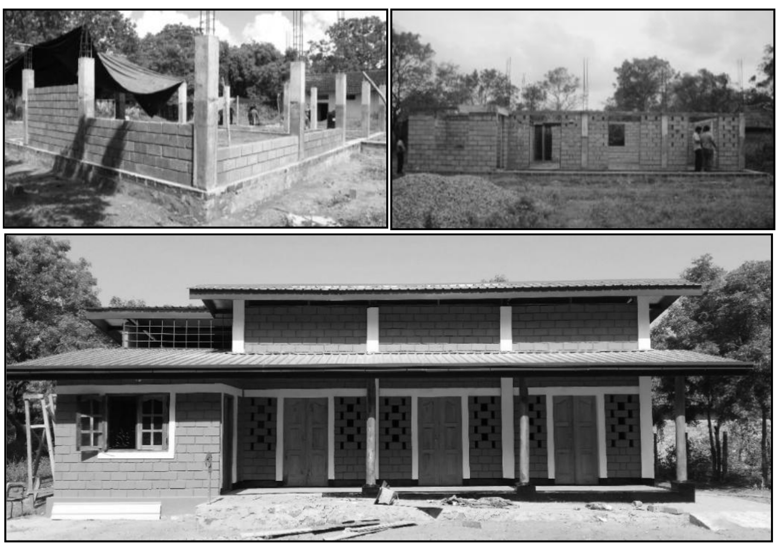


Figure 9: Photographic survey- Different stages of community center construction in Batticaloa

Once the foundation was done the floor concrete was laid to get a uniform surface to do the block casting. This will make sure a continuous water seal membrane at the foundation level and hence, it will minimize/ totally eliminate water movements due to capillary action as well as can reduce the termite attacks. Further, with this a good workable platform will be created and hence, quality of block production will be endorsed. Project cost also can be reduced by avoiding brick work at the foundation level.

Thus cost can be curtailed. Foundation work was kept for 14 days to achieve the strength and until that the labours at the site were used to cast the blocks. 120 blocks were made for a day and the total requirement was 2750 blocks for the whole buildings. As an average amount, 20 days were required to cast the blocks for construct a community building. Hence when the site is ready for waling, the blocks were ready. According to the project records, the typical prototype modelled community centers constructed through Sandcrete blocks was cost 2.995million and Brickwork (rat trap bond) was cost 2.966 million. But the community center constructed through Mud-Concrete block technology was cost only 2.84 million and the technology saved nearly 0.1 million from a building and saved 0.3 million from three projects which constructed at Batticaloa.

Step 01- Table 6: Cost comparison through optimizing added cement percentage

Type	Masonry work	Plastering	Cost per square (single side Plastering)	Cost variation for No. Plastering (%)	Cost variation with plastering (%)
Mud Block (6 ")					
4% cement	8580.11	5279.00	13859.11	0%	Not required
6% cement	9518.41	5279.00	14797.41	11%	
8% cement	10456.72	5279.00	15735.72	22%	
10% cement	11395.02	5279.00	16674.02	33%	
12% cement	12333.33	5279.00	17612.33	44%	
Brick (6")	18753.75	10558.00	29311.75	119%	150%
Hollow block (6")	15213.00	10558.00	25771.00	77%	124%

Step 02- Table 7: Cost Comparison of a MCB block through sharing moulds among different sites per day

Scenario	Practice No.	No. of moulds	No. of Sites	No. of labour	No. of MCB blocks	Cost per MCB block (LKR)
1	i	1	1	2	2500	33.92
	ii	2	1	2	2500	15.78
	iii	2	2	2	2500	12.58
	iv	2	10	2	2500	10.02
2	v	3	1	2	2500	15.85
	vi	3	2	2	2500	11.05
	vii	3	10	2	2500	7.21
3	viii	3	1	3	2500	18.98
	ix	3	2	3	2500	14.18
	x	3	10	3	2500	10.34

4. In conclusions: The Social acceptance towards the Mud-Concrete (MCB) technology

To sum it all, challenge of designing for a war victim community was achieved through a multi-disciplinary practice. In this study, it was integrated with research process to building process and practiced through community architecture to rejuvenate the social interaction to empower the war-victim community within their context. It was a definite factor to identify their extreme social, economic and functional needs prior to the implementation of the project. Further, introducing a new sustainable material to the 'Building Process' to restore a damaged community must incorporate with all these communal needs and ultimately this process should socially acceptable, environmentally compatible and economically viable.

Thus, Mud-Concrete technology was identified as a sensitive technology which utilizes the ambitions of victim community in a third world. Mud concrete technique is sound in strength and durability along with self-compacting nature unlike other mud based conventional approaches. Though there were different walling materials were introduced to build the community centres in identified areas in Batticaloa, Mud-concrete technology was identified as a highly viable solution which could use locally available soil in construction sites. When comparing with the other walling materials MCB took a prime place in load bearing, durability and thermal comfort while maintaining low embodied energy. The natural earth colour, texture and proportions of MCB were added permanent beauty to the building form, creating unity with nature while adapting to the context of space. Easy production process, new appearance, low cost constructions and the less energy consumption of MCB has been attracted people more in to embrace the technology.

Thus, the introduced technology, achieved the challenge of developing the labour skills among the community. Introduced community Architecture helped to intervene community members to the design process and educated them within the building process. Then the end-users understood the actual requirements of a community and how to achieve those requirements through the building process. Moreover, they understood the challenges, failures and how to pre-plan for controllable failures of a construction project. Therefore, construction of community centre projects in Batticaloa resulted in a great success where, Mud concrete block technology was highly appreciated as a sustainable solution by people who are rebuilding their communities.

Acknowledgment – Meant to express the researches gratitude to ‘UN habitat’ as a key funding organization of the “Re-settling Programme”, who implemented community design projects to reform social interaction between refuge communities in Batticaloa with collaboration of University of Moratuwa. This material is based on work supported by the Senate Research Committee (SRC) grant number under SRC/LT/2012/15. Any options, findings and conclusions or recommendation expressed in this material are those of the authors and do not necessarily reflect those of University of Moratuwa.

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DEVELOPING A STRUCTURALLY SOUND AND DURABLE ROOF SLAB INSULATION SYSTEM FOR TROPICAL CLIMATES

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Abstract

Flat roof slabs are gaining its popularity day by day due to its advantages like cyclonic resistance, possibility for future expansion and the possibility of using them as additional working space. However, the major issue associated with roof slabs is thermal discomfort, for which, active cooling in the forms of fans and air-conditioners is the most common remedy used. This has led to extensive use of energy, increasing the operational cost of the buildings and, in the macro scale, contributing to global warming as well. Hence, the current trend is to go for passive techniques. Insulating roof slabs is identified as a better passive way to address the stated issues. In this study, several existing roof slab insulation techniques were discussed and their benefits and drawbacks were identified. While ensuring the same thermal and structural capacity of the insulation system, a new system was developed to address the drawbacks of existing systems. Computer based modelling were used to optimize the system and the small scale model testing was used to validate the results obtained by the computer simulations. Finally, a new insulation system was developed with enhanced thermal performance, structural capacity and the durability.

Keywords: *Passive Cooling, Roof Slab Insulation, Structural performance, durability*

1. Introduction

Due to the rapid development taking place in the last couple of decades, ‘land’ has become one of the most expensive commodities in the world, particularly in urban areas. In this context, multi-storey construction has widespread throughout the world as it enables the users to have a larger working area in a small footprint. Further, use of flat concrete roof slabs has aggravated its popularity as it allows the flexibility to the users to use the space as either a working space or a roof top garden (Banting, 2005; Berardi, GhaffarianHoseini, & GhaffarianHoseini, 2014; Halwatura, 2013). In addition, robustness that a concrete roof slab incorporates to a building enhances the disaster resistance, particularly against cyclones (Halwatura, Mallawarachchi, & Jayasinghe, 2007).

Nevertheless, since concrete is a relatively high thermal conductor, it gets heated up in the daytime and emits long wave radiation to the space underneath, causing a severe thermal discomfort to the occupants in its topmost floor. It has been found that if this issue can be addressed, it will make flat concrete roof slabs more popular among the general public (Nandapala & Halwatura, 2014).

The most common remedy adapted to address this issue is, active means of cooling in the form of fans and air-conditioners. Even though that it solves the issue of thermal discomfort, it is at a higher cost in the form of higher usage of energy, leading us back to the biggest issue that the current world is facing, Global Warming.

It has been found out that in Singapore, buildings use up to 57% of the total energy usage of the country (Kwong, Adam, & Sahari, 2014), and In Malaysia, a country with a similar tropical climatic conditions, more than 30% of the total energy usage is for making buildings thermally comfortable (Dong, Lee, & Sapar, 2005). This proves that around 20% of the total energy used in tropics is for providing thermal comfort in buildings. It is obvious that this is beyond the world can afford, implying that the use of active cooling techniques is not an appropriate solution for thermal comfort in long run. Hence, passive cooling techniques have become popular in the world (Al-Obaidi, Ismail, & Abdul Rahman, 2014; Alvarado & Martínez, 2008; Sadineni, Madala, & Boehm, 2011), insulation in particular (Al-Homoud, 2005; Brito Filho & Santos, 2014; Dylewski & Adamczyk, 2014).

There are several roof insulation techniques tried out in the world, and their heat reduction potentials have been studied. Applying a cool paint is one such technique. In a research carried out in Florida, USA, it has been proven that up to 38% energy saving can be obtained by applying a cool paint (Parker & Barkaszi Jr., 1997). Another research in Italy, a reduction of 54% energy demand is observed (Romeo & Zinzi, 2013). In Greece a set of researchers has used a 60mm air gap as an insulator, and obtained a daily heat gain reduction of 56% (Dimoudi, Androutsopoulos, & Lykoudis, 2006). There is another technique used in Sri Lanka with a 25mm polyethylene layer as the insulator, proving a heat reduction of 75% can be obtained in a tropical climatic condition (Halwatura & Jayasinghe, 2008).

Above figures incontrovertibly suggest that insulation can be very effective in any climatic condition. Since this study focuses on tropics, the system developed in Sri Lanka is found to be the most recent and the best to suit the conditions. However, there are some drawbacks associated with this method. The issues associated and the proposed remedies are discussed in this paper.

2. Findings so far

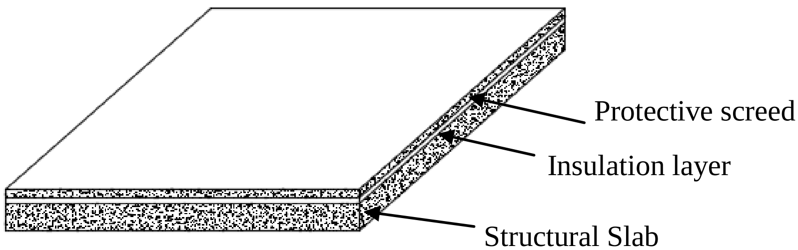

Figure 10: insulation system with a continuous insulation layer

As it has been mentioned, thermal discomfort is the dominant drawback associated with roof slabs, and for which insulation has been identified as a better remedy. The most common arrangement used in practice is shown in Figure 10.

This system is implemented and tested practically, and proven that this performs really well in thermal aspects. However, this imposes a restriction on loading since a layer of weak material is sandwiched in the system.

Figuring this out, a system has been developed with a set of continuous concrete strips within the insulation layer as shown in Figure 11 (Halwatura & Jayasinghe, 2008). This is proven to be structurally sound, with the capability of bearing any practical load acted on a roof.

However, leakages of slabs were observed in long run in the slabs constructed. After an investigation, water was found to be stagnant in the areas where insulation material is. This can be elaborated as follows;

The supporting arrangement of this system in the insulation layer (plan view) is shown in Figure 12. There’s no drainage path for a water drop which passes through the cracked screed to the insuation layer, as the insulation material is enclosed by a set of continuous concrete strips. The waterproofing layer that is used in slabs is not designed to withstand a water head, hence has failed.

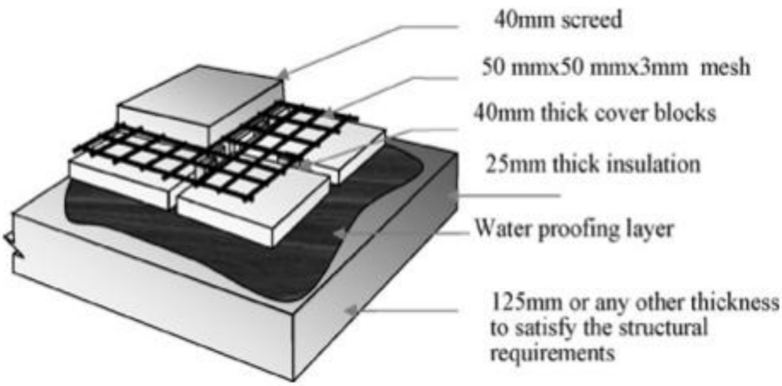

Figure 11: The system with continuous concrete strips (Halwatura & Jayasinghe, 2008)

Hereafter, this paper describes the conceptual design of a drainage path within this insulation system.

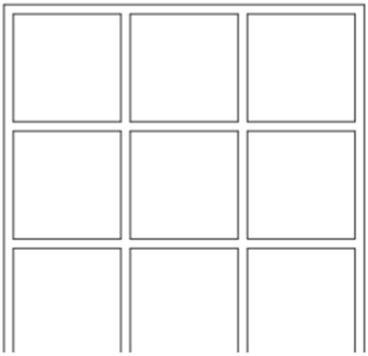

Figure 12: Supporting arrangement of screed within insulation layer in the system with continuous concrete strips (plan view)

3. Methodology

A literature survey has been carried out to figure out the requirement of such a technique in the local context. Further, the existing techniques that have been tried out throughout the world were studied, and the systems that is most efficient has been picked out for further improvement.

Then those particular systems is further investigated by means of a further literature review and a field study to identify the practical issues to be addressed.
In the study, it has been identified that structural performance and the durability are the main issues associated with those systems. The method that was adapted to address those is described throughout this paper.

4. The Conceptual Design

4.1 STEP 1: REMOVING STRIPS IN ONE DIRECTION

The first option considered was to remove strips in one direction as shown in Figure 13. The objective of designing the system, in first place, is to remove the restriction for loading. Hence, the system has to be designed in such a way that it can withstand any practical load applied on that. Therefore, a structural analysis was carried out assuming that the imposed load applied on that is $5kN/m^2$, which is the maximum specified in BS6399-1:1996 (Code of Practice for Dead and Imposed Loads).

In this context, there were four variables to be considered.

1. Spacing between strips
2. Size of strips
3. Mix proportion of concrete used.
4. Reinforcement arrangement of the top screed.

An optimum spacing for the system was to be found out for the system. Because the system could have failed if the strips are too far apart of each other, and the effectiveness of the system reduces drastically if they are placed too closer by since the insulation material is replaced by concrete

.

Reducing the concrete area as much as possible is a major objective in this optimization process of the system. Hence, a minimum size that can bear the predicted load had to be found out.

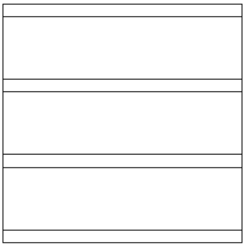

Figure 13: supporting arrangement after removing strips in one direction

The mix proportion to be used in the strips plays a major role as well. It has to be strong enough to carry the load, and should be able to be compacted in an area of a width of 40mm. Hence, a concrete with a lower maximum aggregate size (chip-concrete) was used. A suitable proportionating was necessary to be done.

The screed had to be designed as a slab itself as this system is to be used as a load bearing structure. Since concrete is a material which is very weak in tension, some arrangement of steel had to be incorporated into the system. Several options of having two reinforcement nets were considered. Bottom reinforcement was tried fixed to a 2” x 2” gauge 12 mesh due to the convenience of construction. There were four options considered for the top net: no reinforcement, a 6mm mild steel bar near supports, a 10mm tor steel bar near supports and a same type of a mesh (double nets), with an obvious preference for the ‘no top reinforcement’ case over others.

Since it was not practical to play with all the variables, size of strips was fixed to 50 mm and the concrete was assumed to have a strength of 15 N/mm^2 for initial evaluations. The results obtained by computer simulations by varying the spacing of the strips and type of reinforcement is shown in Figure 5. It suggests that the system can be implemented without any top reinforcement if the strips are provided in a spacing of less than 540 mm (

Figure 14). at this stage, the finalized values for the four variables stated above are as follows;

1. Spacing between strips – 540 mm
2. width of the strips - 50 mm
3. Strength of concrete used – 15 N/mm^2
4. Reinforcement arrangement of the top screed – a single net of 2” x 2” gauge 12 mesh

4.2 STEP 2: OPTIMIZING THE STRIP IN ITS LONGITUDINAL DIRECTION

As it has been stated, reducing the concrete area within the insulation layer is a prime objective of this study. Hence, several options were considered to select the optimum arrangement, varying the spacing of the strips (in transverse diration). In this case, there were three additional variables considered.

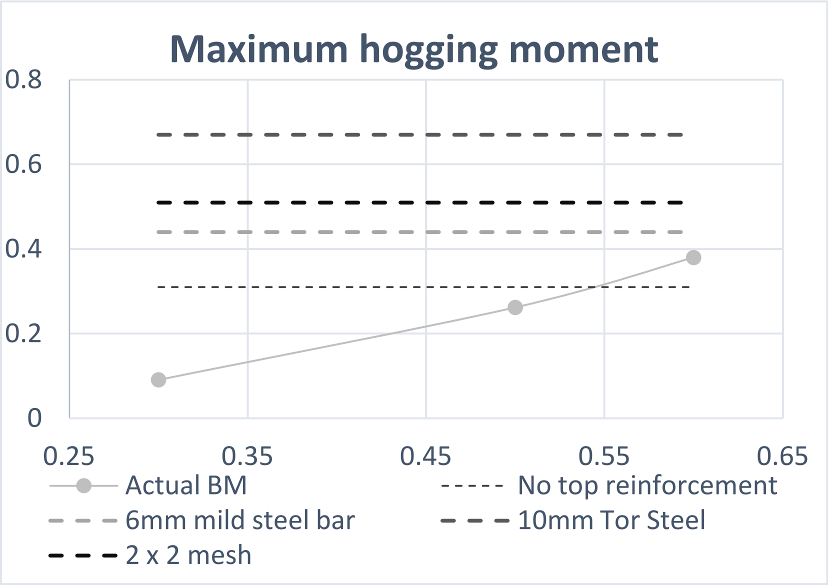

Figure 14: Bending moments and bending moment capacities for different reinforcing arrangements

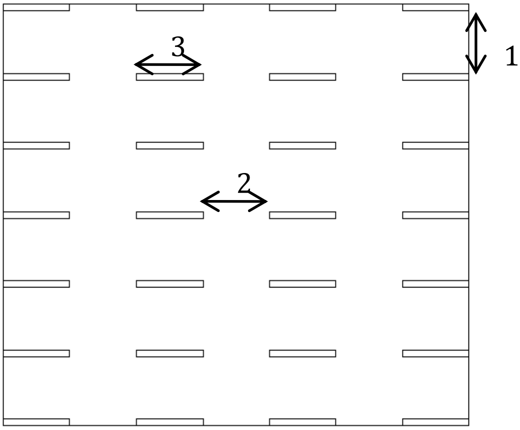

Figure 15: Variables to be considered in optimizing the strips in longitudinal direction

1. Transverse spacing of strips (number 1 in
2. Figure 15)
3. Longitudinal spacing between strips (number 2 in
4. Figure 15)

5. Length of the strips (number 3 in
6. Figure 15)

Sixty possible options were considered by varying these variables and three feasible options were picked out considering the structural aspects (Table 1).

Table 1: The short-listed systems with discontinuous concrete systems with supports

span in transvers direction(mm)	Length of the strip(mm)	Clear spacing between strips (mm)
300	300	400
400	300	300
500	200	100

4.3 STEP 3: FLAT SLAB ARRANGEMENT

The options considered so far were of a typical beam-column supporting system of a slab. However, it was worthwhile to consider the option of a flat slab arrangement too. The results obtained are shown in Figure 16 (only hogging bending moment is shown as it was the critical aspect considered). The results suggested that it is possible to implement this system if 50 mm blocks are spaced at 150 mm.

4.4 STEP 4: SELECTING A SUITABLE WIDTH OF THE STRIPS

The major objective of this study was to find out the optimum supporting arrangement to carry any possible load acting on it. Further, in section 3.1, only two out of four variables in total were considered in the design. In this step, the minimum width of the strip has been worked out.

Since the height of the supporting strips is short with respect to other length, the most likely way is to fail in compressive strength. Hence, the minimum width required is calculated by a simple compressive strength calculation. The results are as shown in Table 2.

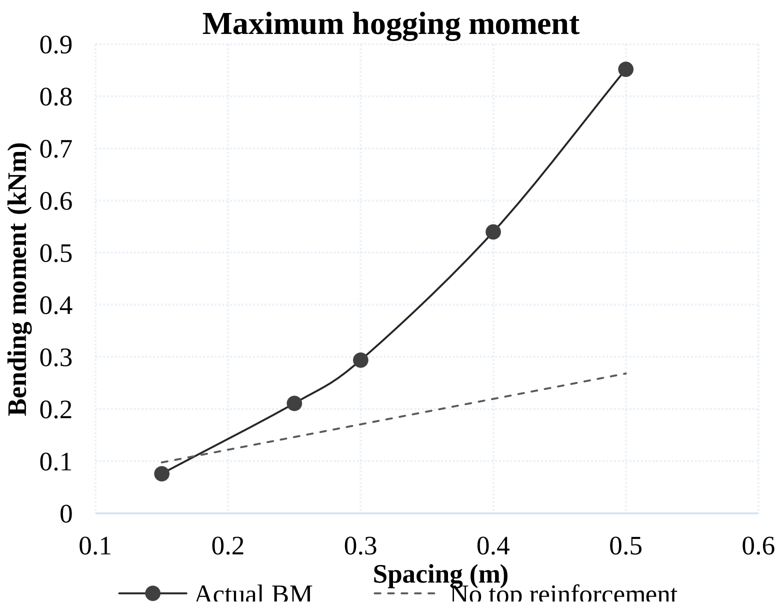

Figure 16: Bending moments and bending moment capacities of flat slab arrangements with different spans

It shows that a very small width is sufficient to carry the load. However, a minimum width of 25mm is selected considering the practical construction aspects.

Table 2: Calculations for finding minimum width of strips

	300mm in transverse	**400mm in transverse**	**500mm in transverse**	**Flat slab arrangement**
effective area (m^2)	0.21	0.24	0.15	0.04
Dead load (kN)	0.2076	0.2394	0.153	0.0399
live load (kN)	1.05	1.2	0.75	0.2
total load kN (with partial factors of safety)	1.97	2.26	1.41	0.38
minimum area (mm^2)	131.38	150.34	94.28	25.06
minimum width (mm)	0.44	0.50	0.47	5.01

4.5 STEP 5: SELECTING THE BEST SYSTEM

As the process suggests so far, the possible options for the structural arrangement is short-listed to four. The next step was to pick one out.

Since the objective is to minimize the concrete area within the insulation material as much as possible, the concrete area of approximately100 m^2- slab was considered. As Table 3 suggests, the flat slab arrangement has a significantly higher percentage than other options, which are more or less having a similar area of concrete. The second option has the lowest value and hence was selected for actual scale testing.

4.6 STEP 6: SELECTING A SUITABLE CONCRETE MIX

The other variable that was fixed in section 3.1 was the mix proportion of concrete used. Since the supporting strips are of 400 mm x 25 mm, it was necessary to specify a lower maximum aggregate size for concrete. As chipped metal with a maximum size of 10 mm is a common construction material a mix design was performed to achieve a strength of 15N/mm^2. Several options were considered as shown in Table 3.

Table 3: concrete areas of the four short-listed systems

	300mm in transverse	**400mm in transverse**	**500mm in transverse**	**Flat slab arrangement**
Concrete area (m^2)	3.71	3.51	3.57	5.61
Total Area (m^2)	97.5	105.5	101.5	99.0
Ratio	3.8%	3.3%	3.5%	5.7%

All the mixes tested did achieve the target strength of 15 N/mm^2. The next step was to specify a volume batch mix proportion to be used in the industry. From a simple calculation it has been found out that the mix with water-cement ration of 0.7 has roughly 1:2:3 proportion of cement, sand and metal respectively.

4.7 STEP 7: ACTUAL SCALE TESTING

Having finalized the system, the next step was to validate results by actual scale casting. The system was loaded with a proving ring calibrated to measure the load applied. The deflection with the applied load was measured by a dial gauge. Both readings were continuously taken till the system fails entirely. The results are shown in Figure 8.

The graph in figure 8 shows that the system can be loaded higher than 30kN without a serviceability failure. This is sufficient to carry any practical load on top of a roof.

5. CONCLUSIONS

Using flat slabs as roofs is a good strategy to recover the land, one of the scarcest resources in an urban environment. Further, it enhances the robustness of structures and thereby increases the resistance to natural disasters, of which the intensity and the severity increases day-by-day as a result of the climate change in the world. However, it increases thermal discomfort in the uppermost floor as the slab acts as a heated body and emits longwave radiation to the immediate space underneath. Mechanical cooling is the most common remedy used in the industry, but it increases the energy consumption which is not favourable for a sustainable world.

Table 48: Mix design options tested to obtain 15 N/mm^2 strength

W/C ratio	Cube #	Load (kN)	Size of the Block		Strength (N/mm2)	Average Strength (N/mm2)
			Length (mm)	Width (mm)		
0.78	1	517.8	150	153	22.56	22.48
	2	530.4	148	151	23.73	
	3	478.3	155	146	21.14	
0.75	1	506.3	150	151	22.35	23.78
	2	526.7	151	149	23.41	
	3	594.7	155	150	25.58	
0.70	1	478.8	150	153	20.86	23.97
	2	562.5	148	147	25.85	
	3	551.5	150	146	25.18	
0.65	1	536.4	150	150	23.84	25.40
	2	567.2	146	148	26.25	
	3	599.5	153	150	26.12	
0.60	1	683.4	150	153	29.78	27.63
	2	589.1	149	151	26.18	
	3	609.3	155	146	26.92	

In this context, insulation of slabs has gained the popularity among the researchers in the modern world. There are many such techniques developed in the world, of those the most effective method was selected. A field study was done to identify the performance of the system. It was noted that this system has a drainage issue as some instances the slabs have become leaked.

The system was further investigated to find out the reason, and a separate technique was developed with a minimum concrete area and a proper drainage path. It has been found out that 300 mm x 25 mm strips with 300 mm clear span, and a transverse spacing of 400 mm is structurally capable.

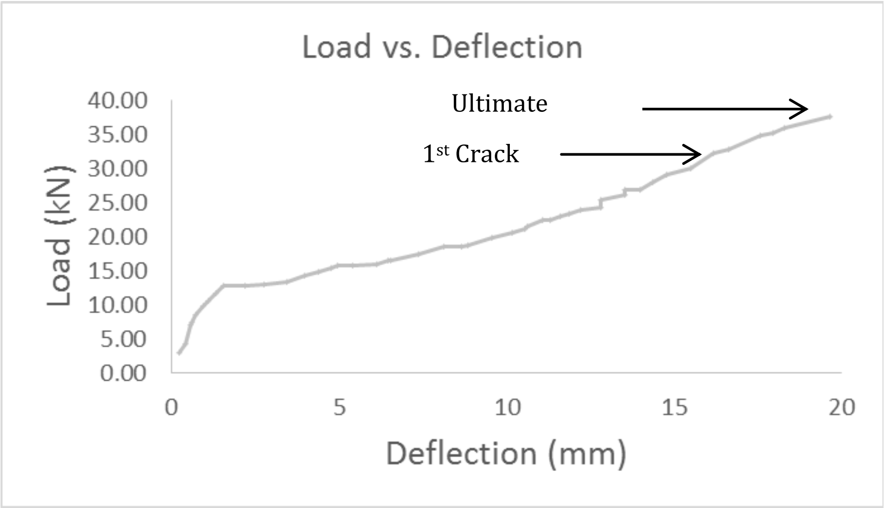

Figure 17: Load Vs. Deflection curve of the actual scale testing

A mix design was done to obtain the required strength out of chip-concrete and 1:2:3 proportion of cement, sand and metal with a water/cement ratio of 0.7 is found to be sufficient to be used in the system.

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MOVING FROM 2015 TO 2030: CHALLENGES AND OPPORTUNITIES FOR HIGHER EDUCATION IN DEVELOPING RESILIENCE TO DISASTERS

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Abstract
In recent years, the higher education community has played an increasingly important role in moving disaster science from a responsive, primarily technical discipline, to a broad, multi-disciplinary movement that seeks to build societal resilience to disaster. This study sets out some of the key challenges and opportunities for higher education towards tackling the challenges set out in the Sendai Framework for Disaster Risk Reduction 2015 - 2030, which was adopted by 187 UN member states in March 2015.

The study brings together existing literature in the field, as well as the results of various analysis and study projects undertaken by a European network project.

Five key areas of focus are identified in working towards 2030: Link research, education and action; Integrate all hazards, stakeholders and disciplines; Collaborate regionally and globally; Facilitate policy dialogue, knowledge sharing and capacity development; Develop flexible and customisable education programmes.

Keywords: *Disaster resilience; higher education; challenges; opportunities.*

1. Introduction

In recent years, the European higher education community has played an increasingly important role in moving disaster science from a responsive, primarily technical discipline, to a broad, multi-disciplinary movement that seeks to build societal resilience to disaster. This movement coincides with the increasing global emphasis on the need to tackle the inter-related challenges of disaster risk reduction, sustainable development and climate change.

The ANDROID disaster resilience network was established in 2011 (Academic Network for Disaster Resilience to Optimise EducatIonal Development). The network was set up to promote co-operation and innovation among European Higher Education and in doing so, to increase society's resilience to disasters of human and natural origin. An underlying tenet of ANDROID is that higher education should be more innovative, providing opportunities to work in close collaboration with industry, communities, humanitarian agencies, private sectors and other higher education institutions.

This study presents a roadmap produced by the network that sets out some of the key challenges and opportunities for higher education towards tackling the challenges set out in the Sendai Framework for Disaster Risk Reduction 2015 - 2030, which was adopted by 187 UN member states in March 2015. A more detailed account of the study and supporting survey projects can be downloaded from www.disaster-resilience.net.

2. Background to the study

Among many communities disasters pose significant concerns and challenges. With growing population and infrastructures, the world's exposure to disaster related hazards is increasing. In addition to loss of life, disasters greatly hamper the social-economic capacity of the member countries and also of the union as a whole. Swiss Re's latest sigma report (2014) highlights 308 disaster events in 2013, of which 150 were natural catastrophes and 158 man-made. Almost 26,000 people lost their lives or went missing in the disasters.

The frequency, scale and distribution of disasters in recent years is also evidence that disaster related hazards are a global problem, threatening to disrupt communities in developed, newly industrialised and developing countries. As the 21st century unfolds, an increasing majority of the world's population will live in cities. By 2050, the UN expects 80% of world's population to live in urban areas. Half of these are in small and medium size cities (United Nations, 2014). In the East Asia region alone, the urban population is expected to double between 1994 and 2025 (World Bank, 2011).

The importance of international cooperation and global partnership to tackle disaster risk is explicitly recognised in the Sendai Framework for Disaster Risk Reduction 2015-2030 that representatives from 187 UN member States adopted in March 2015 as the first major agreement of the post-2015 development agenda. The framework will govern the next 15 years of disaster risk reduction globally. The framework acknowledges that given their different capacities as well as the linkage between the level of support provided to them and the extent to which they will be able to implement the present framework, developing countries require enhanced provisions of means of implementation, including adequate, sustainable, and timely resources, through international cooperation and global partnership for development. It recognises that in addressing economic disparity and disparity in technological innovation and research capacity among countries, it is crucial to enhance technology transfer involving a process of enabling and facilitating flows of skill, knowledge, ideas, know-how and technology from developed to developing countries in the implementation of the present framework.

The Sendai Framework also recongises the vital role of academia, scientific and research entities in tackling disaster risk. It urges them to focus on the: disaster risk factors and scenarios, including emerging disaster risks, in the medium and long term; increase research for regional, national and local application; support action by local communities and authorities; and support on the interface between policy and science for decision-making. In a similar vein, the Science and Technology Major Group that informed Member States and Stakeholders' submission (STMG, 2014) identified the need to promote scientific research into risk patterns and trends, as well as the causes and effects of disaster risk in society; and engage with the national/sub-national research and practitioner community to strengthen the science-policy interface.

3. Methodology

This roadmap brings together existing literature in the field, as well as the results of various analysis and study projects undertaken by project partners (Faber et al, 2014; Indirli et al, 2014; Kaluarachchi et al, 2014; Knezic et al, 2014; Perdikou et al, 2014).

A survey was carried out by means of a questionnaire which collected 57 responses from more than twenty European higher education institutes. The survey focused on disaster-resilience projects and on the main challenges faced in interdisciplinary working (Faber et al, 2014). A second survey set out to establish the current teaching and research capacity among European HEIs in the field (Perdikou et al, 2014). 96 participants directly related to disaster resilience education responded. A third survey studied existing capacity at both national and local levels. The survey respondents represented organisations with total disaster resilience personnel of approximately 19,000 people. Finally, a series of special interest groups studied emerging research and teaching concerns in disaster resilience, selecting Venice and its territory as an emblematic case study of a region that could be affected by crossborder disastrous events. A case study was carried out not only as an engaging exercise, but with the purpose to provide a reference point for scientists and teachers interested to translate multifaceted knowledge into specific solutions. A series of papers have been written (Indirli et al, 2014; Knezic, 2014; Borg, 2014; Kaluarachchi, 2014).

This paper collates the results from these various sub-projects to present the major challenges and opportunities for higher education in contributing to increased societal resilience. The detailed methodologies associated with the individual sub-projects and surveys are described in the respective papers.

4. Results

5.1 LINK RESEARCH, EDUCATION AND ACTION

The Sendai Framework for Disaster Risk Reduction 2015-2030 aims to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health, and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries over the next 15 years.

It has been recognised that the success of this post- 2015 framework hinges on creating and implementing policies that are built on the best available knowledge. Higher education has a vital role in supporting this move to a more disaster resilient society by 2030.

This roadmap considers the challenges and opportunities that must be addressed by higher education in Europe if it to effectively support Sendai Framework for Disaster Risk Reduction 2015-2030.

The prime focus must be that the policy-science gap is closed with research that can be translated to action. Research studies document a trend of increasing disaster losses, but the translation of research findings into practical actions has proven difficult and remains a barrier that prevents the best use of science.

There remains a recognised need for higher education, through researchers and educators, to provide and communicate actionable knowledge with explicit links to inform effective, evidence-based decision-making. As well as creating new knowledge, higher education has a vital to play in capacity development and in doing so, providing a means by which effective knowledge transfer can take place.

5.2. INTEGRATE ALL HAZARDS, STAKEHOLDERS AND DISCIPLINES

Higher education will need to develop multi-actor and multi-sector alliances to tackle the type of emerging priorities in areas such as understanding disaster risk, governance arrangements, investment decisions, preparedness, and rehabilitation and reconstruction. These alliances will support the development of problem-based education and research programmes, and thereby help to create and implement evidence based, resilience building policies and practices.

An all-hazard, problem-focused approach should be used in resilience building research and education to address the complexity of disaster risk. This will require collaboration and communication across the scientific disciplines. Higher education can promote this approach by providing researchers and students with:

- Exposure to a variety of disciplinary work
- Exposure to interdisciplinary work
- Exposure to and experience with tools and methods from a variety of disciplines
- Exposure to and experience with interdisciplinary tools and methods
- Experience working with others in an interdisciplinary mode

Higher education programmes and research training must develop the skills to shift perspectives easily, and continually see things in new ways. Researchers and students must be comfortable with multiple languages and a variety of ontologies, epistemologies, methods, tools, and theoretical perspectives, and shift easily among them.

Funders, publishers and editors must not reinforce disciplinary silos, and should promote and encourage the development and publication of multi- and interdisciplinary research. The scope of scientific panels and peer-reviewed journals should reflect the importance of problem-focused research, rather than be defined by traditional academic disciplines.

Review panels, editorial boards and scientific committees should reflect the diverse array of disciplines required to address major societal challenges such as building disaster resilience.

Researchers and educators must interact and collaborate with policy-makers and practice based actors at the local, national, regional and global levels. Collectively they must work to identify and address problems and knowledge gaps from the field. Rather than being passive recipients of new knowledge, policy makers and practitioners should join with higher education to form multi-stakeholder groups that work together from the outset to design and deliver new knowledge. The scientific results will be more relevant and actionable.

There are already a number of regional initiatives that promote collaboration among higher education towards building resilience. The ANDROID conferences provided a showcase of the type of international, multi-disciplinary and multi-sector engagement that is required. These networks and events have helped to gather a wide and advanced set of competencies in the field of disaster resilience, sharing knowledge, discussing methodologies, disseminating good practices and producing and promoting innovation. These networks should be supported and encouraged to grow.

Given their different capacities, the EU must continue to strengthen its engagement with developing countries through international cooperation and global partnership for development, and continued international support, to strengthen their efforts to reduce disaster risk. In supporting this, the current regional networks should collaborate to form a global higher education network that can influence strategic agendas.

This global network should collaborate with existing bodies such as the UN ISDR Scientific and Technical Advisory Group to ensure that the role of higher education is understood and can be exploited towards achieving the objectives of the Sendai Framework.

5.3 COLLABORATE REGIONALLY AND GLOBALLY

There are already a number of regional initiatives that promote collaboration among higher education towards building resilience. The ANDROID conferences provided a showcase of the type of international, multi-disciplinary and multi-sector engagement that is required. These networks and events have helped to gather a wide and advanced set of competencies in the field of disaster resilience, sharing knowledge, discussing methodologies,

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Funding bodies for science should coordinate their efforts to ensure that resource are being deployed effectively and efficiently, and to promote collaboration across disciplines, as well as regionally and internationally. This will help to avoid duplication of effort and integrate funding.

5.4 FACILITATE POLICY DIALOGUE, KNOWLEDGE SHARING AND CAPACITY DEVELOPMENT

Greater priority should be put on sharing and disseminating scientific information. The research community must make more effort to translate traditional outputs into practical methods that can readily be integrated into policies, regulations and implementation plans towards building resilience.

National research assessment exercises, the European Union and national funding bodies, and higher education promotion policies, which often emphasise traditional academic outputs (e.g., peer reviewed journal articles), should appropriately incentivise and reward non-standard scientific outputs, such as research summaries and policy briefs.

The recent shift towards open access of research outputs and education is to be welcomed and should continue to be encouraged.

The high levels of disaster risk found in low-income countries make it an imperative that European research and education is made widely available. The European Union and other research funding bodies should require all funded scientific outputs to be made available as open access. This includes the use of green publishing routes where possible, or financially supporting gold publishing as necessary.

Higher education should be supported to develop open educational resources that are freely accessible and openly licensed, for use in teaching, learning, and assessing as well as for research purposes linked to building resilience.

Educators and the research community must take time and effort to understand the audience they are seeking to inform.

Scientific results are often subject to misunderstanding due to poor comprehension of numbers and statistics, as well as conflicting languages and terminology. Correct comprehension depends not only on the skills and knowledge of the reader, but also on the way the information is presented. By assuming a weaker background knowledge (e.g. of scientific language) and low “statistical literacy”, evidence summaries can add information to help readers better understand the strengths and limitations of the scientific evidence being summarised. Adding meta-information that explains concepts such as the quality of the evidence may help eliminate frustration and trigger reflection.

The volume of research activity and associated outputs has rapidly increased over recent decades. While expanding the knowledgebase may be considered positive in one sense, it has made the field increasingly difficult to navigate, whether it be for experienced researchers and educators, early career researchers and students, or other stakeholders, including policy makers. Identifying and accessing the most recent and high quality science is proving increasingly challenging despite the advance of technology.

Methods and tools for aggregating knowledge must be developed to facilitate access to science, technology and innovation outputs that help inform policy-making and practice, and also ensure that educational programmes and researchers have access to and can build upon the state of the art.

Science provides an evidence base that can be relevant to and therefore draw together different areas of policy. Knowledge integration provides a starting point for building and operationalizing resilience through the co-design of policies and interventions by scientists, practitioners, policy makers and communities themselves. Standardised definitions are essential to the operationalization of concepts such as resilience for research, monitoring and implementation purposes. For example, in epidemiology, case ascertainment/ definition is essential to accurately understanding the causal relationship between a disease exposure and its outcome.

Common understanding amongst all actors is essential for effective disaster risk reduction and management. Approaching towards 2015, the Joint Research Centre of the European Commission has been contributing to identifying the most common terms and definitions used in disaster risk reduction. This background information would provide a solid basis to continue updating the terminology and contribute to the implementation of the post-2015 framework on disaster risk reduction.

5.5 DEVELOP FLEXIBLE AND CUSTOMISABLE EDUCATION PROGRAMMES

There is an expanding field of disaster management, but simultaneously, a lack of young professionals with appropriate skills and knowledge to support the building of resilience within relevant stakeholders. There is a need to maintain and expand the network of key persons, including change agents and facilitators.

ANDROID's survey on education supply and demand found that despite considerable need for programmes to support the building of resilience, there is currently a lack of programmes that meet employer needs. It also found that the availability of programmes differed greatly across Europe, and that most programmes are recent developments, with very few having been in operation for over 5 years. This emphasises the immaturity of the discipline and the needs for further studies to better understand market needs.

Higher education within Europe must develop flexible and customised programmes and curricular, whether a module in regular Masters or Undergraduate curriculum, or as dedicated postgraduate programmes.

Detailed market research is required to understand the need and interest in potential students, with clear linkages to future job markets.

This will help to ensure that educational programme address the problems from the field and can promote affordable solutions, as per local context, including the cultural calibration of technology.

Educational programmes should promote a multi-disciplinary approach and understanding, drawing upon a combination of different faculty.

The problem-based nature of the field determines that programmes should offer an appropriate balance of theory and field experiences.

Internship programmes for students in government, NGOs, UN agencies, private sectors, research institutions should be strongly promoted.

At the same time, the pace of scientific discoveries demands that programmes are research linked to ensure that what is being taught by higher education is consistent with the state of the art. Improving the link between research, education and action will require the transfer of research knowledge into teaching but also recognising that the research and teaching link as a two-way knowledge transfer process. In a ‘knowledge society’ all graduates have to be researchers. Not only are they engaged in production of knowledge; they must also be educated to cope with risks and uncertainties generated by the advance of science.

5. Conclusion

Scientific data and information, and effective capacity building from higher education are critical to underpinning well-informed policies and decisions across the public, private and voluntary sectors. Much scientific evidence exists but better links to decision-making in policy and planning are needed to continuously enhance our ability to forecast, reduce and respond to disaster risks thereby building resilience.

Science and technology can assist in identifying a problem, developing understanding from research, informing policy and practice and making a difference that can be objectively demonstrated when evaluated.

The new Sendai framework for disaster risk reduction includes a strong call for the research and education communities to support the understanding of disaster risk and promote risk-informed decisions and risk sensitive planning from the local to the global levels. It also calls for the coordination of existing networks and scientific research institutions at all levels and all regions. The goal is to strengthen the evidence-base in support of the implementation of the new framework.

Researchers and educators must work with policy-makers and practitioners to co-design and co-produce research that can be used effectively. Higher education must also play a vital role in translating that research into action through its educational programmes.

Acknowledgments

This study was undertaken by the ANDROID Disaster Resilience Network, which was funded under the EU Lifelong Learning Programme. With a budget of nearly €7 billion for 2007 to 2013, the programme funded a range

of actions including exchanges, study visits and networking activities. Projects are intended not only for individual students and learners, but also for teachers, trainers and all others involved in education and training.

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SHARED LIVING SPACE FOR STUDENTS: THE ROLE OF BACKGROUND AND EXPERIENCE

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Abstract
Individual student satisfaction rates with shared space in student housing vary. Assuming that sharing spaces is a trend towards a more sustainable way of life, there is need to have an understanding of the ways it can be more acceptable for those involved. This survey is focused on the role of the background and experience of students in the acceptability of using shared space. Analysis indicates that many parameters like economic situation, duration of living in student housing, educational field, family size and even the size of the home city can influence an individual's perception of and adaptation to shared space. On the other hand, it seems that shared spaces, where there are more similarities in individual student backgrounds are more successful. The survey results also show students with prior experience of living in dorms and those coming from larger/poorer families and small home cities are usually more satisfied with shared spaces than those who have never lived in a dorm before or come from small/richer families and larger home cities. The results of this survey can be helpful for both designers of future shared spaces and dorm managers who want to organise more effective use of shared spaces.

Keywords: *Shared space; dormitory; background; sustainability.*

1. Introduction

Sharing space is more sustainable because of more efficient uses of resources (Vale and Vale, 2009; 2013) but there are always potential problems. A survey of such a student dormitory in Iran with highly populated rooms and common spaces indicates that the feeling, usage, behaviour and reactions of residents are different, depending on a student's background and previous experience. Additionally, the particular combination of residents in a shared space also plays an important role in its effective use. This investigation suggests shared spaces can be improved if the combination of residents is selected wisely and/or the shared space is purposely designed to suit the characteristics of the residents.

2. Background

Student housing has been researched because of the special nature of the facilities and associated behaviours (Mullins and Allen (1971); Riker and Lopez (1961)). This research can be broadly categorised to four types. The first group has focused on the influences of different aspects of the facilities on student satisfaction. Foubert, Tepper and Marrison (1998) found predictors of student satisfaction in university residence halls, through focussing on facilities, room-mates, noise, safety and security. Roche, Flanigan and Copeland (2010) did similar research on trends, needs and preferences of users of student housing in Italy. Najib, Yusof and Osman (2011) did similar research in Malaysian universities, while Amole (2008) in Nigeria found differences in student satisfaction for bedrooms, floor and common hall. The second group has focussed on emotional points of view, such as student housing as home. Thomsen (2007) investigated examples of Norwegian student housing and found these mostly had an institutional character.

Student housing is also a good place to observe social happenings like interaction and privacy. Amole (2005) found students could not fulfil all their privacy needs in their highly populated rooms. On the other hand, Rutledge (2012) found the enforced sharing in student housing could improve social interactions and build strong social relationships. The forth research type looks at the role of individual differences in the process of adaptation and satisfaction (Altman, 1975), and is the area of investigation of this paper.

Of particular interest for this research is how the students' background affect their adaptation in different situations. Research shows the economic status of students has a linear relationship with their satisfaction with facilities (Amole, 2009), supporting previous findings by Amole and Mills-Tettey (1998); Gifford (1997, 2001); and Kellekc and Berkoz (2006). Najib, Yusof and Sani (2012) researched students' socio-physical backgrounds and satisfaction with their student housing facilities in three Malaysian universities. Within these 91.3% of students were living in shared rooms and they found students with a better economic situation were more satisfied, concluding that this might be related to their ability to choose their facilities. However, Thomsen and Eikemo (2010) in Norway found the rate of satisfaction was not significantly related to a student's economic situation. Other studies have looked at the role of resident age and Christie et al. (2002) found older students had better skills in accessing satisfactory accommodation. Amole (2009) further found a linear relationship between length of stay in student housing and satisfaction with facilities. Najib, Yusof and Sani (2012) found the rate of satisfaction with living in shared spaces had a relationship with a student's experience of living in a shared space in their parental home. Kaya and Erkip (2001) also researched satisfaction with dormitory buildings and found expectation of students for privacy differs with their family size. On the other hand, they found no relationship between perception of room size and a student's family size (Kaya, Erkip, 2001). Gender difference affects adaptation in student housing as Doygun and Gulec (2012) found female students prefer dormitories more than male students. Additionally, Amole (2005) found that males and females choose "highly different" territorial strategies in a high populated dorm room.

3. A brief review of the case study and its residents

Boy's dorm number one of Yazd University in Iran is a five storey building, including a basement level, with a central corridor in each of the residential floors and a total built area of 5200 m^2 (Khajehzadeh, 2006). The linear plan is oriented east to west so half the student rooms face north and the other half south, which is hardly ideal in a hot/cold winter desert climate (Khajehzadeh, 2006). The main spaces including the student rooms, communal kitchens, toilets and baths are located in ground floor to third floor (four levels), all with the same plan, and the underground level consists of a common room for praying and watching TV (a praying room in all public spaces is mandatory in Iran), storage and the boiler room (Khajehzadeh, 2006). Access to the upper storeys is via centrally placed two staircases, with residents using the ground floor corridors to access upper levels (Khajehzadeh, 2006).

The area of each shared student room is 20 m^2, this being a square space with two 2×1 rectangles added to each side for two fixed bunk beds (Khajehzadeh, 2006). There is a common 3.5 m^2 balcony between each pair of rooms. The rooms were designed for 4 students but because of a lack of available dorms, when the study was done most rooms were being used by 5 students. There are 16 residential rooms, 7 toilets, 4 bathrooms and a kitchen on the ground floor shared by 80 residents. Every other level has 25 student rooms, 8 toilets, 10 bathrooms and a kitchen shared by 125 residents (Khajehzadeh, 2006). Each room has 5 wooden lockers, four fixed beds, one additional bed (or foldable mat), two book cases, one study desk with chair and one shoe holder. Every five rooms share a fridge located in the corridor somewhere between them (Khajehzadeh, 2006).

The population of Iran comprises several tribes; Fars (65%), Turk (18%), Lor (6%), Arab (2%), Baluch (2%) and Kurd (7%), with different languages and habits (Statistics centre of Iran, 2013), although there are many common behavioural habits. Yazd University is located in the centre of Iran with a population of 100% Fars. According to government regulation, universities are usually filled by students living in the neighbouring provinces (also 100% Fars) so most students in the case study are from the Fars tribe.

Yazd University delivers different majors at different levels from Bachelors to PhD. In Iran, engineering and science majors are more popular than humanities, and families in large cities prefer their children to study the former. Conversely, most humanities students come from small cities and rural areas. In this survey, cities of more than 1,000,000 are “Big”, those between 100,000 and 1,000,000 persons are “Medium” and those with less than 100,000 persons are “small” cities. Consequently, in this survey 62.3% of engineering students are from “Big”, 17.0% from “Medium” and 20.7% from “Small” cities, and 25.0% of science students are from “Big”, 37.5% from “Medium” and 37.5% from “Small” cities. Additionally, 21.6% of humanities students are from “Big”, 32.4% from “Medium” and 45.9% from “Small” cities.

In this dorm, rooms are normally filled by bachelor students from different majors in the same year but students can swap although this has to be arranged between the students and the dorm manager (Khajehzadeh, 2006). This rarely happens, because finding someone in a favoured room who will to move with the acceptance of all residents of both rooms is not easy. According to the dorm manager who was interviewed as part of this study, the aim is to accommodate students of the same tribe in the same room (Khajehzadeh, 2006).

4. Methodology

Observation and a paper based questionnaire were used for collecting data. Observation was possible as the first author lived in this dorm for a year and was familiar with its problems, but to complete the information, days were spent in different parts of the dorm talking and living with students and collecting data using voice recording, taking photographs, writing notes and drawing plans. Private rooms, public common spaces such as kitchens, toilets, baths, corridors, and praying and TV room were all observed in this way. The dorm manager and a number of students were also interviewed.

To support and control observations, a questionnaire of 24 questions was administered to a cross-section of students. Questions were a mixture of rating options, choice selections, short answers and drawing. The questionnaire was completed by 100 students. Students were selected from different storeys and rooms in each storey facing different directions and having different distances from public spaces. This helped to ensure a mixture of different quality rooms in the sample. In addition, students were selected from different degree majors, family backgrounds and also from different cities of Iran. This helped to ensure different social/family backgrounds in the student sample.

Those completing the questionnaire were from Engineering (54.5%), Humanities (37.4%) and Science (8.1%) majors with no-one from Arts. All participants were aged 19-32 years with 81% of students aged 20-22 years. Analysis showed that 23.0% of the participants belonged to families with low (less than 2,000,000 IRR per month), 70% middle incomes (between 2,000,000 to 10,000,000 IRR per month), and only 2.1% from high income families (more than 10,000,000 IRR per month). According to the Central Bank of Iran a monthly income of less than 730,000 IRR per person (at the time the survey was done), is below the poverty line.

Participants also came from different sized families: 33.3% from families with 3-5 members, 54.0% from families of 6-8 and 12.6% from families of 9-13. Income was divided by the number of family members. The poverty line was a monthly income of 730,000 IRR/person in 2006 (Najm, 2008)) and this or below was assumed a “poor” participant, those with a monthly income twice this (1,460,000 IRR/month) had an “acceptable income” and those with a monthly income over twice the poverty line (1,460,000 IRR/month) were “rich”, producing 79.5% of students from poor families, 16.9% from families with an acceptable income, and only 3.6% from rich families. According to the analysis, 10% of the students had lived in the dorm for 2, 51% for 4, 32% for 6, and 4% for 8 semesters. It should be noted that this survey was done at the end of the second semester (May/June) so even new students had the experience of two semesters of living in the dorm.

5. Data Analysis

5.1. DURATION OF LIVING IN THE DORM

It seems if shared spaces are used longer the rate of satisfaction also increases, as residents adapt to sharing. This trend can be seen in all common facilities (kitchens, toilets and baths) although not for the praying and TV room. Satisfaction with private rooms seems not to change much with the duration of living in the dorm (see Table 1). As mentioned before, the praying and TV room is located in the basement floor and because of the absence of elevators, access to this space is difficult for most students and this could be the reason behind the low satisfaction rate with this space.

Students were asked if their initial emotional reaction to their crowded shared space changed over time. Most students stated their reaction reduced (48.4%) or did not change (26.8%) with 24.7% of students thinking it had increased. On the other hand, a comparison between the results and the duration of living shows that while there is no steady linear pattern students who have lived in the dorm for 4 or more semesters think that their reactions to crowded spaces have reduced more than the new comers (Table 1). Additionally, Table 1 indicates that in most public spaces students who have lived in the dorm for a longer time have greater senses of ownership of its public spaces. Comparing students of each different term of residence independently shows this trend can be seen for the bath, kitchen and toilet but not for private rooms, praying and TV room and corridors. However, comparing satisfaction rates between two groups of students who have the experience of living in the dorm for 4 semesters and more and new comers (2 semesters), then the sense of ownership increased for those who had lived there longer for all spaces except the praying and TV room (Table 1). These findings support the findings of Amole (2009). It should be noted that the number of participants who lived in the dorm for 8 semesters is low (4 persons) and so the figures in the last column are not reliable.

Table 1 Residents' reactions to crowded shared spaces and percentage of students with sense of ownership of different spaces in the dorm with different lengths of residence

		Duration of living in the dorm (semesters)				
		2	4	6	8	4 & 4+
Change in emotional reaction to crowded shared space	increased	40.0%	19.6%	28.1%	25.0%	23.0%
	decreased	40.0%	52.9%	43.7%	50.0%	49.4%
	unchanged	20.0%	27.4%	28.1%	25.0%	27.6%
Sense of ownership of different spaces in the dorm	Private room	80.0%	87.5%	87.5%	75.0%	86.9%
	Bath	30.0%	43.5%	40.0%	75.0%	43.7%
	Praying/TV room	22.2%	x8.3%	00.0%	00.0%	x4.9%
	Kitchen	00.0%	x8.7%	x9.7%	25.0%	x9.9%
	Toilet	11.1%	29.2%	30.0%	50.0%	30.5%
	corridors	00.0%	x8.5%	x3.2%	00.0%	x6.1%

5.2. FAMILY-SIZE

It seems students from large families can tolerate a crowded shared space better than those from smaller families. Analysis shows a slight difference in sense of room size for the latter students who see the room as small (see Table 2). Assuming students from large families are more likely to have lived in shared spaces in their parental houses, these findings here do not support those of Kaya and Erkip (2001). On the other hand, Table 2 indicates students from smaller families are more satisfied with shared spaces like the kitchen and bathroom but the rate of satisfaction with the toilet does not change much with family size. This trend is reversed for the praying and TV room. Additionally, it seems students from very big families are more satisfied with their private room compared to others (see Table 2). Again, assuming students from large families are more likely to have living in shared spaces at home then the findings for spaces like praying and TV room and your room support the findings of Najib, Yusof and Sani (2012) but those for kitchen and bathroom do not.

Table 2 Relationship between resident's sense of room size, rate satisfaction with different spaces of the dorm, ideal room population, and quality of residential rooms for privacy and family size

		Family size of the resident		
		3-5	6-8	9-13
Resident's sense of his room size	Big or Well sized	20.7%	26.1%	27.3%
	Small or Very small	79.3%	73.9%	72.7%
Satisfaction with different spaces	Your room	70.4%	66.0%	72.7%
	Kitchen	25.0%	23.9%	9.1%
	Bath	44.8%	40.0%	27.3%
	Toilet	17.3%	17.0%	18.2%
	Praying and TV room	24.1%	28.9%	50.0%
Ideal room population	1	3.4%	00.0%	00.0%
	2	17.2%	12.8%	18.2%
	3	41.4%	48.9%	27.3%
	4	34.5%	34.0%	45.4%
	5	x3.4%	x2.1%	00.0%
	More than 5	00.0%	x2.1%	x9.1%
Your room provides a good quality for your privacy		60.7%	66.7%	63.6%

Table 2 also indicates most students from very big families (9-13 persons) prefer rooms with 4 persons while others prefer rooms with 3 persons, suggesting people who used to big families prefer sharing spaces with more people. Students in this dorm did not experience the same sense of privacy in their rooms. Some students could not tolerate the situation and used territorial strategies or even left the room to achieve their desired level of privacy. Table 2 shows the relationship between family size and sense of privacy in private rooms, showing students from small families have the least satisfaction with the acquired privacy level in their rooms, although there is no linear relationship apparent (see Table 2). These findings support those of Kaya and Erkip (2001) who found that student expectation of privacy differs with family size.

5.3. ECONOMIC BACKGROUND

As shown above, the number of participants from rich families is low (3 persons) and so the relevant analysis is probably not reliable but the results for participants from poor and moderate families indicate a meaningful relationship between a resident's economic status and rate of satisfaction with some shared spaces. According to Table 3, residents from poorer families are more satisfied with the shared kitchen, bath, toilet and praying and TV room facilities. On the other hand this relationship is not seen in the private rooms. These findings do not match previous research by Amole (2009), Amole & Mills-Tettey (1998), Gifford (1997, 2001), Kellekc & Berkoz (2006), and Najib, Yusof and Sani (2012). Students were also asked whether their shared room felt big or small but analysis indicated no meaningful relationship between sense of size of the shared room and economic situation.

Table 3 Relationship between resident's economic status and duration of using a shared space and his satisfaction with shared spaces

Percentage of students satisfied	Economic status of the resident			Duration of living in the dorm (semesters)	
	poor	moderate	rich	2	4 and 4+
with their room	67.7%	69.2%	66.7%	66.7%	65.1%
With the kitchen	23.1%	23.1%	00.0%	11.1%	23.5%
With the bath	44.6%	38.5%	00.0%	40.0%	41.2%
With the toilet	21.2%	7.1%	00.0%	10.0%	17.2%
With the praying and TV room	30.2%	28.6%	33.3%	70.0%	27.4%

5.4. SIZE OF HOME CITY

Students in this survey came from different cities, with 43.0% from "Big", 24.0% from "Medium" and 31.0% from "Small" cities. Analysis further indicates percentage of students from "Large" cities who think their room is good or excellent for privacy is less than those from "Small" and "Medium" cities (see Table 4), suggesting sense of privacy could be related to the size of a student's home city. Satisfaction with the shared spaces of the dorm also differs according to home city size. According to Table 4, students from small cities are more satisfied with the shared facilities in comparison to others. This trend can be seen for all common facilities including the praying and TV room but not for private rooms.

Table 4 Perception of privacy in student rooms, satisfaction with different shared spaces of the dorm and ideal room population for students from different sized cities

		Size of home cities		
		Big	Medium	Small
How is your room quality for your privacy	Bad/moderate	46.3%	21.7%	26.7%
	Good/excellent	53.6%	78.2%	63.3%
Satisfaction with different shared spaces of the dorm	Your room	66.7%	73.9%	61.3%
	Kitchen	25.0%	12.5%	25.8%
	Bath	37.2%	34.8%	48.4%
	Toilet	14.0%	16.7%	19.3%
	Praying/TV room	27.9%	30.4%	36.7%
Ideal room population	1	00.0%	00.0%	x3.2%
	2	x9.3%	12.5%	32.2%
	3	44.2%	45.8%	35.5%
	4	39.5%	37.5%	29.0%
	5	x2.3%	x4.2%	00.0%
	More than 5	x4.6%	00.0%	00.0%

Additionally there is no difference between the ideal room populations of students from different cities as most prefer 3 persons in a room, with a slight trend for those from small cities to prefer fewer and those from bigger cities more occupants (see Table 4). The reason behind this might be that families in large Iranian cities usually have to live in small houses because of high land and house prices while people in small cities can live in bigger houses.

5.5. EDUCATIONAL BACKGROUND

In iran there is a difference between the family background of students who study engineering or science and those who study humanities. additionally, the nature of these disciplines differs (humanities students might be expected to spend more time in their room reading books and writing, while science and engineering students spend time in the lab and computer rooms).

In iran laptop computers were not popular at the time this survey was done (may and jun 2006). this perhaps explains why the survey found differences between students of different disciples and their preferred places for studying.

Observations indicate that humanities students study and work in their private rooms more than others. They also prefer not to go out of the dorm to fulfil their study needs, and humanities students prefer to study in the praying and TV room more than others. This, along with the outdoor spaces of the dorm and friends' houses are their first choices for studying if they cannot study in their rooms, while they use the library much less than the average use by all students. On the other hand, engineering students use the library more and the praying and TV room, outdoor spaces and a friend's room much less than the average. Additionally, science students select outdoor spaces and a friend's room more and do not use spaces like the library and friends' houses at all for their alternative study place (see Table 5), although the number of science students in the survey was small.

Table 5 Preferred alternative place of study related to study discipline

	Places students select for studying if they cannot study in their room					
Field of study	Study saloon	Praying/TV room	Library	Outdoor spaces of the dorm	Friend's room	Friend's house
Humanities	40.0%	34.3%	5.7%	11.4%	8.8%	9.1%
Engineering	64.7%	14.0%	16.0%	3.9%	4.0%	2.0%
Science	62.5%	12.5%	0.0%	14.3%	12.5%	0%
Average percentage	55.0%	21.3%	10.7%	7.5%	6.5%	4.4%

Students were asked for their ideal number of students to a room. Analysis indicates humanities students prefer less populated rooms (2-3 persons) compared to science and engineering students (3-4 persons), which might be related to the fact humanities students use their room more for studying.

Students were also asked whether they were satisfied with the different spaces of the dorm. Analysis indicates the rate of satisfaction with common spaces like toilets, baths and kitchen did not differ much according to the student major, except for the big differences for the two spaces of "your room" and "praying and TV room". The reason behind this might be linked to the activity of "studying" which happens in both places and the differences could be related to the fact that students of some majors can study in the shared spaces while others cannot. It seems that both places are the worst for science students. On the other hand, engineering students are much more satisfied with their rooms, which might be related to the fact most of them do not study there but only use it for social interaction and sleeping. The reason might relate to the previous experiences of students and the fact that engineering students are more likely to come from “Big” cities (62.3% of engineering students). This finding tends to support Altman’s (1975) statement that people who have lived in large cities for years are better at regulating their interaction level in a shared space (Table 6). Students of different majors have different perceptions of their room size. According to Table 6 all science students think their room is small or very small. The rates for engineering and humanities students are respectively 81.8% and 70.3%. It seems that students of more analytical and intellectual majors (science and engineering students) feel they need bigger rooms compared to humanities students (Table 6). This might be related to their experiences in their parental houses, although this was not investigated in this survey.

Table 6 Rate of satisfaction with dorm spaces and sense of room size for students of different majors

		Engineering	Science	Humanities
Satisfaction with rooms	Your room	78.8%	37.5%	54.1%
	Kitchen	19.2%	12.5%	27.8%
	Bath	44.2%	37.5%	35.1%
	Toilet	16.7%	25.0%	13.5%
	Praying and TV room	25.0%	12.5%	44.4%
Resident’s sense of his room	Big or Well sized	18.9%	00.0%	29.7%
	Small or Very small	81.1%	100.0%	70.3%

6. Discussion and Conclusion

Sharing spaces is a practical way of moving towards sustainability. Although, this has been a tradition in many societies in the past it is less familiar in modern lives except in situations of crisis (like lack of financial resources or man-made or natural disasters). However, accepting a situation in which humanity is not permitted to use the natural resources of the next generation (Brundtland, 1987). It seems humanity is already living in a crisis situation as in 2010 the ecological footprint of humanity exceeded the biological productive capacity of the planet by approximately 50% (Ewing et al., 2010). This is, therefore, a critical to learn how to live more sustainably and save resources, including learning more about how shared spaces work and how to make them work better.

A shared space consists of two parts: the physical part (shared facilities and floor areas) and a behavioural part (human), with the ideal situation being one in which both parts operate effectively. Most research has been undertaken on the first part with little focused on the role of user characteristics in the success of a shared space. Designers need to be aware of the latter, meaning they should not design shared spaces if they are not familiar with the characteristics of the users, since a shared space can work some users but not for others. Results of another study on the physical aspects of the same building show that a better architectural arrangement of spaces within the same overall structure can lead to a potentially more satisfactory student living environment (Khajehzadeh and Vale, 2014).

The results of this research indicate that users with different backgrounds and characteristics may share spaces successfully because their perceptions and experiences of living in this way are different. In other words, a good and successful shared space is one designed for the characteristics of the residents. In this research, the financial situations, family size, duration of living in a shared space, the city or country they come from and even the major they are studying are among the parameters that impact on the success rate of shared space in a student dorm.

The results indicate that students with a better economic situation prefer more private rooms. The same is true for students from small families or those who have not had the experience of sharing space in their parental home. On the other hand, students with a worse economic situation can cope with crowded shared spaces more than others. Additionally, students who belong to large families and have had the experience of sharing space at home tend to be more satisfied with shared spaces. It seems having shared spaces designed for different numbers of occupants and having some private rooms in a dorm building would better meet the different student background characteristics.

Students from the same country, ethnicity and city also seem to form more successful groups in shared spaces. The findings of this survey indicate differences in expectation of privacy and satisfaction with shared facilities for students who have grown up in large and small cities. Interviews with students and the dorm manager also showed that both students and officials prefer rooms for students from the same city and tribe.

The duration of living in shared spaces has an influence on the user perception of these. This research indicates that students who stay longer in the dorm, are more satisfied with and have more sense of ownership of shared spaces. Additionally they are more likely to enjoy the crowded situation of a shared space.

Students of different majors have different needs because of the nature of their courses. A room with a defined area, population and facilities may be very efficient for a group of science students but much less so for a group from engineering. It seems shared rooms should be designed more carefully according to the kind of behaviour likely to happen there.

Finally, the results of this survey could be useful for designers by making them aware of the very important role of users and their characteristics in shared spaces. It is also useful for managers of existing dormitories and similar buildings when it comes to allocating rooms. A good result is where each room has students from similar backgrounds, including financial, educational, ethnicity and prior experiences of living in shared spaces. A great part of student requests in the dorm surveyed was for swapping rooms to create groups of students from the same city or undertaking the same major, a trend the dorm manager has tried to accommodate, suggesting that both students and the manager have found this approach to be most effective and sustainable one.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 240–252. ©

INVESTIGATION OF LOCAL HAND KNITTING CRAFT PRACTICES FOR BUILD A RESPONSIVE TEXTILE ENVIRONMENT ON THE ACTIVE HUMAN BODY

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Abstract

Literature of the knitwear says, it originated to satisfy the functional aspects of human, at present it has gone beyond a mere functional aspect and has assumed a fashionable value in the clothing industry and keeps spreading rapidly. The main objective and the intention of this research is to experimenting innovative textile developments to the active wear fashion with a novel conception. Main hypothesis is to be 'By using an inherent quality of local hand knitting craft practice, molding different three dimensional(3D) voluminous spaces and handle the voluminous space in between the human body and the fabric is a most important thing to build a responsive textile environment on the active human body. Initially the research would be paying more attention to the inner side of the textile material and innovative textile fabric material is designed and practice here by making use of 3D structural, architectural and sculptural hand knitting potentials. The knitted layer here is interpreted as a second skin on the biological skin of man. That is by making use of the idea related to this research. This is namely, "Responsive Knitted Skin with Voluminous inside Spaces". The research would be paying more attention to the inside knitted spaces in between biological skin and knitted skin and there are three types of sub inside knitted spaces introduced through this research.

Keywords: *3D Hand knitting, local hand knitting craft practice, responsive second skin, functional to fashionable*

1. Introduction

Hand knitting technology is a very valuable hand craft technology with several features inherent in it. The special features in it can be ability to create 3D forms and textures on one production process, structural and Architectural forms, stretchable fabrics by using non stretchable yarns and moulds of sculptural forms. Out of these qualities, some of them are used in the fashion industry presently and are being debated. As at present there is a good demand and inclination towards the use of 3D techniques even in hand knitting techniques. But still, although there are good skilful hand knitters with techniques within Sri Lanka, there is no adequate attention interest shown about this aspect. In this research it is expected to divert the attention more towards inner side of the fabric than the outer surface of the knitted fabric. In other words, concentrate more on the in-between spaces of the human body and the fabric. The innovation part of this research is to create 3D textures and 3D forms with different voluminous spaces on the inner side of the knitted fabric by making use of the potentials of 3D structural, architectural and sculptural hand knitting. If it is necessary to create 3D textures and forms as mentioned above by making use of any other technology, it would be necessary firstly to create a 2D textile fabric and secondly 3D textures and forms have to be created by using different fabric manipulating systems. But the unique ability and the feature of hand knitting technology is that, in the process of developing the fabric itself it can create different voluminous spaces with 3D textures and 3D forms to the inner side of the fabric.

2. Aim and Objective

The main objective of this research is to experimenting innovative and responsive textile developments for active human body with a novel conception.

3. Methodology

The research would be a practice led approach with engaging local hand knitting craft communities. Initially, identify the local hand knitting craft communities with unique potentials and start relevant experiments through their existing practices. Subsequently continue the appropriate experiments with design intervention. Finally In keeping with the concept an innovative hand knitted textile materials were designed through experiments. When the designed materials are used as a functional to fashionable' Environment/skin on the human body, all features such as silhouettes, forms and patterns were also experimented to check the suitability of the responsive textile environment, if not responsive knitted skin on a human body.

4. Fashion and Textiles for Human Body

"....Are you happy with your body? Some people are not – if not yours somebody's and have tried to disguise it, hide, reshape it, transform it, and remake it in to a cultural object" (Koda, 2010)

As at present, man has become much more conscious about his body both internally and externally than in the distant past. By now fashion has become a very significant external medium of responding to the human body. Fashion has also achieved a unique status as a medium of transforming the human body and also as a medium of de contextualizing and restructuring when creating a design considering the human body, one cannot do it solely on the material alone, but in this regards the presence of a strong structure also plays a vital role. In order to get various complex human needs such as protection, adornment, identification, modesty, status, value, attitudes and conformity versus individuality fulfilled garments are used. At the same time, a rapid progress in technologies, techniques and materials etc... could be seen in fashion industry today.

5. Knitting Industry, Hand Knitting and 3d Knitting

Knitting industry has made its control and importance felt in the fashion world all over. Knitting fabrics made by employing advanced technological techniques have a big demand in the fashion market currently. As at today, machine knitting technology too has reached its peak while knitting technology as well as knitting techniques appears in different forms in the fashion world. 3D structural knitting garments which are of wearable quality and condition appear to be in high demand in the modern fashion world. 3D knitting is utilized not only for the manufacture of wearable garments, but also in various other areas of disciplines 3D knitting is applied. The designers seem to make use of 3D techniques mainly to display their creativity skills, for communication purposes and for the socialization of message etc.

Irrespective of the high degree of progress the machine knitting techniques have reached, the popularity and the demand for hand knitting industry has not in any way got reduced. The reason for this is that many knitting designs and creations could be created by using the hand knitting technology which the machine knitting cannot create. For example, the 3D knitting techniques mentioned above could be created very well by making use of the hand knitting technology. In addition, by making use of the hand knitting industry which makes use of the craft skill of men is accepted as a more valuable industry.

6. Fashionable Knitting and Fashionable Wearable Concept

"Fashionable knitting" when considered in general, people tend to think of it as knitting carried out according to the latest trends or prevailing styles.

However, when the history of knitting is examined, it reveals very clearly that, “functional knitting” is a strong medium of knitting responding to the human body and the functionality of the human body. With the passage of time along with the development of functional knitting to fashionable knitting within the fashion world,” fashionable knitting” has received a deeper meaning to it is not just knitting designs or techniques carried out only with the objective of an aesthetic value, but done giving the “fashionable wearable” concept prominence. In the text “Fashionable Technology” by S. Seymour, he points out the fact that “Fashionable wearable” concept is a result of blending aesthetic and styles with that of functional technology. “Fashionable wearable are designed garments, accessories, or jewelry that combines aesthetics and style with functional technology.

“....as designers of fashionable wearable, we view end user as fashionable beings who are attentive to style and the powerful potential of wearable technologies. Our design philosophy is based on the notion that garments are the immediate interface to the environment and thus are a constant transmitter and receiver of emotions, experiences, and meaning.” (Seymour, 2008)

When the market development in the knitting industry from the functional to fashionable knitting techniques which occurred towards the end of the 19th century and at the beginning of the 20th century is reviewed, it is very clearly evident that “fashionable knitting” is not a knitting technique based primarily on aesthetics, but a more advanced state of a blend of both functionality and fashion ability than ever before. In fashionable knitting although fashionable wearable concept received a prominent status with the tag of “fashionable” conspicuously emerging, the “functional” aspect also got a prominent place during that time.

“Fashionable wearable can enhance the cognitive characteristics of our epidermis. Our clothing is often referred to as our second skin. Today this is more than just a metaphor as advances in technology produce fabrics that mimic many of the skin’s properties.” (Seymour, 2008)

S. Seymour in his text on “Fashionable Technology” has pointed out clearly that several factors are inter linked in the making of fashionable wearable.

“The many considerations for the construction of fashionable wearable are based on body ergonomics, perception, functionality, technology, materials, energy and environmental impact. The table below can be used as a guideline for the construction of fashionable wearable.” (Seymour, 2008)

Factor	Considerations
Body Ergonomics/ Wearability	Placement, form language, human movement, proximity, sizing, attachments, weight, accessibility, heat, body shape, comfort, cut of the garment, compartments.
perception	Aesthetics, look and feel, design, culture and psychological functions
Functionality	Usable interaction with the system (input & outputs), wearer's control, modular construction for multi- purpose
Technology	Ubiquitous computing, sensor technology, embedded systems design, physical computing
Materials	Interactive or reactive materials/textile, electronic textile, washing/ cleaning, shielding, durability
Energy	Batteries, solar, kinetic, fuel cells
Recycles	Ecological, biodegradable, modular construction for dissemble

7. Local Hand Knitting Craft Practices

For the sake of trade purposes in 1980 "Scandinavian method of circular knitting" was introduced for the first time to Sri Lanka. Knitting canters were established in Sri Lanka by Scandinavian countries like Norway for this purpose most of the women labor in Sri Lanka was obtained. Small knitting canters were opened in cities in the costal belt like *Balapitiya, Munnakkara*, Negambo, Galle, *Matara, Kalutara, Wadduwa, Wattala* etc... The main livelihood of those people was the fishing industry, but as they led very tough and poor lives, the hand knitting industry became an additional method of income to their families.

Hand knitting companies such as Dale Craft, Octa, CHF, KALARO started in Sri Lanka by now have provided training in knitting for about 4000 women. The knitters so trained have now been able to produce very high quality hand knitting finished products. The main Business concept of these companies was "The industry to Village".

Figure 117: Local Hand Knitters at Balapitiya

There is a special community engaged in this knitting handicraft along the coastal areas in 30 years with a very too rough knowledge, experience and with very high skills in this trade.

8. Inspiring Active Wear Trends

MAS active Linea Intimo (Pvt) Ltd, Biyagama, innovation team was awarded to development the most suitable knitwear fabric for the sportswear collection for the year 2012 expected to be produced by NIKE brand. The project was ‘Experimentation of Contemporary Three Dimensional knitting techniques for Nike Sport wears using machine knitting. Ms Sashi Hewakapuge, Senior Designer, Linea Intimo (Pvt) Ltd, Biyagama said that, their sportswear collection is meant for a men’s collection, while the material qualities that they expect also have been specified. MAS’ active has taken in to consideration few qualities for their special consideration, namely Breathability/ Ventilation (the ability to absorb and wick sweat away from the body fast), Compression (a firm fabric that is stretchy to get strong and high in modulus: able to firmly hold muscle during high impact strenuous workout and sport), Insulation (a 3D sort of fabric able to keep the warmth in harsh cold weather and protect muscles from cooling down too fast after workout and games) .According to the NIKE stipulations the quality requirements of the material expected to be developed must have all the above qualities or properties in that single material.

Unlike developing normal knitwear, in developing a sports wear a good knowledge of the human body structure is very essential. Here, in developing body related 3D knitting structures as stated before they have once again focused attention on the **‘Breathability/Ventilation’**, **‘Compression’** and **‘Insulation’**

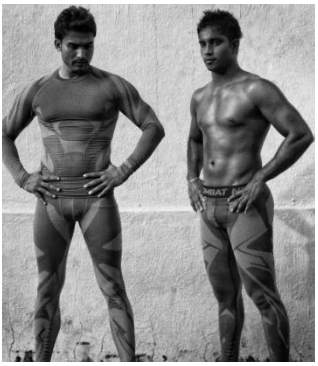


Figure 218:3D structural active wear

The above photographs show how, the 3D knitting structure is developed by the MAS active innovation team to achieve the above qualities when the knitted structure is worn. When the body parts get stretched, the narrow drains like grooves get opened due to the stretching, and provide good ventilation to the body due to the enhanced entry of air through the stretched spaces or openings from the outer environment. At the same time, however much the fabric is stretched, the muscles are kept in position preventing any damage and keeping them in correct position when engaged in sport activities.

The 3D knitting structure is developed to achieve all these properties or functions successfully. At the same time the body is kept warm and it is retained, so all these functions are fulfilled satisfactory by this 3D knitting structure developed. The 3D knitting structure is developed to achieve all these properties or functions successfully. At the same time the body is kept warm and it is retained, so all these functions are fulfilled satisfactory by this 3D knitting structure developed. The novel fabric structure with the 3D knitting techniques developed for NIKE brand by MAS active, a final garment was designed by placing these fabric structures in different places of the body so that the functional aspects of the fabric suits those different places. This process is called 'body mapping'. Finally to show to what extent this sportswear with the 3D knitting techniques match for a masculine body functionally and aesthetically it is put on to an actual masculine body with the final design. According to the case study, the three types of requirements (Breathability, Compression and Insulation) for sport wear, are the main reference to develop the unique inside hand knitted spaces in this research.

9. Raising a Research Question

Initially the research would concentrate on local hand knitting craft practices and their potentials. There are special communities and groups who possess about 30 years' experience in Hand knitting technology engaged in this hand knitting craft along the coastal areas. As stated above, the existing local hand knitting craft practices has many issues like they are concentrate only on export production, new experiments are not carried out with hand knitting techniques, not attempting to vary and modify knitting technology to produce new patterns and designs, attach more emphasis only to flat knitting, not making use of different kind of yarns for hand knitting practices, there is hardly any use of 3D structural, sculptural and architectural forms of hand knitting techniques. So main research question is to be how to build a responsive textile environment on the active human body through local hand knitting craft practices

10. Hypotheses

Main hypothesis is to be ‘By using an inherent quality of local hand knitting craft practice, molding different three dimensional(3D) voluminous spaces and handle the voluminous space in between the human body and the fabric is a most important thing to build a responsive textile environment on the active human body.

11. Building a Responsive Knitted Skin on the Human Body

Further, experiments are being carried out presently to find out how a knitted layer acts as an additional 2nd skin to the biological skin. Alana Clifton describes through her research, *‘SECOND SKIN: EXPLORING PERCEPTIONS OF CONTEMPORARY KNITTING’* how knitted skin act as a second skin. She said that,

Second Skin explores contemporary knitwear design functioning within the ‘high-fashion’ area of design. It challenges traditionally established rules and perceptions, and potentially blurs the boundaries of what is considered fashion design, into art. While conceptual fashion design has always been a debateable issue among fashion scholars as to whether it can be viewed as fashion, anti-fashion or possibly art, this work observes the influences of modernity and deconstruction in relation to knitting. Knitting has the ability to be manipulated and molded into two and three-dimensional forms through the knitting/making process. It is highly versatile can be highly patterned and textured, making it a unique medium. Through hand and machine knitting methods of making, the work interrogates the notion of ‘deconstruction’ by looking past the traditional knitted coverings for the body. Knitting here functions as a vehicle for ‘deconstruction’, with familiar garment structures transformed into disarticulated ‘body pieces’” (Clifton, 2007)

During this research, by using Hand Knitting techniques an innovative knitted textile will be experimented, as a trial and that is the most important and main part of this research. Here the 3D structural, architectural and sculptural hand knitting potentials are used; two methods are adopted to develop a textile with inside knitted spaces. They are namely, through knitted textures and knitted forms. The research would concentrate on various types of knitted textures and knitted forms with using different moods and inspirations. Using various kind of yarns like cotton, silk, metallic yarns, wool ect.. And yarns of different gages for those experiments. Subsequently, develop the inside knitted spaces by using the potentials of 3D structural, architectural & sculptural hand knitting technology. By the above two methods, mainly one type of inside knitted space can be designed namely, Inside knitted spaces in between biological skin and the knitted skin. The fabric development in this manner with different voluminous inside spaces can be categorised in to three types of inside spaces based on the purpose for which it can be used as a 2nd skin on a biological skin. They are; **Breathable inside spaces, Compressible and moveable inside spaces** and **Insulating inside spaces**

11.1 BREATHABLE INSIDE SPACES

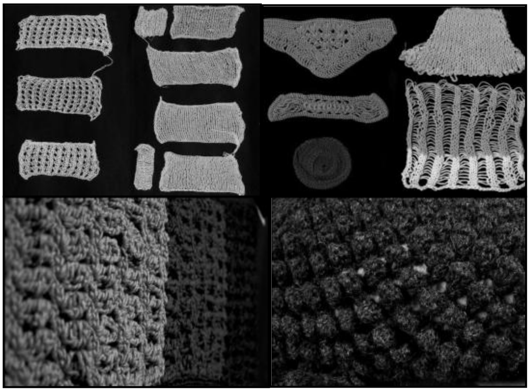


Figure 3: experiments of breathable knitted spaces with and without 3D quality

Here, the inside spaces are designed in such a manner to create a very efficient ventilation system between the body and the knitted skin. Here the important feature is that 3D textures and the 3D forms of quality of the knitted structure is retained as it is, with holes facilitating the exchange of gases very smoothly. Firstly I experiment Breathable knitted fabric without 3D quality. After that I tried to create the breathable knitted spacer fabric with 3D quality.

11.2 COMPRESSIBLE AND MOVEABLE INSIDE SPACES

The inside spaces designed here between the body and the fabric varies from zero to different volumes in keeping with the corresponding body movement showing its ability for moving freely. By using a non-stretchable yarn and applying knitting technology a stretchable textile was designed and then using this stretchable quality an inside spaces was designed and it was developed so that it would be changed from zero up to different volumes. The special feature here is within the frame of the 3D textures and the 3d forms all the above mentioned material developments are will be carried out. If attention is focused to examine how this 3D knitted fabric with compressible and moveable inside spaces act, it can be seen that this is able to hold the body muscles very strongly and it capable of functioning as a firm fabric varying the volume of the inside spaces in keeping with the corresponding movements of the biological skin.

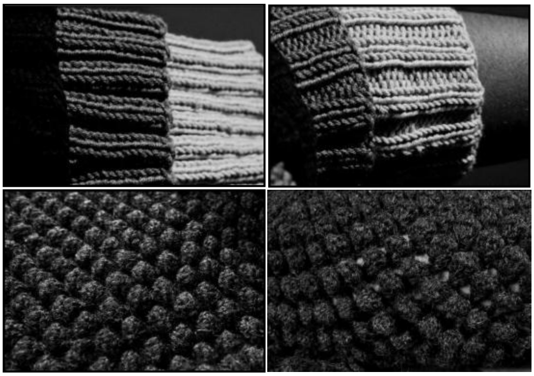


Figure 4: experiments of compressible and moveable knitted spaces

11.3 INSULATING INSIDE SPACES

Designed here a 3D fabric with different textures and forms. These types of inside spaces create 3D textures and forms to outside. This knitted material therefore can provide protection; retain the warmth, protect the muscles and acts as a 2nd skin.

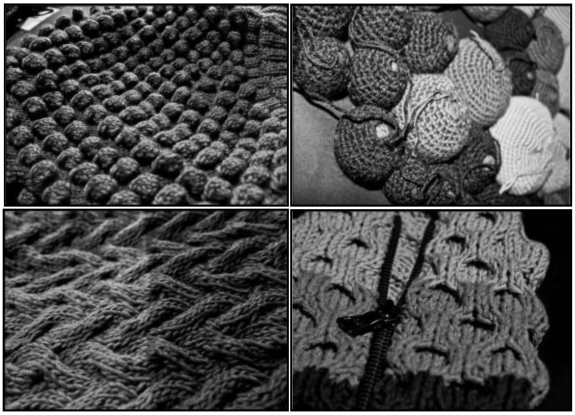


Figure 519: experiments of insulating knitted spaces

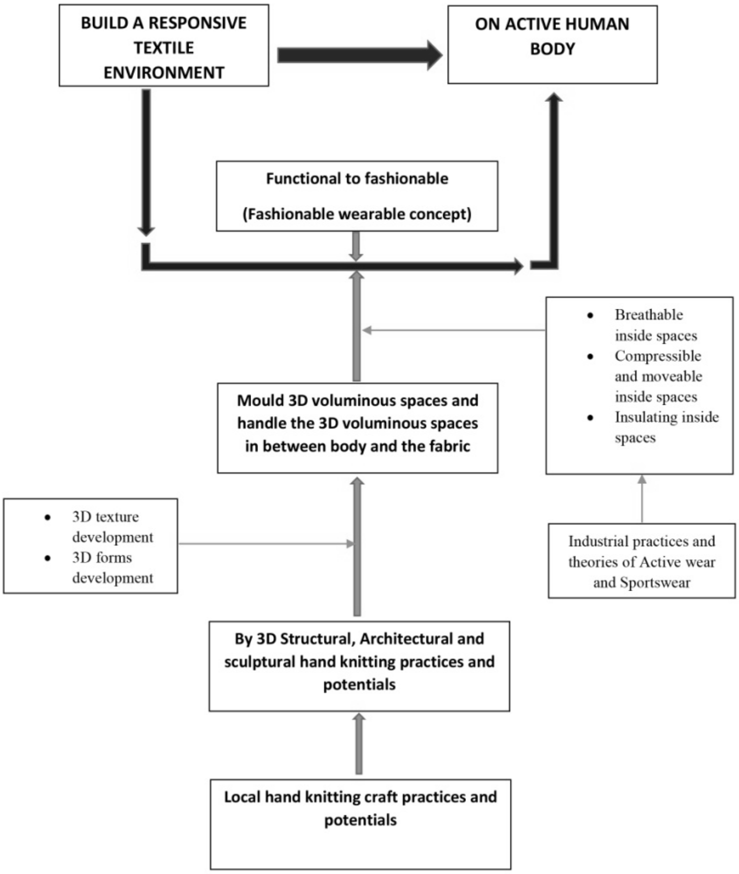
11.4. TEXTILE APPLICATION AND DESIGN PROTOTYPES

Figure 620: design prototypes

CONCLUSION, FINDINGS AND FURTHER STUDIES

Especially, this research is not carried out according to a brief or to fulfil the requirements of a client at all. It was based on the main concept of “Space in between”, and this basic concept was further developed supported by experimental studies to introduce the novel concept of the “Responsive textile environment (Knitted Skin) with Voluminous inside Spaces”. So it can be described as purely an academic research backed with practice led experimental studies. As an experimental research, studies were carried out mainly on three key topics, namely; **responsive knitted Skin, inside knitted spaces** and **functional to fashionable knitwear.** According to the ‘responsive knitted skin’ the knitted layer here is interpreted as a **2nd skin** on the biological skin of man. Through this research, hope to introduce **“Inside knitted spaces** in between biological skin and knitted skin”. By developing the above mentioned method, there are three types of sub inside knitted spaces introduced through this research. They are namely.

- Breathable inside knitted spaces.
- Compressible and moveable inside knitted spaces.
- Insulating inside knitted spaces.



Finally all those experiments have been demonstrated how to build a responsive textile environment on the active human body through local hand knitting craft practices and unique potentials.

By the way as the pointed out previously the modern man in using garments goes a step beyond covering the naked parts of the body. It shows very convincingly as at today that garments act as highly advanced and active second skin with **functional aspects as well as fashionable aspects**, very close to the biological skin of man, because of this very reason, several important facts for launching this research have been identified. They are summarized below,

- As an important research study to explore the **potentials that the hand knitting technology** possesses as a knitting industry and especially as a **craft technique.**

- As a collection of study with various capabilities of knitting by making use of hand knitting techniques which cannot be done by other methods of using machines or any other machinery.
- To carry out trial experiments with the potentials of hand knitting technology to explore the **possibilities of developing 3D structural, Architectural and sculptural forms** further.
- To carry out trial experiments to see the possibility of using hand knitting and 3D structural and sculptural quality to **mould spaces** of different sizes **in-between the biological skin and the knitted skin**.
- To **introduce three new inside knitted spaces** by developing 3D structural and sculptural hand knitting techniques.
- It was possible successfully to develop inside spaces using 3D structural and sculptural hand knitting techniques during the production process itself.

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GENDER EQUITY IN DISASTER EARLY WARNING SYSTEMS

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Abstract

Capacities of societies, communities and individuals or a social-ecological system to deal with adverse consequences and the impacts of hazard events define the resilience. New and innovative Emergency Communications, Warning Systems (ECWS) technologies and solutions improve resilience of the nations. Research shows that different types of systems (e.g. decision support, resource management, early warning, communications, and inter-agency) are highly valued in emergency and disaster events reducing live losses. As many individuals have online access today and young women have increased their online communication and young men tend to explore technology resources, the potential of using user friendly third revolution digital technology such as semantic features and devices (e.g. SMART phones) have the potential to improve the access to early warning/risk information supporting community decision making saving lives. These personal and social relations that reflect gender dimensions can certainly be examined improving resilience making communities more prepared for disasters with proactive decision making for early warning. Fostering awareness about gender equity which is the recognition of women and men as active participants in development can tailor made within the context of resilience and more specifically within early warning systems saving lives of the people at immediate risk including the dependence of mother's care (children and older people). In this context, this paper attempts to synthesis literature on the topic of gender equity within disaster early warning systems.

Keywords: *Disaster, Early Warning, Gender Equity*

1. INTRODUCTION

This paper is organized into key sections starting with the abstract, disasters in context, community preparedness for proactive responding, gender dimension, Early Warning Systems (EWS), conceptual framework, methodology and finding in the contexts of need for gender equity within

EWS and potentials for gender sensitive early warning with third revolution digital technology and conclusions. As an entry point disasters in context is explained in the following section.

1.1 Disasters in context

Over the last 10 years disasters have continued to impact on well-being and safety of persons, communities and countries claiming over 700 thousand lives, over 1.4 million injured and approximately 23 million homeless affecting more than 1.5 billion people by various ways. As a result, International mechanisms for strategic advice, coordination and partnership development for Disaster Risk Reduction (DRR) had been involved in disaster prevention. Taking example from the recent past Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in Sendai, Japan focusing on four priority areas such as understanding disaster risk, strengthening disaster risk governance to manage disaster risk, investing in disaster risk reduction for resilience, enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction. This highlights that, more dedicated action is anticipated tackling underlying disaster risk drivers and calls for a broader and a more people-centered preventive approach for disaster risk reduction improving resilience (SFDRR, 2015). Resilience or the capacity of a system, community or society potentially exposed to hazards to adopt by resisting or changing reaching and maintaining an acceptable level of functioning and structure within early warning system thus can play a vital role reducing risk drivers such as inefficient communication of risk information specifically early warning to the people at immediate risk resulting live losses (UNISDR, 2004). This capacity can also fill the gaps in preparedness deficiencies advocating proactive responding.

1.2 Community preparedness for proactive responding

Preparedness means the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current hazard events or conditions (UNISDR, 2009). Capacity can be discussed in various contexts but this paper attempts to discuss diverse community capacity in terms of preparedness within early warning systems. As a result, literature synthesis on understanding diverse community capacities in terms of gender based differences and gender relations, the ways in which a culture or society defines rights, responsibilities of men and women in relation to one another for improving preparedness will be discussed in detail (Mbunga, 2003). For example, specific gender factors that derive from the social relations between men and women are reflected in mobility of individuals as women are less able to move away from domestic responsibilities, that makes them more vulnerable for disasters(Centre for Policy Studies, 2001; Enarson and Fordham , 2001; Ariyabandu and Wickramasinghe, 2003; United Nations, 2006). Another example is mothers attend to the safety of children during disasters disregarding their own safety due to social bonding between the mother and the child. This has been proved analyzing the composition of tsunami victims of devastating tsunami 2004 on 26 December that struck eight countries in Asia and five in Africa claimed over 230,000 lives over representing women and children in death toll. The bodies of many women were found tangled with those of children or older people, which suggests that they died trying to save those dependent upon them (Ree et al., 2005). In addition, analyses of mortality rates indicate that due to poorer health, nutrition, living and working conditions of women make them 14 times more likely to die during natural disaster compared to men (AfDB, 2011). This highlights the need for recognizing gender dimensions in decision making during disasters for saving lives.

1.3 Gender dimension

As Moser (1993) highlights triple role of women (productive, reproductive, community managing roles) needs to be recognized to seek meeting strategic gender needs through direct state intervention giving political and economic autonomy and reducing inequalities with men. In gaining gender equity as proposed in the Women in Development (WID) approach, during the UN Women's decade 1976-85 recognizes women as active participants in development strengthening decision making systems. This is evident within early warning system that target saving lives of people at immediate risk including the dependents of mother's care such as children and older people.

Social studies research had also recognized equity as a central concern answering the intrinsic questions of power and positionality but ignores gender equity in Technology (Crocco et al., 2008). This is a critical omission intentionally or unintentionally which this paper critically examined within disaster early warning systems. Development of EWS can be discussed with reference to revolution of digital technology as explained in section 2.2 of this paper. However, access to and familiarity of digital devices and technology emerge with the internet access needs to be further explored improving networking capacities of the men and women in the communities at risk.

Women's interest in computer with the internet access is linked more to its capacity for delivering new ways to accomplish tasks or connect to others, than to technological features like its power or speed, which hold interest for men (Venkatesh and Morris, 2000, as cited in Brown et al., 2003). Women's interest on connect to others needs to be further examined and strengthened as a measure of building networking capacities of women during early warning saving lives of them and the dependents. There are influential factors in girls' changing interest in computers such as male-dominated computer use, societal gender bias, and gender bias in computer software (AAWU, 2000) as mentioned before become important in this regard. Recent research by Bain and Rice (2007) indicates that girls and boys have relatively equal interest in computers as far as middle school. While conducting a study of project-based learning in which middle-school girls and boys collaborated for ten weeks, researchers found they had to intervene to make a gender equitable learning environment (Ching et al., 2002, p. 178; McGrath, 2004). This suggests women's and men's equal access to technology needs to be facilitated by external decision makers. This is an important consideration in EWS as early warning is generated externally expecting proactive response by the communities internally saving lives.

1.4 Early Warning Systems

A critical consideration in early warning systems is informing diverse community groups ensuring proactive and accurate responding of those who are at immediate risk. Therefore in developing early warning systems, an essential requirement will be to recognize that different community groups have different vulnerabilities according to culture, gender or other characteristics that influence their preparedness capacity and proactive responding to early warning. As a result, influencing the institutionalization of early warning process within communities. In achieving institutionalization of early warning process gender based responsibilities within the community saving lives during a disasters become important. Women and men often play different roles in society and have different access to information in disaster situations. Therefore, information, institutional arrangements and warning communication systems should be tailor made to meet the needs of men and women in the vulnerable community (EWC III, 2006). For example, as Zillman (2003) points out, an increasing number of governments have implemented meteorological and hydrological warning systems for reducing disaster impact through a top bottom approach. Nevertheless, a comprehensive review of issues related to early warning systems undertaken and presented by Mileti and Sorensen (1990) highlights that, a warning system means of getting information about an impending emergency, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger cannot be achieved with top down approach. Therefore, important aspects such as factors affecting how people receive and perceive warning information, how information is presented to individuals to ensure adequate response minimizing the impacts provoked by such events become key considerations. Mileti and Sorensen (1990) further identify four sequential processes which should take place when the warnings issued as below.

1. People receive the warning message
2. The warning message is understood
3. The warning message is believed
4. The warning is then personalized

When the warning message is personalized by those at risk it is expected people to react via execution of specific activities such as evacuation (Mileti and Sorensen, 1990). However, people believe in the warning message will depend on the degree of reliability or trust concerning the imminent event people assigned to the institutions or source of the information that is provided (Patton, 2008; Haynes et al., 2008). Therefore, credibility of the early warning provider is an essential consideration for people to react. People at risk can disregard warnings because of the credibility issues resulting life losses. Credibility is very much applicable with reference to gender roles such as mother's care giving role for children and elders protecting their lives during a disaster. Highest credibility could be seen with mother's care giving role compared to all other gender roles such as father, grandmother, etc. This is a good opportunity to institutionalization of early warning process within the community for saving lives. In turn both women and men who have the potential to play the mother's care giving role will get the equal recognition that counts for gender equity.

Expected credibility can be gained through accurate forecasts and may be lost due to issuing false alarms. As stated by ISDR-PPEW (2005a; 2005b) and by de Leon et al. (2006), there are four basic elements which must be incorporated into every early warning system to make it effective.

1. Prior knowledge of the risks faced by communities
2. Technical monitoring and warning service for these risks
3. Dissemination of understandable warnings to those at risk
4. Knowledge and preparedness to act

Operational aspects of early warning systems can be illustrated with four sequential phases as follows (de Leon, 2003, 2005; de Leon et al., 2006).

1. Monitoring of precursors
2. Forecasting events

3. Warning: declaration and dissemination
4. Anticipated response

There are two important aspects to be considered here and the first one to be in a case of earthquakes and avalanches system do not really monitor precursors but rather all potential events and issue a warning as quickly as possible in case the events trigger a disaster. Second factor is that the early warning systems also encompass cross-cutting aspects such as governance issues ensuring vertical and horizontal cooperation, legal mandates delegating responsibilities to agencies to carry out monitoring, forecasting and emission of warnings, perceptions and expectations on the type and degree of response expected from institutions and people at risk according to different level of alerts/warnings. Operational aspects related to these systems such as communication systems and formats to exchange information among the different agencies and dissemination schemes and specific systems which originate from the type of hazards or events being targeted for early warning become important. Therefore it is understood that what information related to risk needs to be carefully select and present in an understandable manner to the target group is essential to improve the effectiveness of EWS. For example hazards maps can only represent the current state of knowledge in terms of probabilities of occurrence of events associated with particular period of return, in particular geographical area in the world. EW frameworks developed focusing above four sequential phases (monitoring, forecasting, warning dissemination and anticipated response) are formalized through Standard Operating Procedures (SOPs) institutionalizing of early warning process among the relevant agencies. However, SOPs are yet to be developed for working men, women as well as men and women in the domestic sphere providing mother's care giving role for children and older people.

Given the explained background the research gap, associated research aim, objectives and methodology of this study can be elaborated as follows.

1.5 Research gap, associated research aim, objectives and methodology

Even if the literature related to gender and disaster management intensely recognise the need of gender sensitivity improving disaster resilience, it barely identifies ways of achieving gender equity specially in pre disaster phase during early warning and responding to early warning using third revolution digital technology. Therefore, the overall research aims to critically examine the effect of third revolution digital technology on gender equity within disaster early warning systems. However, objectives of this paper within the overall research context can be elaborated as follows.

- Carry out a detailed literature synthesis on identifying the need of gender equity within early warning systems
- Examining potentials for gender sensitive early warning with the third revolution digital technology.

In view of synthesizing literature on gender equity in early warning systems extensive literature review was done referring journals paper, reports, case reports, assessments and related literature reviews. In addition, two discussions were conducted with the EW focal points of Disaster Management Centre and Department of Meteorology Sri Lanka to clarify case reports. Analysis of community decision making toward institutionalization of early warning process in the community with the use of third revolution digital technology was carried out. Third revolution digital technology in early warning for improving community capacities achieving gender equity, strategies for gaining risk knowledge and communicating risk with the use to social support digital networks improving community preparedness were other areas focused synthesizing this detailed literature review. Detailed literature synthesis on the topic of gender equity in disaster early warning thus helps justifying the need to have gender equity within early warning systems and potential for gender sensitive warning with third revolution digital technology.

2.0 LITERATURE REVIEW

2.1 Need of gender equity within early warning systems

According to Castells and Cardoso (2005), networking societies with electronic based technologies can change social morphology, where key social structures and activities are organized around electronically processed information networks. As a result, operation and outcomes in processes of production, experience, power and culture can be modified. In this regard semantic features and SMART phone emerge as a result of third revolution digital technology can play a vital role. However, critical knowledge and evidence of disaster managing agencies become important to engage with community networks and support people playing a vital catalytic role bridging or linking emergent roles and strengthening disaster preparedness for early warning. Therefore reliable links between providers and users of warnings, capacity of communities and authorities to respond appropriately need to be considered. A failure in any of these elements can mean the failure of the whole warning system resulting life losses (Tsunami Early Warning Service Guidebook for InaTEWS, 2012). Factors such as people's knowledge on hazards that lead them for self-early warning and react appropriately, access to risk knowledge, ability to understand risk, need to react/ response to avoid risk, acting accordingly become importance saving lives due to disasters. This is an important social factor to be considered as children and women over represent in disaster death tolls. Therefore, political and governance environment should be sensitive enough identifying such social factors and promote access to risk information via familiar devices such as computers and mobiles phones.

With reference to Sri Lanka, social factors such as political environment and governance had influenced computer literacy in areas prevailed internal conflicts (Eastern and Northern Provinces) resulting low computer literacy. However, Jaffna belongs to Northern province had high computer literacy due to improved access to internet with the establishment of various institutions, communication centers, educational centres with internet access (Department of Census and Statistics, 2012) facilitated by the governance mechanisms after ending the internal conflict in 2009. This highlights, the importance of political and governance environment for improving computer literacy. Similarly computer literacy as well as familiarity with digital technology for improving risk knowledge is influenced by gender biased societal norms and digital technology usage norms and power structures within the communities. As highlighted before, there are three influential factors in girls' changing interest in computers such as male-dominated computer use, societal gender bias, and gender bias in computer software (AAUW, 2000). This can be further elaborated taking another example of woman with a high computer literacy getting more accepted by the traditional decision making hierarchies disregarding societal gender bias such as subornation of women. This motivates more women acquiring computer literacy and knowledge on technology usage. Therefore, access to internet is a better approach overcoming societal gender bias ensuring equity in accessing early warning information /knowledge for both men and women. This is a critical consideration in EW as highlighted before for saving lives of the people at risk specially the dependents of mother's care.
With reference to EW system in Sri Lanka it is evident that the features such as mobile applications have been developed called Disaster Early Warning Network II (DEWN II) for ensuring equal access to both men and women while ensuring last mile EW. Further, strategies at national level such as, use of female voice to send EW alters (recorded) through 77 number of EW towers along the coastal belt of Sri Lanka can be highlighted recognizing women as active participants due to community credibility on women compared to men. People at risk in the coastal belt believe in female voiced recorded alerts as males send false alerts climbing the early warning towers. In addition, high frequency of female voice compared males can reach long distance supporting last mile early warning. However, this high credibility on women compared to men within early warning system is yet to be adequately recognized institutionalizing early warning process within the communities at risk. This aspect can be further elaborated taking evolution

of tsunami warning systems that reflects revolution of digital technology in to consideration.

2.2 Potentials for gender sensitive early warning with third revolution digital technology

The evolution of Tsunami Warning Systems (TWS) reflects the development of Information Communication Technology (ICT). For example, computer systems in Phase 1 (Mainframe Era) were used for very dedicated Tsunami Warning System (TWS) functions in early times before year 1980. A strong influence of digital technology on TWS architecture became visible in Phase II (Microcomputer Era) with the digitalization of sensor data and the availability of microcomputer systems during the period of year 1980 -1990. Phase III (Internet Era) created the concepts and foundation for the architecture of modern TWS and their basic components which include decision support components, sensor systems and warning components during the period from year 1990 – 2000. The development of ocean-wide warning infrastructures happened in Phase IV (Ubiquitous Computing Era) since year 2000 up to date. This paper identifies Phase III (Internet Era) and transition from Phase III to Phase IV (Ubiquitous Era) as critical phases that improved access to warning information by both men and women at immediate risk. The standardization processes of component interfaces and the encoding of data were fostered by the development and success of the Internet promoted by the work of standardization organizations such as World Wide Web Consortium (W3C), Organization for the Advancement of Structured Information Standards (OASIS), Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) promoting data sharing and shared understanding. Nevertheless, unless access to right information on right time is ensured benefits of the technological advancement will not be able to trickle down to the communities. Prominent research shows that different types of systems (e.g. decision support, resource management, early warning, communications, and inter-agency) are highly valued in managing disasters (Zschau and Ku¨ppers, 2003; Glantz, 2003; Basher, 2006; Kapucu, 2006; Kurita et al., 2006; Thompson et al., 2006; Troy et al., 2008). For instance, some decision support systems research argues that shared understanding promotes sound communication and coordination across emergencies and disasters (Smith and Dowell, 2000; Thompson et al., 2006; French and Turoff, 2007; D'Antonio et al., 2009). The ongoing development of satellite, wireless, mobile, radio and internet based ICT should allow early warning capacity to expand and grow, subject to any supporting infrastructure limitations. In looking forward with optimism, it is anticipated that future research might examine the use of promising new digital technologies for communication as part of the Emergency Communication and Warning Systems (ECWS) capacity improving equal access to risk information by both men and women (Martin and Rice, 2012). It is equally important to understand that, how familiar men and women using electronic devices/equipment for accessing information. For example in Sri Lanka from total housing units, 78.8 % use TV, 68.9 % use radio, 78.9 % use mobiles, 42.4 % use fixed telephone connections, 15.0 % use desktop and 5.6 % use laptops (Department of Census and Statistics, 2012). This highlights in Sri Lanka many use communication electronic equipment and mobile had become popular compared to land phones, desktop and laptops due to intersecting benefits of easy accessibility in terms of low cost, no documentation requirements and equal access by any individual. Considering the electronic equipment usage highest percentage was recorded in urban sector (85.1%) compared to rural and state sector. In addition, from the total housing units 10.9 % had the access to internet from home comprised with 23.4 % urban, 8.6% rural and 4.1% state sector housing units (Department of Census and Statistics, 2012). On the other hand the capability of third revolution digital technology sending the same alert to mobiles and all media stations simultaneously contributes strengthening more capable, relevant and responsive interactions that support institutionalization of early warning process within the communities. This can be further facilitated with the improved access to SMART phones with internet. As Sri Lanka's total internet connections grew 68.4 % during 2014 largely supported by growth in mobile internet due to people's familiarity with SMART phones accessing internet based information. As a result Sri Lanka's mobile phone sales reached one million unities in the third quarter of 2014. (The Official Government News Portal of Sri Lanka, 2015). Usage of SMART phone is positively influenced on expanding insular bonding networks enabling horizontal information and knowledge flow (Akama, 2014). Therefore, this horizontal information and knowledge flow can be better utilized strengthening mother's care giving role as a measure of saving lives. This also helps better institutionalization of early warning process within vulnerable communities with improved access to information without barriers of mobility or subordination as interpreted in figure 02.

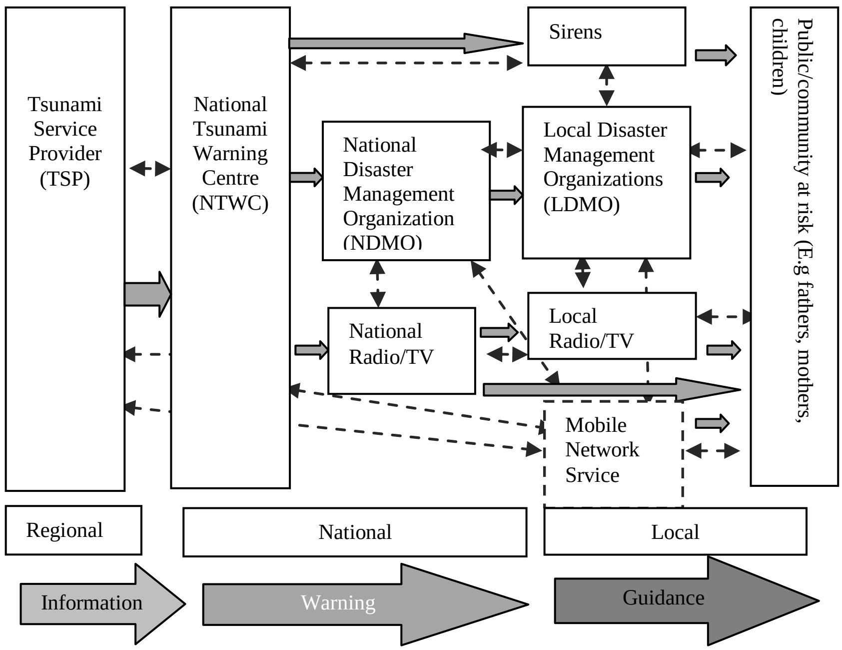

Figure 02: Tsunami Warning Chain with decision making for guidance at local level adapted from IOC/UNESCO (2015)

3.0 FINDINGS

Networking societies with electronic based technologies can change social morphology, where key social structures and activities are organized around electronically processed information networks modifying operation and outcomes in processes of production, experience, power and culture. This is a good entry point devising community capacities with digital technology improving community networking capacities proactively responding to early warning saving lives. As the evolution of Tsunami Warning Systems (TWS) reflects the development of Information Communication Technology (ICT) for networking and the Internet Era that is the third phase of development that created the concepts and foundation for the architecture of modern TWS and their basic components including decision support components, can be better utilized strengthening mother's care giving role as a measure of saving lives. This also helps better institutionalization of early warning process within vulnerable communities with improved access to information without barriers of mobility or subordination as explained in section 2.1. In this regard semantic features and SMART phone emerge as a result of third revolution digital technology can play a vital role. Usage of SMART phone is positively influenced on expanding insular bonding networks enabling horizontal information and knowledge flow. However, critical knowledge and evidence of disaster managing agencies become important to engage with community networks and support people playing a vital catalytic role bridging or linking emergent roles and strengthening disaster preparedness for early warning saving lives.

4.0 CONCLUSIONS

Use of third revolution digital technology and familiar devices such as SMART phones can improve equal access to early warning for both men and women at risk, filling knowledge gaps within the communities for better institutionalization of the early warning process and ultimately achieving gender equity overcoming gender biasness for saving lives. These literature findings confirm the need of gender equity within early warning systems and potentials for gender sensitive early warning with the use of third revolution digital technology achieving two key objectives within the overall research aim of critically examining the effect of third revolution digital technology on gender equity within disaster early warning systems highlighted in the methodology.

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THERMAL COMFORT IN LIBYA - FIELD STUDY

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Abstract

As part of the thermal comfort investigation in Libya a thermal comfort field survey was carried to set local thermal comfort temperature. This paper will present a field study results of thermal comfort in Libya. A thermal comfort survey has been held out in 39 domestic building across the three cities from three climatic zones, The criteria of selection only limited in free running domestic houses (naturally ventilated houses). Nearly 160 persons were included in this survey, they have been interviewed in their houses under their normal living conditions during the hottest (Summer), the coldest (Winter) and the moderate (Spring) periods of the year. The study investigates and assigns the thermal comfort temperature in three climatic zones in Libya, and three equations were concluded from the study, using the running mean outdoor temperature as predictor of the thermal comfort, that can indicate the limits of the comfort zones for the three cities. The paper also presents the researcher study on thermal insulation values for traditional Libyan clothing. The most common ensemble clothing for women and men were tested using thermal manikin.

Keywords: *Thermal comfort, Adaptive thermal comfort, Thermal insulation values for traditional Libyan clothing.*

1. Introduction

This paper reviews three thermal comfort studies that have been conducted in the three cities Tripoli, Ghadames and Gheryan. From the three cities nearly 160 individuals have been interviewed in their own houses, 16 houses in Tripoli, 12 houses in Ghadames and 11 houses in Gheryan, during the hot period of the year. The buildings were selected from naturally ventilated buildings ranging from vernacular traditional houses to new houses in the three climatic zones. However, In Ghadames and Gheryan most of the data was collected from new houses, since most of the traditional vernacular houses were deserted.

The subjects were asked to complete a questionnaire, which was divided into two parts Personal questions (Gender and Age) and thermal comfort questions; which referred to their thermal sensation, the air movement, humidity and their preferences. In addition they have been asked about their clothing and activities during the last hour. The subject marks their thermal sensation in seven steps according to the ASHRAE scale, and the environmental variables air temperature and RH, air flow and Air quality were measured. The subjects concerned in the survey were from both genders; the gender distribution was 43% percentage of the votes for female and 57% male, and their age ranging from 18 to over 80 years old. The study covered three seasons summer 2010 and winter 2010 and spring 2012.

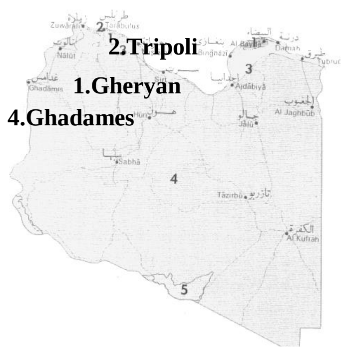


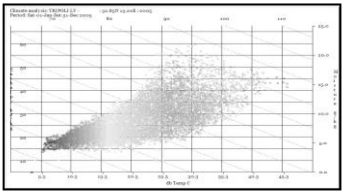
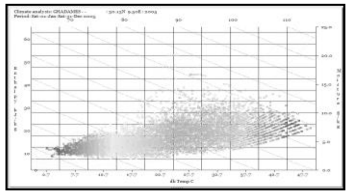
Figure. 1, the general classification of Libya's climate, after Buxtehude, 1981

2. Climate of Libya

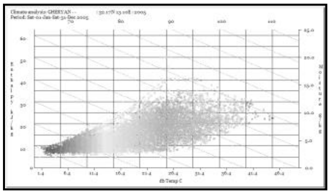
The Libyan population is mainly distributed in three climatic zones: Semi-Mediterranean on the coastal area (2-hot-humid), Mediterranean climate on the mountains (1-cold zone) and Steppe (4-semi-arid). In this study three cities were selected each featuring these main climatic zones, respectively Tripoli, Gheryan and Ghadames.

3. Clothing

Clothing is one of the main parameters that effect the thermal sensation of the people; therefore evaluating the clothing thermal insulation of subject's clothing is important. In Libya cultural factors have a great influence on clothing type, the clothing preferences of the Libyan people have been categorise into two categories western clothing and traditional clothing.

Tripol Ghadames



Gheryan

Figure. 2, Annual Psychometric charts.

In order to estimate the clothing insulation for the western clothing the study uses ASHRAE tables, (ASHRAE, 1992; ISO, 1994, 1995). These have been developed from clothing insulation studies conducted in laboratory studies, mainly for western clothing. However, the data from the field survey shows that a number of subjects included in the survey were wearing traditional Libyan clothing, therefore finding the thermal insulation value for the traditional Libyan clothing is important to study the thermal sensation and comfort temperature in Libya.

Recently, ASHRAE extended the western clothing table to include the non-western clothing, in the 1504-TRP, “Extension of the Clothing Insulation Database for Standard 55 and ISO 7730.” The data also include the effect of posture on air movement. Unfortunately Libyan traditional clothing is not included in the tables. This led the researcher to conduct a test to evaluate the thermal insulation of the traditional Libyan clothing in the climate chamber. With the help of Dr. Simon Hodder, a Technical Tutor (Ergonomics) at the Environmental Ergonomics Research Centre (University of Loughborough), the thermal insulation properties of the Libyan traditional was tested using thermal manikin.

3.1 THE DESCRIPTION OF LIBYAN TRADITIONAL CLOTHING

The traditional libyan clothes are unique in their components and ensemble, as they are products of the mediterranean civilizations influence on the libyan tradition. the libyan traditional male clothes changes according to seasons (figure 3). it consists of two parts the internal and external clothing, the internal clothing include (1) the serwal a loose light trousers made of cotton, (2) Suriya is a short loosely fitting gown that covers the body to the knees, and (3) Farmela, a cotton vest is worn in summer; however in winter a long sleeve Farmela (4) replaces the vest or worn over the vest.

Figure. 3, Libyan traditional clothing for male and female

The external clothing part (Al Ja'red)(6) a garment that is similar to the Ancient Roman toga. A white cloth of 4-meter long and 1meter width is wrapped around the body in special way. It is worn over the internal clothing. The male clothing ensemble changes according to seasons. In summer, a man usually wears the Serwal and Suriya only without the vest inside the house. However wearing Al Jared in winter is most common in older generation.

There are two sorts of female traditional clothing: the internal clothing and external clothing. The internal clothing includes; (7) Serwal, light loose trousers made of cotton, (8) Eqmeja a short loosely fitting long sleeve dress, usually made of light material in summer and heavy material in winter. (8)Al Re'da is the external part worn by female in everyday. It is a coloured cloth of 4-meter long and 1 meter width, usually made of cotton and sometimes wool and silk, but cotton is the most common material for everyday wear. It is wrapped around the body over the dress and trousers. The material of the Re'da changes according to seasons, in summer, they are made of cotton material while in winter they are made of wool (figure 3). Wearing a headscarf is part of the Libyan female traditional clothing; usually it is made of the same material of the Re'da. These days female wear Re'da over their western clothing mainly over a dress. However cu\lturally, the external part of the clothing cannot be worn by it self the Re'da have to worn all the time.

3.2 EVALUATING THE THERMAL INSULATION OF THE TRADITIONAL LIBYAN CLOTHING

The Libyan traditional clothing for women and men were tested using the most common ensemble, and the everyday clothing.

Figure. 4, the traditional Libyan clothing for female and male worn on the thermal manikin (Newton)

The test of the thermal insulation for winter and summer traditional Libyan clothing for male and female are listed in the following table.

Male summer clothing	Clo	m2.oC/W	Female-summer clothing	CLO	m2.oC/ W
(1) Shirt (Suriya)	0.22	0.034	(8) Long sleeve light shirt-Eqmeja	0.22	0.034
(2) Trousers (Serwal)	0.26	0.040	(7) Trousers (Serwal)	0.26	0.04
(3) Vest (Farmela)	0.15	0.023	(9) External material (Ra' da)	0.69	0.107
Total for Summer	0.63	0.098	Total for summer	1.176	0.182
Hat (Al Shana)- wool hat	0.17	0.026	Head scarf	0.062	0.01

Table 1 Thermal insulation value for the female and male traditional Libyan clothing in summer

Male – winter clothing	CLO	m2.oC/W	Female – winter clothing	Clo	m2.oC/W
(1) Shirt (Suriya)	0.22	0.034	Long-sleeve shirt (Eqmeja)	0.29	0.045
(5) Trousers (Serwal)	0.26	0.04	Heavy long-sleeve sweater	0.37	0.058
(4) Heavy jacket– (Farmela)	0.49	0.076	Trousers (Serwal)	0.26	0.045
(6) External material (Al-Jared)	0.98	0.155	External material (Ra' da)	0.69	0.107
Total for winter	1.95	0.35	Total for winter	1.61	0.25
Hat (Al Shana)- wool hat	0.17	0.026	Head scarf	0.06	0.01

Table 29 Thermal insulation value for male and female traditional Libyan clothing in winter

In winter season the traditional Libyan clothes for women are usually heavier than summer as they wear a heavy Cardigan. On the other hand the men traditional clothing for winter are even heavier as they wear (Al Jared), wrapping it around the body over the internal clothing (long sleeve shirt and trousers and heavy vest or jacket) as illustrated in figure (3).

The above tables show that the thermal insulation for the women traditional Libyan clothing are heavier then men in summer and lighter in winter. This can be related to cultural factors, as wearing Re'da is obligatory for women in many families especially in extended families houses and in most of the older generation. Men's clothing varies from light clothing with low insulation value 0.63 clo to higher thermal insulation value in winter with 1.952 clo by wearing a heavy jacket, 0.49clo, and Al Jared with 0.982 clo.

From investigating the thermal insulation of Libyan clothing; where in the summer, females in Libya usually wear heavier clothes than the male clothing, while in winter men were recorded to wear heavier clothes than women. The research shows that, older generations tend to wear heavier clothing than the younger generation, and wearing traditional Libyan clothes is more common in the older generation.

The variation of clothing is subject to climate and culture, in terms of climatic aspect; from the survey the subject were found to wear less than 0.5clo if the operative temperature is higher than 25°C and they wear heavier cloths when temperature is low. The clothing as an indicator of behavioural adaptation to the climate is illustrated in figure (5).

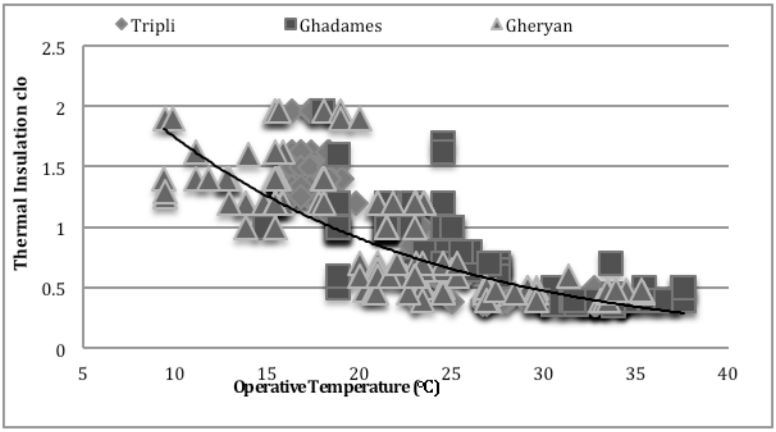


Figure. 5, the average clothing insulation worn in the three cities

The subjects were asked about their activity over the last two hours before the interview, and this information is used to develop a met estimate for each participant. Using the Metabolic Rate table, ANSI/ASHRAE Standard 55-1992R (Activity levels – Metabolic Rates for Typical Tasks). According to ANSI/ASHRAE Standard 55-1992R (Activity levels – Metabolic Rates for Typical Tasks) most of the activities are ranged between standing or sedentary work with 1.2 met (70W/m^2), to medium light work with 2 met (116 W/m^2). This shows that women tend to record more activity than men; this is mainly as a cultural factor in the country where only women are responsible for housework.

However, the standard table has been calculated based on the western life style, there is many factors determined the metabolic rate such as the meaning of the activity description can be vary according to culture, using 2.0 met as an estimate for housekeeping in the ANSI/ASHRAE Standard 55-1992R cannot be applied on the Libyan women were housecleaning includes heavy work such as cleaning carpet or courtyards.

4. Comfort Vote Data Analysis

The result obtained from the survey, are used to indicate the comfort temperature for Tripoli, Ghadames and Gheryan. First Linear regression analysis using the least square method have calculated between the thermal sensation as dependent variable and the indoor operative temperature, from the results the thermal comfort temperature was calculated using Griffiths method (Griffiths, 1990). Finally, the linear regression analysis was used to predict the thermal comfort temperature using the running mean outdoor temperature as predictor.

The response of the subjects to the thermal environment (Actual Mean Vote) is plotted against the indoor operative temperature. The linear regression of the relation between the thermal sensation and the operative temperature in the three cities in summer, winter and spring shows that the respondents were thermally comfortable in a wide range of indoor operative temperature. The air movement below 0.5m/s and with average relative humidity 50%, the operative temperature is sufficient thermal index to define the neutral temperature.

Location	Values for a	Values for b	Correlation coefficient r2
Tripoli	0.1684	-0.4368	0.69
Ghadames	0.1005	1.2014	0.4
Gheryan	0.1599	-0.0664	0.63

Table 310 the result of the linear regression

The relationship between the AMV and the operative indoor temperature for the three cities are shown in Figures (6). According to the polynomial trend line illustrated in the graphs, in the three cities people voted comfort in wide range of operative temperature; in the city of Tripoli the people voted comfort in operative temperature ranges from 20℃ to 32℃, and in Ghadames they vote comfort in operative temperature ranges from 20℃ to 35℃, while in Gheryan people vote comfort when the operative temperature in between 20℃ and 30℃. This shows that in Libya people tend to adapt to wide range of temperature.

Moreover a linear regression analysis shows that the desert (Ghadames) is higher than the coastal zone (Tripoli) and the mountain zone (Gheryan), indicate that people in Ghadames tolerate higher temperature than Tripoli and Gheryan. The neutral temperature found from the linear regression equations illustrated in Figure (6) Shows the results of linear regression in the form: C = aTi + b. In other word to calculate the comfort temperature (Tn) for the summer and winter, in Tripoli subjects voted neutral (C=4) when the temperature is 26.3℃, In Ghadames the subjects voted neutral in a higher temperature 27.8℃. In Gheryan the subjects voted neutral in a lower temperature 25.4℃. Statically, the correlation coefficients for comfort temperature in the three cities are low; there are two reasons for this result; first this is expected for any field studies that attempt to predict human psychology and respond toward thermal comfort. Secondly, the low number of subjects in the survey for each city (nearly 50 per season) and measurement error can result this low regression.

Taking the comfort temperature value from the people who voted neutral reduces the data by neglecting the other votes and therefore an unreliable comfort temperature. As noted by Nicol "If, for any block of data, the mean operative temperature and the mean thermal sensation are known it is simple to calculate the thermal comfort temperature" this also known as Griffiths method, (Nicol, Humphreys, and Roaf 2012 -P16). Therefore, for a small group of subjects using the Griffiths method is more reliable for evaluating the mean comfort, by assuming the increase in temperature for each thermal sensation scale point using the Griffiths slope G (K-1), this is equivalent to the regression coefficient between the comfort vote and operative temperature.

In this study the regression coefficient between the comfort vote and operative temperature was found from the scatter chart illustrated in figures (6). The study used Griffiths method and adopted Humphrey's assumption for the G value where the increase in temperature for each thermal sensation scale point is 2K. And the correlation between the comfort vote and operative temperature was found from the chart illustrated in figure (6), the comfort temperature was calculated for each vote using the following equation

$$T_{comf} = T_{op} - {}^{TS}/_{G} \qquad (1)$$

Where T_{comf} is the comfort temperature, T_{op} is the mean operative temperature, and TS is the mean thermal sensation. The Top and Ts was found from the field survey for each city and during each season, the comfort equation for the three cities was as follows

$$T_{comf} = a\,T_{op} + b \qquad (2)$$

According to research questionnaire for example at operative temperature 30 ℃ a person voted (5 slightly warm) on the thermal sensation scale, therefore to feel comfort (4) we need to reduce the operative temperature 2K which is equivalent to one thermal sensation, and his comfort temperature will be 30-2K= 28℃. According to chart figure (6) the thermal comfort temperature equations for the three cities have been calculated as follows

$$T_{comf} = 0.6631T_{op} + 8.8735 \quad (3) \qquad R^2 = 0.90 (Tripoli)$$

$$T_{comf} = 0.799\, T_{op} + 5.5972 \qquad (4) \qquad R^2 = 0.91$$
(Ghadames)

$$T_{comf} = 0.6803\, T_{op} + 8.1283 \qquad (5) \qquad R^2 = 0.89 (Gheryan)$$

From the above equations (3,4 and5) it is clear that subjects in Ghadames tolerate higher temperature than Tripoli and Gheryan. For example for the indoor operative temperature 30℃, Ghadames comfort temperature is nearly 29.5℃, while in Tripoli and Gheryan it is 28.5℃.

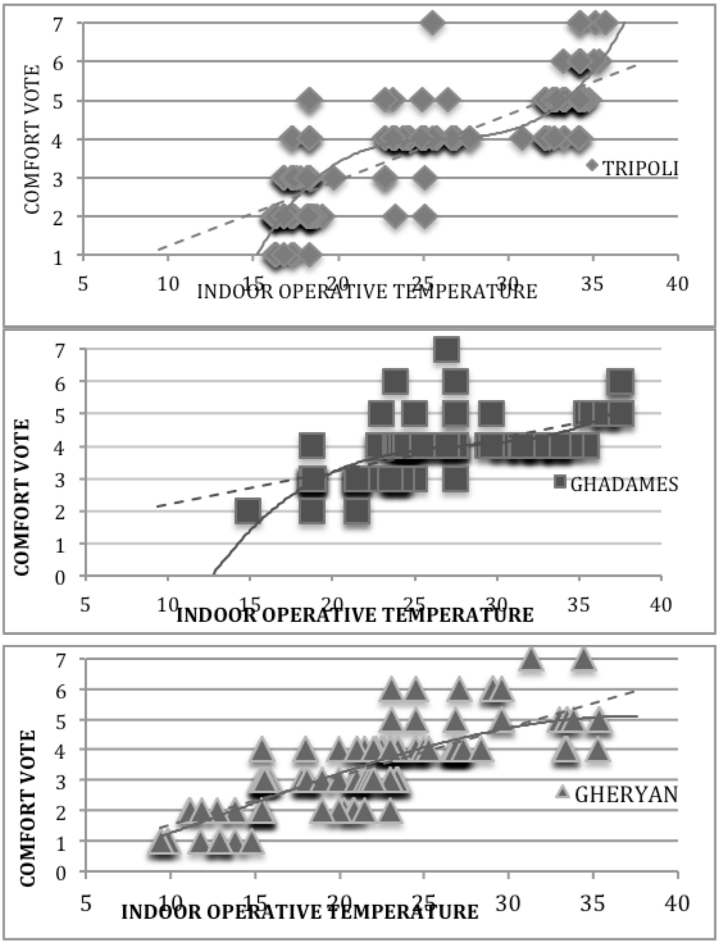


Figure. 6, Poly. and linear regressions of AMV on indoor Temperature for objects in three cities during the three seasons

3.3 THE COMFORT TEMPERATURE VERSUS RUNNING MEAN OUTDOOR TEMPERATURE

According to Adaptive theory, predicting thermal comfort temperature is dependent on indoor environment and out door temperature. Therefore calculating comfort temperature using the running mean outdoor temperature is crucial. In this study the running mean outdoor temperature was selected as predictor of the comfort temperature with $\propto = 0.8$ using the following equation (Humphrey, 2010);

$$\mathrm{T}_{\mathrm{rm(tomorrw)}} = \propto \times \mathrm{T}_{\mathrm{rm(yesterday)}} + (1 - \propto) \times \mathrm{T}_{\mathrm{m(today)}}$$

The running mean outdoor temperature was taken from the data collected from the three cities using a long term-temperature reading computer chip (iButtom) installed outside the houses for 10 days during summer, spring and winter seasons, using the courtyard temperature data in Tripoli and Gheryan, and the roof temperature in Ghadames. However, for missing data, it has been estimated with respect to the weather data collected from meteorological stations. Chart illustrated in figure (7) shows the correlation between the running mean outdoor temperature and the comfort temperature for the three cities. Comfort temperature for the three cities can be found from the above chart as follows:

$$T_{comf} = 0.51T_{rm} + 14.12 \qquad R^2=0.85 \qquad (6)$$

$$T_{comf} = 0.46T_{rm} + 16.72 \qquad R^2=0.7 \qquad (7)$$

$$T_{comf} = 0.47T_{rm} + 14.26 \qquad R^2=0.7 \qquad (8)$$

To indicate the limits of the comfort zones for the three cities it can be assumed that subjects can be comfortable in a range from 3 to 5 on the thermal sensation scale, 3 for slightly cool and 5 for slightly warm.

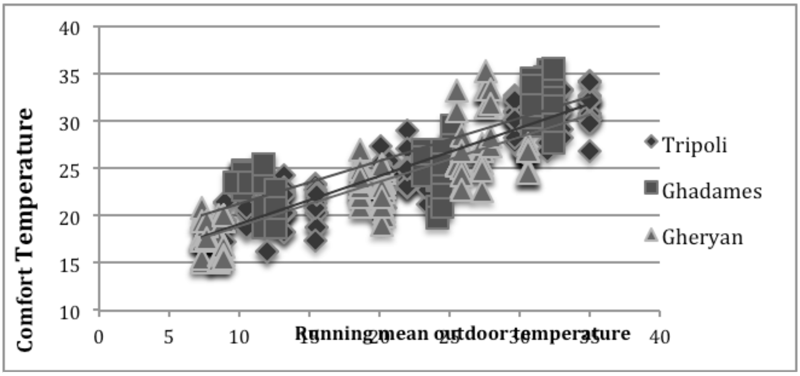


Figure. 7, Comfort temperature versus running mean outdoor temperature

5. Conclusion

The Paper analysis the outcome of two studies, first, is the finding from investigating the thermal insulation of Libyan clothing; where in the summer, females in Libya usually wear heavier clothes than the male clothing, while in winter men were recorded to wear heavier clothes than women. Thermal insulation of the traditional Libyan clothing was tested in a climatic chamber and the results show that male traditional clothing is 0.63clo in summer and 1.95clo in winter. While female traditional clothing is 1.17clo in summer and 1.6clo in winter. The research shows that, older generations tend to wear heavier clothing than younger generation, and wearing traditional Libyan clothes is more common in older generation.

Secondly, a thermal comfort investigation in the three cities is conducted to calculate comfort temperature in Libya; Occupants' adaptive adjustments have a great influence in setting the thermal comfort temperature in the three cities. The study correlates the comfort temperature with the indoor operative temperature and the running mean outdoor temperature to define comfort temperature. The study investigates and assigns the thermal comfort temperature in three climatic zones in Libya, and three equations were concluded from the study, using the running mean outdoor temperature as predictor of the thermal comfort, that can indicate the limits of the comfort zones for the three cities.

It is important to highlight the critical use of Griffiths method and the Humphrey's assumption for the G value where the increase in temperature for each thermal sensation scale point is only 2K, and according to the field study people seems to adapt and feel comfort at high temperature, therefor more studies in the field are required.

There is limited thermal comfort research in Libya conducted by just a few studies (Ealiwa et al. 2001; Alzubaidi, 2002; Akair and Bánhidi 2007)(Akair and Bánhidi, 2007; Alzubaidi, 2002; Ealiwa et al., 2001), thus, thermal comfort standards are not defined in Libyan Codes yet. The small numbers of respondents in most of the thermal comfort investigations in Libya do not give a good estimation for population responses. Therefore more studies in the field are required. The data in this research can be part of a broader study to set a thermal standard for the North African Countries 'Al-Maghreb Al-Arabie' includes (Libya, Tunisia, Algeria, Mauritania and Morocco).

Acknowledgements

I acknowledge with gratitude and sincere appreciations to Professor Nicol Fergus at London metropolitan University for his enlightening comments and advice and I further extend my thanks to Dr. Simon Hodder, a Technical Tutor (Ergonomics) at the Environmental Ergonomics Research Centre (University of Loughborough) for valuable support in testing the thermal insulation properties of the traditional Libyan clothing.

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MAPPING A NEXUS BETWEEN URBAN BUILT FORM AND ENERGY INTENSITY: CASE OF OFFICE BUILDING STOCK IN COLOMBO MUNICIPAL COUNCIL OF SRI LANKA

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Abstract

Residential and commercial buildings consume one fifth of the world's total energy and accounts for one third of the global greenhouse gas emissions. Annual Energy consumption in Sri Lanka has rapidly increased over the past years. Building accounts for 64.7% of the total national energy consumption in 2013 and 26.1% of the energy is consumed by non-domestic buildings. Thus highlights the importance of investigating the energy consumption of urban office building stock.

Majority of the office buildings in Colombo are dominated by air-tight envelopes with glazed facades. . Thus demands for active systems to condition the indoor environments. This trend in the office building stock has originated energy intensive office interiors with an average annual building energy index of 250 KWh/m2.Although 80% of the urban building stock in Colombo Sri Lanka is composed of office buildings there is a limited research attention on the energy behavior of this building stock. Thus this study focuses on mapping a nexus between urban built form and energy intensity of the office building stock in Sri Lanka.

Physical configuration of the building stock varies along the main arteries of the study focus area. Of which 53% and 47% of the buildings have a shallow and a deep plan form respectively.75% of the office buildings are attached with another structure and these physical configurations have a direct impact on the Building Energy Index. Further fenestration details of the critical façade have different compositions of glazed and Aluminum cladding Of which 17%, 26%, 57% are evident for glazed, Aluminium cladding and Aluminium cladding with glazed respectively. Results indicated that the energy intensity of the buildings associated with the orientation, fenestration detailing of the critical faced and building form.

Keywords: *office buildings, energy consumption, building form typologies*

1. Introduction

Residential and commercial buildings consume one fifth of the world's total energy and accounts for one third of the global greenhouse gas emissions (IEO, 2010). During the past half a century new building construction has increased and consequently affected the energy demand from buildings due to the present practice on energy intensive artificially conditioned building interiors with mechanically ventilated, artificially lit and air conditioned mechanisms.

In office buildings, energy is mainly used for lighting, cooling and heating. Cooling energy demand of a building is affected by heat gain internally (electrical lighting, building equipment, and people) and externally (solar radiation, air temperature, and wind) and also heating energy demand is affected by heat loss through facades (Susorova et al., 2013). Many studies have investigated the thermal performance of building forms in respective to climates (Steadman et al., 2000, Steemers et al, 2003).

The research on building shape proposes the shape Coefficient is directly proportionate to its external wall surfaces. The relationship between the building shape and energy consumption changes with the climatic conditions. In rigorous climates a linear correlation is evident. However, there is no significant relationship in mild climates (Depecker et al. 2001).

Other influencing building configuration factors on energy consumption are focused on façade formations such as window orientation, window to wall ratio (WWR) and geometric factors on internal spaces such as a ratio of room width to depth. These design strategies were investigated using energy stimulations for different climate zones. A model room of a typical office building has been simulated to identify the annual energy consumption and the results show that energy consumption in hot climates are significantly affected by the façade formations and geometric factors (Susorova et al., 2013).

Most of these studies on the impact of building form on energy consumption have followed a common research approach focusing on different climates, seasonal changes with simplified built forms. However a less research focus towards actual office built forms and existing building stock is evident.

Although few studies represent the energy consumption patterns of the built forms in tropical climates (Charde et al., 2013, Fasi et al., 2015, Steemers et al., 2010), it is vital to investigate the actual building stock in tropics as the 70% of the global urbanization will be concentrated in developing countries of Asia and Africa by the year 2030 (UNFPA, 2007).

Since the current urban expansion of the city of Colombo is planning towards the implementation of Megapolis development, which will initiate a burgeoning trend in the construction of more and more urban office buildings in the Colombo Municipal Council Region. However a limited research attention is evident on the impact of the office building forms and energy consumption pattern. Thus it is vital to explore the existing office building stock to comprehend a relationship between the physical configuration of the built forms and its energy demand.

Current building stock in Sri Lanka accounts for 64.7% of the primary energy consumption, of which 26.1% is consumed by non-domestic building sector (SSEA, 2013). Office building stock dominates the urban built forms in the city of Colombo. However unavailability of actual data of this building stock has become a prime restriction in future research. Thus this study focuses on developing a nexus between urban built forms and energy intensity of the existing office building stock in Colombo Municipal Council region.

2. Colombo Municipal Council Region

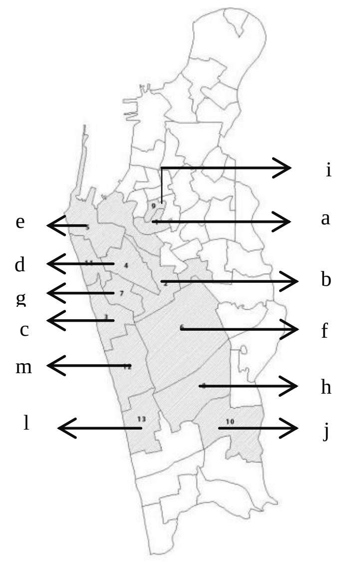
Colombo Municipal Council region which is the focus area of this study is situated in the Colombo district (6°55' N, 79°51' E at a latitude of 8m), in the Western province of Sri Lanka. This district represents the highest population density of the country within the range of 2001 to 4000 persons/Km^2. Colombo as the commercial capital is composed of a residential population of 647,000 with 700,000 floating population (Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs CoMTrans Urban Transport Master Plan). Approximately 50% of the floating population commute for employment. The maximum office building stock of the Colombo district is concentrated in the Colombo Municipal Council region which contains 35 Grama Niladhari (GN) divisions. Thus the study investigates the office building stock distributed among 35 GN divisions of the CMC region.

*2.*1 IT'S CLIMATE

Climate of Colombo is characterised as a tropical monsoon climate with uniformly high temperatures with high humidity. Mean monthly temperature over the year varies from 26°C to 29°C with the highest average in March to April (Maximum temperature 36°C). Mean monthly relative humidity varies from 60% -80% during a year. Colombo experience long hours of sunshine and mean hourly global horizontal radiation varies from 398 to 350 W/m^2 within a year with the highest in the month of March (Maximum hourly global radiation, 1030 W/m^2).

2.2 OFFICE BUILDING STOCK IN CMC REGION

Figure 1 shows the percentage distribution of office building stock in the CMC region. The GN divisions such as, Keselwatte (18.92%), Suduwella (16.19%), Kollupitiya (15.02%) and Fort (11.42%) represent the highest building stock in this region. In these GN divisions the location of the office buildings are predominately along the major traffic arteries which represents Galle road, Dharmapala Mawatha, Sangharaja Mawatha, Sir James Peiris Mawatha and D.R Wijewardana Mawatha.



GN Divisions	Percentage of office buildings
a. Kesellwatte	18.92%
b. Suduwella	16.19%
c. Kollupitiya	15.07%
d. Hunupitiya	12.25%
e. Fort	11.42%
f. Cinnamon Gardens	9.94%
g. Wekanda	9.38%``
h. Thibirigasyaya	7.46%
i Aluthkade West	6.92%
j. Kirula	6.93%
k. Kompannaweediya	5.77%
l. Millagiriya	5.05%
m. Bambalapitiya	4.39%

Figure 21 Percentage of office buildings in Colombo Municipal Council (CMC)

2.1 JUSTIFICATION FOR SELECTION OF THE STUDY FOCUS

East-West orientation is one of the significant design strategies on heat gain of tropical buildings. Among the 35 GN divisions of CMC region, 13GN divisions have a concentration of office buildings more than 4%. Within the 13 GN divisions, the highest office building stock of 75% of the East-west orientation is evident in the GN division of Kollupitiya. These buildings are predominantly located along Galle Road and R.A De Mel Mawatha. Thus the study represents the critical office building stock for heat gain in the CMC region and this paper presents physical configuration and energy indices of the office building stock in the Kollupitiya GN Division.

3.0 Characteristics of the office building stock in the study focus

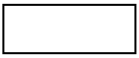
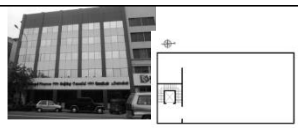
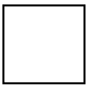
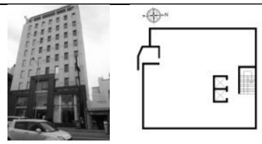
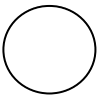
Major characteristics of this office building stock are that 90% are fully air-conditioned and mean number of floors is within the range of 5 to 7 storeys. However 10% of the stock has amalgamated air conditioned working spaces and naturally ventilated common areas like lobbies and corridors. Mean building energy index (BEI) of this office building stock is 243.12 KWh/m^2/annum.

Five types of office building plan forms were identified and these plan forms can be generalised as basic plan forms and composite plan forms. The basic plan forms consist of square, linear and circular plan forms. Composite plan forms derived from a combination of basic plan forms and they demonstrate L and U shapes. Within this stock 75% of the buildings demonstrates a combination of linear and square plan forms distributed along the Galle Road and R.A De Mel Mawatha. In these basic plan forms 58% and 17% are with linear and square plan forms respectively. Circular plan forms are not evident in this office building stock.

Composite built form of L shape is a combination of two linear plan forms or a linear and a square plan form. Moreover the amalgamation of three linear plan forms represents the U shape. These composite plan forms along the Galle Road and R.A De Mel Mawatha are consists of 16% of L and 9% of U shape plan forms respectively. Graphical representation of the basic and composite plan forms and its combinations are shown in figure 2a.

East and west facades in the tropics are affected by direct solar radiation and influence the solar heat gain into the building interiors. Thus these facades denote critical facades for tropical climates. Furthermore these facades represent the front of the building due to easy access from the road. These East and West front facades represent different compositions of glazed and Aluminium cladding. Of which 17%, 26%, 57% are evident for glazed, Aluminium cladding and Aluminium cladding with glazed respectively. These glazed facades are composed of fixed and openable panels with blinds to control the heat gain. Fenestration details of these critical façades are shown in figure 2b.

When considering the positioning of these buildings this stock represents 75% of attached built forms and the balance is free standing. Thus the figure 3 shows a combination of the positioning of the built form in relation to two main types of plan forms with the East West orientation.

Basic plan forms		
Linear plan forms 		58% of the buildings has a rectangular plan form
Square Plan form 		17% of the buildings has a square plan form
Circular plan form 		Non of the buildings have a circular plan forms facing east west orienation

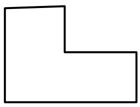
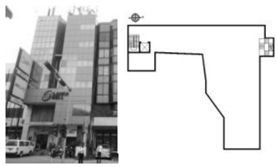
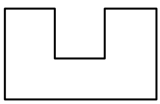
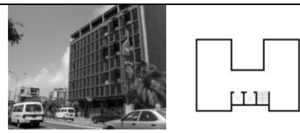
Composite plan forms		
L shape Plan form 		16% of the buildings are with a L shape plan form
U shape plan form 		9% of the buildings are with a L shape plan form

Figure 2a Categorization of buildings according to the plan forms

Critical façade characteristics		
Buildings with glaze and Aluminium	Buildings with aluminum facades	Buildings with fixed/non fixed glaze panels
		
57% of the buildings are cladded with Aluminium and glasses in the front faced	26% of the buildings are Aluminium Cladded throughout the front façade.	17% of the buildings have full length glass openings in the front façade.

Figure 2b Categorization of the critical façade

3.1 NEXUS BETWEEN THE BUILDING ENERGY INDEX (BEI) AND THE BUILT FORM

Building Energy Index is a quantitative measure to evaluate the energy consumption of a building within a period of an year in relation to its floor area. The unit of this index is kWh/m2/annum. Corresponding building energy indices of the stock was calculated and the Figure 4 represents the building with the highest Energy Index of this building stock. It is evident that the Building Energy Index of this stock varies within the range of 150 – 300 kWh/m2/annum. Of which 68% and 16% corresponds to 200 and 300 kWh/m2/annum respectively. Figure 5 shows the physical configuration in relation to positioning and plan forms of the 5 buildings which represents the maximum BEI of this building stock.

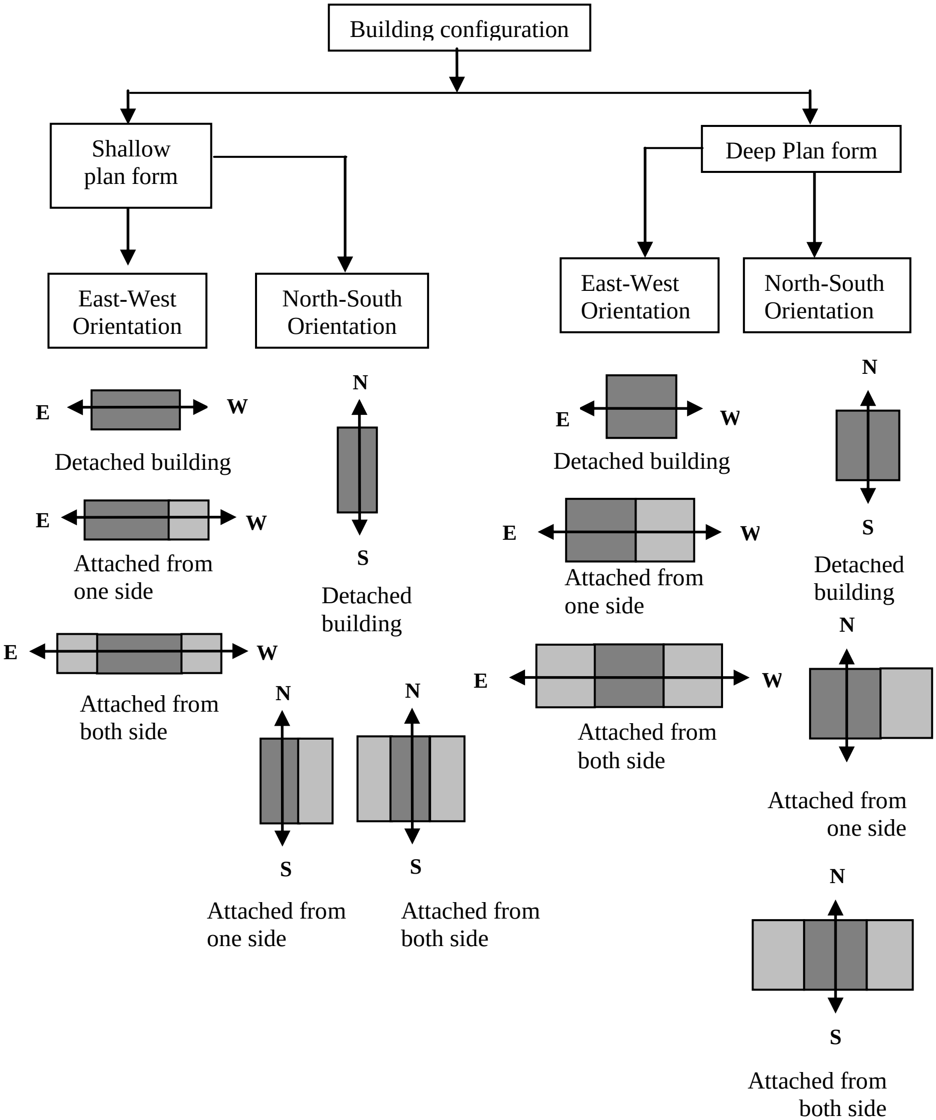


Figure 3 office building typology

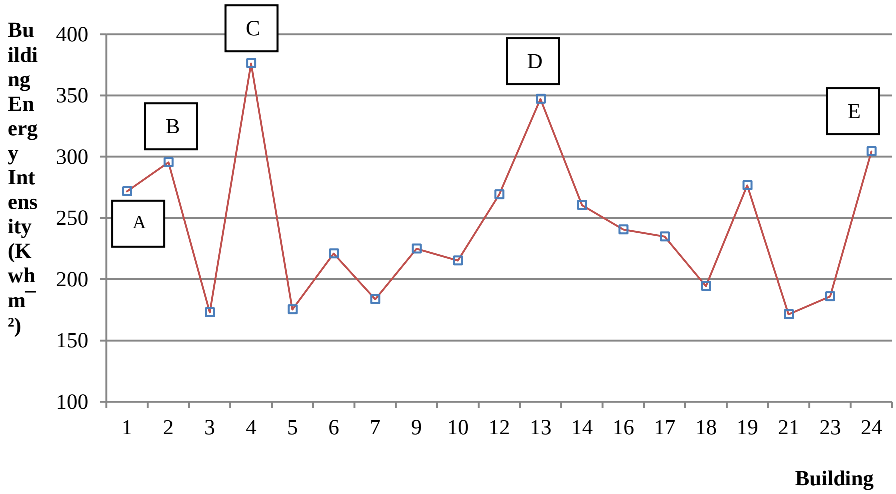


Figure 4Buildings Energy Index of the office building stock

Buildings with the highest Building Energy Index have a configuration of basic and composite plan forms. Buildings with basic plan forms has a higher building Energy Index than composite plan forms. Furthermore buildings with glazing in the critical façade have a higher Building Energy Index than the other fenestration details.

3.2 NEXUS BETWEEN THE BEI AND ASPECT RATIO

Aspect ratio of a building is a ratio between length and width. Literature has informed a building with an aspect ratio above 2 with an East West orientation consumes more energy due to the increasing demand in the operation of cooling plant (Geoffrey J et al., 2004). Moreover the buildings where the long side of the building facing east-west orientation has more energy use intensity as a result of the direct heat gain. Buildings with an aspect ratio (length/width) above one have a shallow plan form. A deep plan form has an aspect ratio less than one. Buildings with deep plan forms consume more energy due to artificial lighting and air conditioning. Figure 6 shows the relationship between the BEI and aspect ratio.

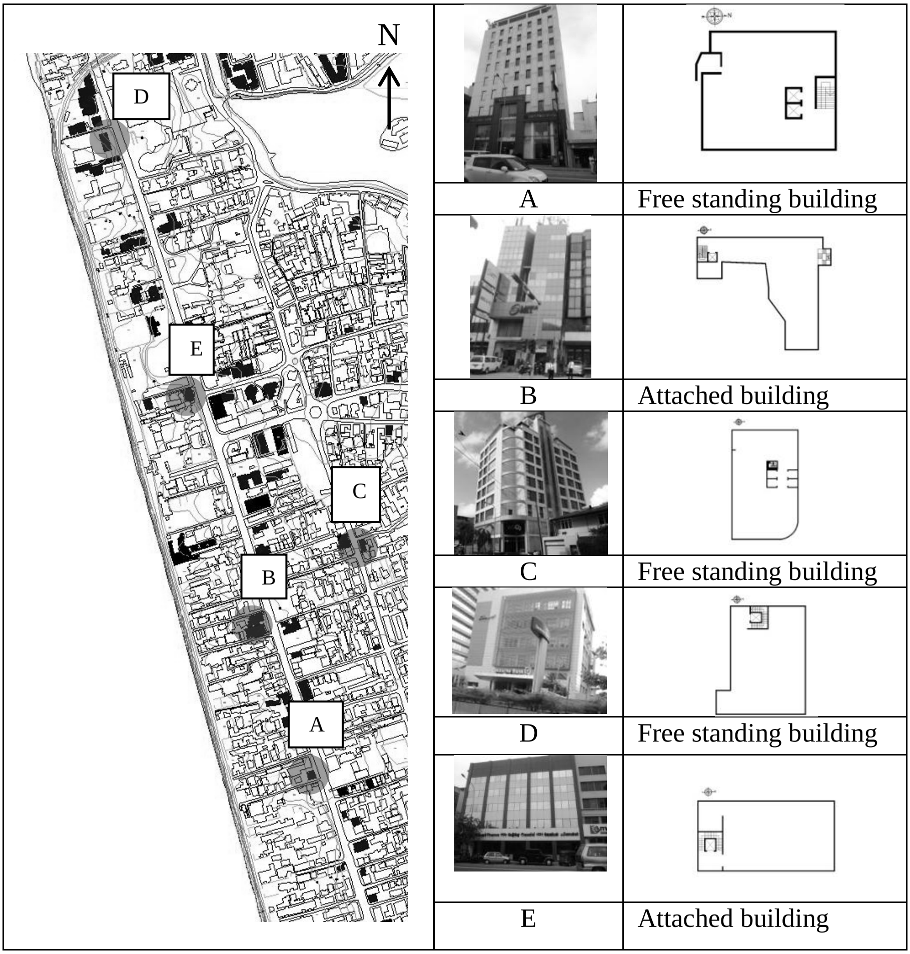


Figure 5 Physical configurations of the buildings with the highest BEI

It is evident that the physical configuration of the building stock varies along Galle Road and R.A De Mel Mawatha. Of which 53% and 47% of the buildings have a shallow and a deep plan form respectively. Critical façade of the shallow plan forms are East-West oriented. Thus these plan forms get direct solar radiation. Critical façade of the deep plan forms are North-South oriented. Conventional wisdom reveals that the shallow plan forms consume less energy than deep plan forms. In contrary some buildings with shallow plan forms had higher building energy index than the deep plan forms. Thus denote that these buildings are attached with another structure from one side or both sides. In addition fenestration details of the building envelop influence the energy consumption of the building.

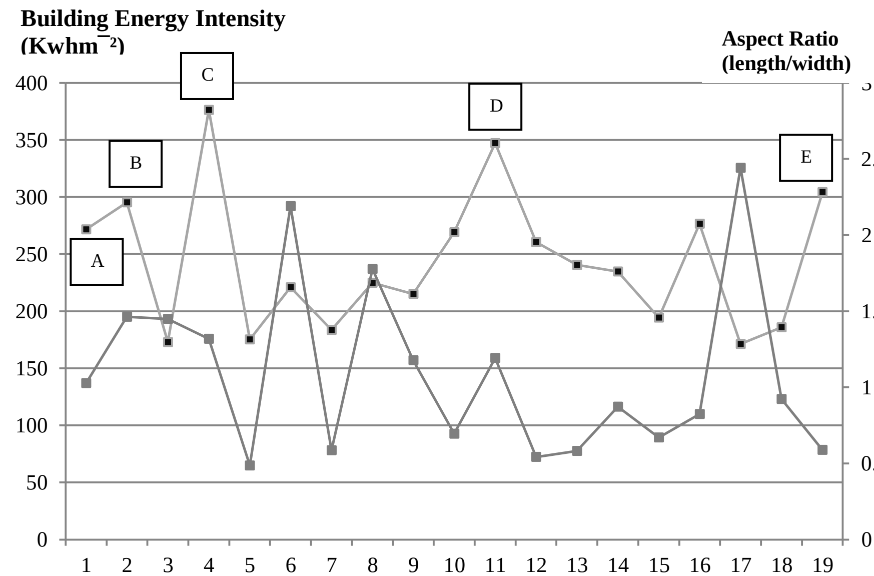


Figure 6 Building Energy Intensity (BEI) and Aspect Ratio

4.0 Conclusion

Analysing the office building stock with respect to its energy intensity is a prime importance to enhance energy consumption especially in a tropical climate. In addition this analysis is the beginning of developing a data base for the existing building stock which will be a foundation for the construction of new building with low energy consumption.

, The highest office building stock of 75% of the East-west orientation is evident in Kollupitiya.GN Division and they are predominantly located in Galle Road and R.A De Mel Mawatha. 90% of the building stock has sealed envelopes with air conditioned building interiors. Building Energy Index of this stock varies within the range of 150 – 300 kWh/m2/annum. Five types of office building plan forms were identified and these plan forms are generalized as basic and composite plan forms. Within the building stock 75% and 25% of the buildings demonstrates a combination basic plan forms and composite plan forms respectively.

Further more critical facades represent the front of the building due to easy access from the road. These East and West facades represent different compositions of glazed and Aluminium cladding. Of which 17%, 26%, 57% are evident for glazed, Aluminium cladding and Aluminium cladding with glazed respectively. These fenestration details of the critical facade have an impact on the building energy index of the building.

The positioning of this buildings stock represents 75% of attached built forms and the balance is free standing. Thus a typology of building configuration was developed based on the building plan form. Of which 53% and 47% of the buildings have a shallow and a deep plan form respectively. It is evident that the Energy used index has an impact on the positioning of the critical façade and the building plan configuration.

Factors such as window orientation, window area, room dimensions, size and position of shading, and floor plan configurations have a significant impact on the building energy consumption. Majority of the office buildings in Colombo are dominated by air-tight envelopes with glazed facades. Thus demands for active systems to condition the indoor environments. Subsequently the office building stock has originated energy intensive office interiors. This study will help to set out a holistic approach of new future town planning, on setting out of new roads and cutting of geometry for fabric of new sites in reference to more “energy optimized” building volumes.

In addition this will be a platform to develop a fundamental database matrix, focusing on enhancing the screened office buildings with more specific research on façade renovation by means of energy conscious replacing of worn out façade materials, and creating or optimizing positioning and size of shading devices. Thus further studies for Colombo office building renovation or construction of new structures could be fired positively by proposed matrix typology.

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STRATEGIES TO REDUCE THE RELIANCE OF FOREIGN WORKERS: A CASE STUDY OF SINGAPORE'S CONSTRUCTION INDUSTRY

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Abstract
Singapore has one of the most open economies in the world in terms of foreign labour inflows. Foreign workers served to overcome the labour shortage in the Singapore construction sector; however, over the years the influx of and over-dependence on foreign workers have become a serious social problem and controversial issue in the country. This study attempts to examine the benefits of and problems caused by foreign workers, and propose and discuss ways to reduce the reliance on foreign construction workers in Singapore. This study is mainly based on secondary data. It was found out using foreign workers have benefits. Foreign workers can contribute to Singapore's economic growth, provide labour that the local workers avoid, reduce the cost of labour for companies, among others. However, foreign workers caused congested infrastructures, jobs competition, and housing pressures etc. To reduce the reliance on foreign construction workers in Singapore, this study proposed policies and strategies such as the minimum wage policy, "Singaporean First policy", and reducing the Dependence Ratio Ceiling (DRC), among others. These policies and strategies recommended may help to reduce the reliance on foreign workers in the country.

Keywords *Foreign workers, construction industry, Singapore, reliance, policy*

1. Introduction

Since Singapore's independence in 1965, the country's economic growth has attracted a new wave of foreign manpower especially in the construction industry because the local workforce is unwilling to work in this sector Wickramasekera (2002). Singapore greatly depends on the inflow of foreign workers to support the growth of the economy since independence (Ofori, 1997). This study provides an overview of foreign workers in Singapore, and its main focus is to suggest ways to reduce the reliance on these workers in the Singapore construction industry. This is a complex issue faced in Singapore because there are both benefits and disadvantages when employing foreign workers (Thangavelu, 2012; Yap, 2014).

2. Literature Review

2.1 OVERVIEW OF FOREIGN MANPOWER IN SINGAPORE'S CONSTRUCTION SECTOR

Construction industry in Singapore is one of the most important industries that are closely related to other economic sectors. The construction industry in Singapore contributes around 6.5 per cent of Gross Domestic Product (GDP) in 2014. According to Singapore’s Statistic Bureau, the total construction output was estimated to be around $33.30 billion in 2013. Singapore uses some of the most advance construction method and technologies available, and is constantly providing training and up-skilling to the workers (Ofori, 1997). One of the key distinguishing feature of the construction industry in Singapore is that it relies greatly on foreign workers, even the largest construction companies in Singapore employ and relies on foreign workers (Lim & Alum, 1995). This practice has been linked to the industry's poor image and labour-shortage problems (Ofori, 1997; Thangavelu, 2012; Yap, 2014). There are only about 104,000 local residents, or 3.3% of the total labour force, working in this sector (Ministry of Manpower, 2015). As of December 2014, the sector employed over 491,000 workers comprising mainly foreign workers (Ministry of Manpower, 2015).

Employing foreign workers with temporary work pass is a global business trend, especially in countries that faces labour shortage in a specific industry (Rogler, 1994). Yap (2014) and Rogler (1994) noted that Singapore ranks as one of the countries in the world with the highest proportions of foreigners in its population and among its workforce. Foreigners make up close to 40% of its total workforce, and over 30% of its 5.43 million population in June 2015 (Ministry of Manpower, 2015). Singapore construction industry and other economy sectors has been experiencing acute labour shortages since the 1970s when Singapore had achieved full employment (Cunningham & Debrah, 1995; Debrah, 1994). Yap (2014) found out that in 2009, there are still shortage of labour, especially in construction sector. According to (Ministry of Manpower, 2015), there are three main types of work passes in Singapore, namely work permit (WP), S-Pass (SP), and Employment pass (EP). Meanwhile, foreign construction workers are classified into three classes based on their respective skills and academic standings. The highest class is the skilled workers, the middle class consists mainly of the semi-skilled and the lowest class is the unskilled workers. A New Skills Framework for the construction sector in Singapore was implemented since 2011 with increasing requirement on the workers' skill level.

2.2 FOREIGN WORKERS – PROS

2.2.1 Contribute to Singapore's economic growth

Piper (2004) and Borjas (1994) noted that foreign workers can push up the income of the economy as the low cost of employing foreign workers can lead to more investment and the skilled foreign workers could also contribute to the increase of productivity. Singapore reaps unlimited benefits from its importation of skilled and unskilled foreign labor, it enables Singapore to increase its Gross National Product (GNP) and also quicken Singapore's economic and GDP growth (Borjas, 1994; Fong, 2006; W.-T. Hui, 2002; Piper, 2004; Thangavelu, 2012). Fong (2006) found out that 41% of Singapore's GDP growth in the 1990s came from the inflow of both the skilled and unskilled foreign workers.

The use of foreign workers will not constrain economic growth and economic restructuring. Rather, it can acts as buffer for cyclical demands for labors, meaning that during a business boom, more foreign labor will be employed while a recession will see fewer foreign workers being employed. This way, the economy will be insulated from business cycle (Chew & Chew, 1995; Chia, 2011; Piper, 2004).

2.2.2 Helps in the declining total fertility rate

Gubhaju and Moriki-Durand (2003) found out that some countries in Asia have total fertility rates (TFRs) at or below replacement level. This is more serious in countries like Singapore, Republic of Korea, Japan and China. The implications are momentous as they affect the age structure of the population, giving rise to population ageing and labor force shortages.

The TFRs among Singapore residents was only 1.2% in 2012. With a low TFR in Singapore, the country might become a small population with an aging society, which will affect the economy of the country (Chia, 2011).

2.2.3 Provide labor that the local workers avoided

By the mid-1970s local workers preferred to work for lower wages in other sectors, or even stay jobless rather than take up the many jobs that are available in the construction industry (Ofori, 1997). Subsequently, contractors and consultants working in the design, engineering, and construction industries faced labor shortage and unable to tender for construction projects. The use of foreign workers would help the situation improve (Ofori, 1997). Chia (2011) noted that as Singaporean become better-educated and increasingly affluent, they will want to move towards high value-add industries and shun lowly-paid and "dirty, demeaning and dangerous" (3D) jobs so there is a need of foreign workers to fill these vacancies.

2.2.4 Transfer relevant skills to the local workers

Foreign skilled professional and managers have the transferred and relevant skills, technology and capital while the unskilled foreign workers ensured the labour-intensive sector such as the construction sector have sufficient labours to complete the works (Piper, 2004). Leow (2010) noted that foreign workers are not only increase the human capital directly but also indirectly by transfer their knowledge to Singaporeans. Skilled foreign workers could also bring the distinguish knowledge which could link Singapore to globe and achieve a sustainable development (Leow, 2010; Yap, 2014).

2.2.5 Reduce the cost of labour for companies

Werner (1996) highlighted that foreign workers in Singapore can cut the cost of labour. The benefits that arise from the lower labour cost due to qualified and cheaper foreign workers, increases efficiency and strengthens the competitive position of individual companies and the national economy.

Without foreign workers, companies need to pay higher wages to the local workers which will result in higher price in outputs, this mean that the price of housing and complete projects will increase.

2.2.6 Reduce the use of illegal workers

Yap (2014) found out that the food and beverage (F&B) and construction sectors appear to be the main users of illegal foreign workers in Singapore. Werner (1996) found out with the use of foreign workers, illegal labour in the country is reduced, and highlighted that due to the shortage of labour in a country, companies may relies on illegal workers if the use of foreign workers is being greatly controlled.

2.2.7 Enable Singaporeans to enjoy good social and municipal services

Foreign workers provide healthcare, eldercare and domestic services to support the ageing population and working families. Foreign construction workers build housing and infrastructure, and do maintenance and conservancy work. Thus, without foreign construction workers in Singapore, Singaporean will not be able to enjoy the good infrastructure and housing.

Foreign workers may help in reducing inflationary pressure on Singaporeans, by simulating some costs of living for the local citizens (Thangavelu, 2012). Many say that the foreign workers reduce the jobs opportunity for local workers, but the Government of Singapore claim in their paper that the foreign workers flow into jobs sector that Singaporean are unwilling to do.

2.3 FOREIGN WORKERS – CONS

2.3.1 Caused social problems

Foreign workers served to overcome the labour shortage in a country. However the over-dependence on foreign workers had caused social problems (Abdul-Rahman, Wang, Wood, & Low, 2012). With an influx of foreign workers in Singapore, there are pressures on housing, and congestions for public services and infrastructure in the country (Gross, 2011; Kim, 2013; Thangavelu, 2012). Thangavelu (2012) also found out that foreign workers are competing for jobs, housing, schools, medical care and space in public transport. Yap (2014) notes that with the increase of foreign workforce in Singapore, it would cause overcrowding in the country.

2.3.2 Communication problems

Communication problems with foreign workers are difficult, Toh (1993) highlighted that the problem faced by foreign construction workers and Singaporean is language; communicating between Singaporean and largely semi-literate or illiterate foreign workers is difficult and often caused misunderstanding between the foreign workers and locals.

2.3.3 Widening income inequality and jobs competition

Foreign workers would disturb and upset disadvantaged groups of local workers by undercutting their already low wages and widening income inequality (Briggs Jr, 1994; Camarota, 2005; Ofori, 1997; Yap, 2014). Yap (2014) found out that some foreign workers are willing to accept lower wages than the local workers. This led to increased competition for jobs and local workers are put at a disadvantage as employer will choose to employ the worker who accepts the lower cost of production. Ofori (1997) highlighted that cheap foreign workers drive down the income of local workers and this would further erode the attraction of careers in the industry.

2.3.4 Low productivity and slow economic restructuring

Chia (2011) highlighted that with low-skilled workers will delay Singapore economic restructuring and result in lower productivity performance. Wu and Thia (2002) found out that Singapore's overall Total Factor Productivity (TFP) growth could have been higher if not for foreign labour. The "labour churning" practice of replacing foreign workers by new batches on expiry of their work permits, meant foreign workers are unable to improve productivity through training and accumulating work experience. Similarly, Thangavelu (2012) found out that foreign workers have negative effects on productivity in a panel study of 24 OECD countries, as each foreign worker is estimated to be only two thirds as efficient as a local worker.

2.4 POLICIES TO THE RELIANCE ON FOREIGN CONSTRUCTION WORKERS IN SINGAPORE

2.4.1 Progressive increase in foreign workers levy

To control the inflow of foreign workers in Singapore, Singapore devised a new immigration policy in 1980, using a price mechanism called foreign workers levy (Ofori, 1997). Foreign construction workers were the first for whom employer had to pay a levy (Ofori, 1997). The levy would make employment of foreign workers expensive (Ofori, 1997; Toh, 1993). In April 1982, the foreign worker levy was introduced for work permit holders in all sectors including construction (Ofori, 1997). In 2015, the construction levy for higher skilled and basic skilled workers is $600 and $950, respectively.

2.4.2 Reduction in Man-Year-Entitlement (MYE) quota

MYE refers to the total number of foreign workers a main contractor is entitled to employ, based on the value of contracts awarded by developers. It is allocated in the form of the number of "man-years" required to complete a project (i.e. 1 man-year = 1-year employment under one work permit). There is a cumulative of 45% reduction in MYE quota from 2010 - 2013, this means that while previously a project before 2013 may be allocated 1000 workers, but a new project of the same scale that start from July 2013 would only be granted 550 workers. The Government did not propose to reduce the

MYE quota in 2014 and 2015, but indicated that the foreign levies for the basic skilled foreign construction workers will be increased.

2.4.3 Dependency ratio ceilings (DRCs)

The DRCs refers to the maximum permitted ratio of foreign workers to the total workforce in the stipulated sector is allowed to hire. Different industries have different DRCs. In construction sector, the DRCs is 1 local: 7 foreigners. The construction DRCs is the highest DRCs across all sectors in Singapore (Ministry of Manpower, 2015). In 2012 and 2013, the Government has tightened the foreign worker quota by reducing the DRCs in some sectors (Oon, 2012). However, this does not affect the DRCs in the construction industry as the DRCs for the construction remained the same since 2010. Yap (2014) found out that DRCs enable Singapore to reduce the reliance on foreign workers and curb the growth of foreign workers, but industries may face labor shortage if the DRCs quota is too low.

2.4.4 Boost local workforce through incentives

To boost and retain the local workforce, there will be more incentives given to older workers, early retirees, homemakers. There are incentives introduced to attract and retain older workers. Employers will get a Special Employment Credit (SEC) for their Singaporean workers who are above 50 years old. The SEC will be 8 per cent of the salaries and will cover almost 350,000 older Singaporean workers. The scheme will be in place up to 2016.

However, W. T. Hui (2002) notes that increasing older workers labor force participation in Singapore is limited compared to countries like Japan and Sweden. Singapore’s labor force participation rate for those aged 55 to 59 in 1999 was close to 73 per cent and 28 per cent, for males and females respectively (W. T. Hui, 2002).

2.4.5 Fair Consideration Framework (FCF)

The FCF had implemented on August 2014, as part of the Government overall effort to strengthen the Singaporean core in the workforce. With FCF, before employing new EP holders, companies must advertise the job vacancy on a new jobs bank administered by the Singapore Workforce Development Agency (WDA). The advertisement must be open to Singaporeans, comply with the Tripartite Guidelines on Fair Employment Practices and run for at least 14 calendar days (Ministry of Manpower, 2015).

3. RESEARCH METHOD

This is a conceptual paper which presents the results of an extensive review of the literature on foreign worker issues. It start with literature reviews, which had investigated and interpreted what previous researchers have carried out. Qualitative information provides an understanding of the benefits and problems of foreign workers. Given the nature and scope of this study falls on the Singapore context, as well as the difficulty of searching every related research work. The qualitative secondary data collected for this study are mainly from various sources such as Government white paper, academic papers, government reports, and books. The reason these sources are used is because of its reliability. In addition, policies and management of foreign workers from other countries (i.e. Hong Kong and Malaysia) were also consulted. Subsequently, this study proposes the implementing strategies and policies to reduce to reliance of foreign worker in Singapore.

4. Discussion

This study recommends a few new polices to effectively reduce the reliance of foreign construction workers. It also suggests making changes to current policies in order to reduce the reliance of foreign workers effectively, these new changes made will bring benefits to the society.

4.1. MINIMUM WAGES

Minimum wage is the lowest level of remuneration an employer must pay an employee to work legally (Hui, 2013). This is an important policy that balances the needs of an economy with those of low-income workers so that economic growth occurs in a sustainable manner. Most developed countries in the world have minimum wages. Currently in Singapore, there is no minimum wage, only the cleaning sector have mandate basic level wages of SGD$1,000, and from September 2016 onwards the mandate basic level wages of SGD$1,100 will be implemented to the security sector.

In Hong Kong the minimum wage came into force on 1 May 2011, the minimum wage had benefited the low paid workers, these workers enjoy increases in their monthly salaries (BBC News, 2011). One of the reasons to implement minimum wages is to boost the pay of Hong Kong lowest paid sectors of the society and to reduce poverty (BBC News, 2011). A survey conducted by the People's Alliance for Minimum Wage in Hong Kong found out that workers in the cleaning, security guards and catering industry benefited the most. Thus, this study recommends national minimum wage policy should be implemented in Singapore. However, the national minimum wage in Singapore must not be standardized, meaning the minimum wage will be determined by occupation and industries. If the national minimum wage is standardized, people may switch to a less physical demanding job, in the case of Hong Kong. It may also cause an impact in the industries local workers avoided, such as construction. The minimum wages in Singapore should not include the foreign work permit holder in the construction sector and the foreign domestic workers. If the minimum wage includes the entire workforce, foreign construction work permit workers may increase instead of decreases, if there are still no locals willing to undertake the construction jobs.

Even with a minimum wage policy, which lead to higher wages, local workers may still unwilling to undertake "3D" jobs, to address this issue, this thesis suggest that industries such as construction and process sector should have a higher minimum wage when compared to other sector, such as banking where there is a low proportion of foreign workers.

4.2. "SINGAPOREAN FIRST" OR FAIR CONSIDERATION FRAMEWORK (FCF)

Singapore had implemented the FCF, but the requirement apply only to firms applying for EPs, and not for S Passes and WPs holders. The main rationale of FCF is to give priority to Singaporeans for jobs.

This section begins with the loopholes of the FCF. The loopholes are the employers can make the wages and benefits unappealing to local workers so this will deter them from applying and hence they can bring in foreign workers for the jobs. Employer can put tough job description and unappealing requirement to deter the local workers; however upon hiring a foreign worker, there may be internal discussion to make amendments to the job requirement.

It is hard for the Government to check if the job description applies after the hiring process. FCF hiring process is rather subjective, as the employer may interview many local applicants, but select none due to biased and subjective reasons such as lack of suitable skills and experience. With the few loopholes identified, FCF may not work in the Singapore and in Singapore’s construction industry. It is then proposed that "Singaporean First" policy to reduce the reliance on foreign construction workers. The “Singaporean First” policy means that the employer must try their best to employ a local first. If an employer is unable to hire a local worker, they must submit a comprehensive document stating that hiring a foreign worker is necessary and MOM must approve. With this policy, job continue to be created for Singaporeans.

4.3 PROGRESSIVE INCREASE IN FOREIGN LEVY

Singapore has foreign levies which are progressively increasing to encourage employer to reduce reliance on the foreign workers. However this study found that increasing the foreign worker levy is ineffective and unlikely to reduce Singapore reliance on foreign workers, instead it will increase the financial burden on employers. The progressive increase in foreign levies is part of the Government's plan to control the influx of foreign workers, but this may not work because employers may pass on the additional cost to their employed foreign workers, thereby diminishing any incentives to switch to employing Singaporeans. Locals that working in a foreigner-dominated sector, such as the construction sector, their wages will fall correspondingly and leave unsolved social problem and stagnating salaries. This forces the local workers to leave and avoid the construction sector. This study suggests that there should be foreign levy policies in Singapore, but the foreign levy should be paid by the foreign workers instead of the employer, in the case of Malaysia. The amount of levy to be paid should be pledged to the wages and skill level of a foreign worker, unlike the current fixed levy that is paid by the employer. This policy also helps to reduce the reliance on foreign workers in Singapore because foreign workers may not wish to pay the levy by themselves.

4.4 RAISING THE QUALITY OF FOREIGN CONSTRUCTION WORKERS

There are many unskilled foreign construction workers in Singapore, and the bulk of them hold basic skilled (R2) worker permit holder. Figure 1 shows the classification of construction work permit holders after July 2011.

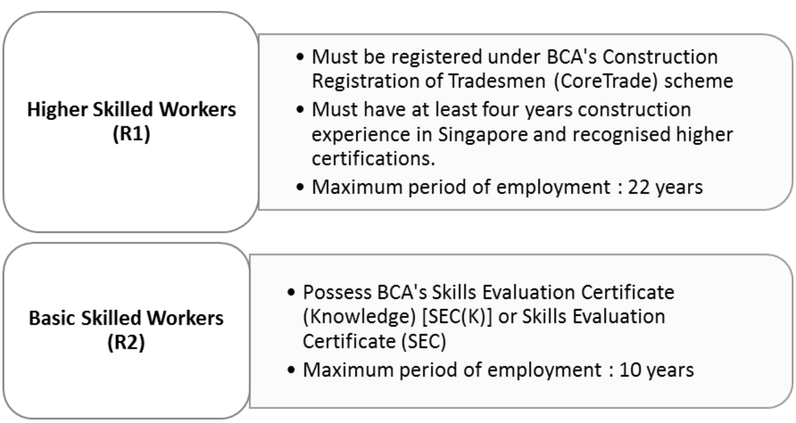

Figure 1: Classification of Construction Work Permit Holder
Source: Building Construction & Authority (2012)

Reducing the number of R2 work permit holder by increasing the use of higher skilled (R1) work permit holder might be a viable strategy. A pool of higher skilled workers will reduce the needs for basic skilled workers thus reducing the number and reliance of foreign construction workers.

The current maximum employment period of a R2 construction work permit holder can be employed in Singapore is 10 years. It is recommended to reduce the maximum employment period of these workers to 7 years. However, the R2 workers can stay employed in Singapore if they are eligible to upgrade their work permit to higher skilled (R1) status after their maximum period of employment of 7 years. During their period of employment, R2 workers will be given opportunity to attend training to upgrade their knowledge and skills. These R2 workers must pass a skill test and meet all R1 work permit requirements before they can upgrade their work permit to R1. Those that failed to meet the requirements will not be allowed to renew their work permit.

One of the requirements to apply for R1 work permit is to have at least four years' experience in Singapore construction industry, this study proposes to reduce the years of experience needed to two years, but the applicant must pass a comprehensive test before they are allow apply for the R1 work permit. The reason is to reduce the years of experience is because these workers may have relevant work experiences before coming to Singapore.

4.5 DEVELOP A CORE HIGHLY SKILLED LOCAL WORKERS

It is necessary to enhance the image of the construction industry in Singapore. There must be a change of mindset toward blue collar work, such as in construction, through education. The reason to enhance the status of local workers in the construction sector is that they can take pride in their employment. With an enhanced status, it may even draw more locals to join the construction industry, thus reducing the reliance of foreign construction workers. The construction industry in Singapore must re-establish its position in the job market as a profession that is innovation, creativity and productivity, doing this will improve the image and status of the construction industry. To have a better employment condition, Government agencies such MOM and BCA must work together to promote better welfare and wages for the local workers. For example, currently BCA is giving generous scholarships and sponsorships to the local students. This study suggests that student should learn both management and construction skills in the course of their studies, as doing so may reduce the reliance on foreign workers as some of the jobs can be performed by the local graduates.

5. Conclusion

This study has highlighted the benefits of foreign workers, which include helps in Singapore's economic growth, transfer relevant skill to the local workers, and reduce the cost of labour for companies. The consequences of employing foreign workers that are found out are as follows, social problems, job competitions and others. Moreover, this study proposes various ways to reduce the reliance of foreign construction workers in Singapore construction industry. This includes raising the quality of foreign construction by providing sill-upgrading, develop a highly core skilled local workers by providing apprenticeship training and higher starting salary, etc.

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CUSTOMER BEHAVIOUR AND ENERGY USE IN EUROPEAN SHOPPING CENTRES

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Abstract
Society spends more and more time in shopping centres; shopping, working, relaxing and socialising. Shopping centres are complex physical structures which require large amounts of resources in their day-to-day activities. There is an urgent need to reduce energy use - in 2007, in Europe alone, there were 5700 shopping malls - and to provide stakeholders with the tools to develop the next generation of sustainable shopping centres. The intention here is to identify how the user behaviour among customers influence energy performance in European shopping centres. The user behaviour influences whether actions to reduce energy use are implemented and how effective the actions are.

To gain a European-wide understanding of the technical, functional and social situation in shopping centres today, a survey was carried out amongst customers in European countries. The survey gathered information about energy efficiency, facilities, functions, management, ergonomics, safety and logistics within shopping centres today, with focus on the reasons behind energy efficient upgrades or the lack of them, and expectations about what an upgrade would achieve.

Keywords. *shopping centres, sustainability, retail architecture, user behaviour, energy efficiency*

1. Introduction

Policies and research often focus on technology and buildings and not on social aspects associated with future developments. There are many reasons for this, and one of the most pertinent may be that behaviour is both difficult to control and to predict and that the technological solutions that are introduced are perceived as part of a purely technical system. The ambition to identify the systemic inefficiencies of shopping centres requires a more holistic systems view, which cannot be achieved by simply studying isolated parts or individuals in the shopping centre.

While occupant's behavior on energy use in residential buildings is focus of many research publications (Keyvanfar et al.,2014) publicly available documentation on energy use reduction focusing on shopping centres is still very limited. While some studies take a broader view on commercial buildings (Staniaszek, 2013), other focus on measurement and evaluation of thermal comfort (Haberl and Komor, 1989; Lam et al., 2001; Yan et al., 2013). However, it is necessary to study the system of shopping centers and customers as an interrelated whole. Shopping centres as systems consist of many relevant factors. In order to ensure a holistic view throughout the analysis of the shopping centres the study aims for a socio-technical systems approach. In a socio-technical system, the user(s) are parts of the system itself making it a socio-technical system rather than a purely technical one (Ingelstam (ed), 1996). Is there a conflict between customer satisfaction and energy efficiency in shopping centeres? It is hypothesized that customer satisfaction is not achieved by shopping in a sustainable shopping centre. There might be other influential factors and challenges to become more sustainable. What is the role of the customer in achieving more energy efficient sustainable shopping centres? What are the roles of other stakeholders like owners, managers and tenants in relation to customers themselves?

A socio-technical systems approach is more likely to be able to point out inefficiencies associated with both components and users. The overview of the total system increases the chances of identifying and providing possibilities for how to solve the inefficiencies rather than if these actors and factors were handled separately. In addition, a socio-technical systems approach increases the chances of identifying inefficiencies that are not only affecting isolated parts or members of the system, but those having a negative influence on the system as a whole, so called systemic inefficiencies.

2. Objectives

To gain a European-wide understanding of the technical, functional and social situation in shopping malls today, a survey was carried out amongst customers of shopping malls. The intention was to identify how user behaviour influences the energy performance of shopping malls. Customer satisfaction is what defines shopping centres. However, it is here postulated that customer satisfaction is not achieved by shopping in a sustainable shopping centre. The aim of these questions was to find out the influence of energy saving aspects and environmental profile on the customers’ choices. It also, for instance, asked for information on the customers’ acceptance of possible energy saving measures.

2.1. QUESTIONNAIRES

The survey has a cross-methodical approach (Cresswell, 2009). Questionnaires are the primary method applied, one for each group was sent to five European countries; Norway, Spain, Italy, Germany and Austria. The questionnaires were supported by information gathered through interviews and site visits. The customer questionnaire asked questions related to the customers' preferences when choosing shopping centre (approximate time to finish it was 5 to 10 minutes).

When working with questionnaires it is common to approach a randomly selected group. Random selection is considered important because it reflects a commitment to the production of findings which may be generalized beyond the confines of those who participate in the study. However it is rarely possible to gain contact with all parts of the population, which means a survey usually ends up with a sample of contacts. Within this project the approach to achieve a sample group within the three stakeholder groups varied according to participating country.

2.2. INVITATIONS TO PARTICIPATE

Getting in touch with both customers has its challenges. Customers belong to the "general public" and are not necessarily associated with shopping centres and the retail industry. Shopping is for convenience and leisure and there is no automatic link between a customer and a shopping centre; customers choose the type of shopping centre according to retail needs, location, weather conditions, habit or impulse (Haase et al., 2015). Therefore, getting in contact with customers requires being on site in a shopping centre and approaching customers as they enter or leave the shopping centre. Alternatively a digital survey which sends the questionnaire to customer clubs or shopping clubs associated with shopping centres may be used. Both these methods were used in this survey. However, the choice of methods meant that the physical and social range of the survey activity was limited to one or two shopping centres. The use of a digital survey through customer clubs was also limited because not all shopping centres have a customer club.

Table 1 – Response to the customer's questionnaire

Country	*Number of respondents Answered*
Germany	**8**
Italy	**481**
Norway	**232**
Other	**13**

Three demo-cases were the main focus of the customer survey, and two main methods were used to get in touch with customers.

- In Norway the majority of response was achieved through sending an invitation and link to the questionnaire by email. The shopping centre management in Norway provided a random selection of 2000 addresses from its customer club address list. The shopping centre representative indicated that we could expect a low response from customers, and the final result of 232 was considered a good result from both the project group and the shopping centre representative. Customers were informed about the survey through the shopping centres' facebook-page, and only one customer club member complained about the use of their email address for the survey.
- In the Spanish shopping centre there was no customer club and an internet survey was therefore not an option. Representatives from the Spanish partners collected some questionnaires, but the number of responses was low (4 respondents). Some interviews were also done in Germany.
- The Italian partners were able to include the questions from the questionnaire in another customer survey that they were currently working on. This survey was carried out outside the Italian shopping centre and resulted in 481 responses. The results from this survey were included in the results of the Italian customer survey.

3. Results

Customers were asked a wide range of questions relating to sustainability in shopping centres. Energy efficiency and the building fabric were not the only factors considered. Customer's habits and preferences were also considered, in relation to for example transport, merchandise, thermal comfort, accessibility and architectural quality.

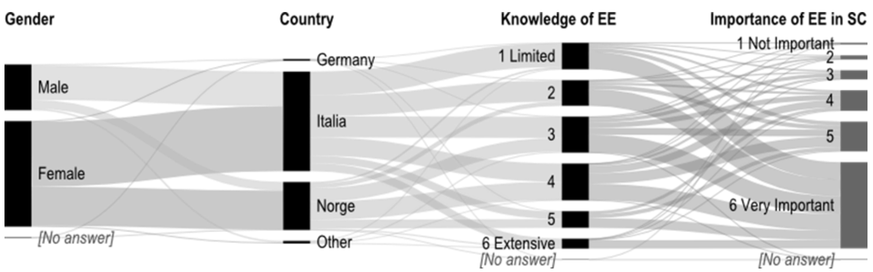

Figure 1 – Visual mapping of customers by countries, knowledge of energy efficiency (1-6) and opinion on the importance of energy efficiency in shopping centres (1-6).

3.1. CUSTOMER KNOWLEDGE

70% of respondents to the customer questionnaire were female. This is related to the factor that women dominate global spending and are in the majority amongst shopping centre customers. The survey shows that female respondents claimed to have limited knowledge about energy efficiency, and it also shows that men claim to have more extensive knowledge. In addition, the data suggests that female Norwegian respondents have more knowledge about energy use in shopping centres than female respondents in Italy. It is difficult to generalise about the reasons for the differences in perceived knowledge about energy and sustainability issues amongst men and women, and from country to country, without conducting a separate survey since there is a danger of introducing old and outworn stereotypes. However, it is important to note that the main customer group in shopping centres considers themselves to have limited knowledge about energy efficiency. Customers are not one homogenous group, campaigns aiming at increasing customer knowledge and interest in energy issues should therefore be tailored towards the needs and interests of different customer groups, such as teenagers, seniors, women and men.

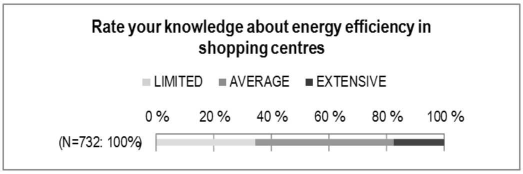

Figure 2 – Customer questionnaire. Answers to the question "How would you rate your knowledge about energy efficiency in shopping centres?"

Representatives from a large British retail company, which has stores all over the UK, told us that sustainability issues were very important for the company. This was because "Customers want to be associated with brands that are deemed to be sustainable and are looking after the environment." They believe that they have to improve the energy use in stores because of customer awareness and that there are signs of increasing interest in sustainability issues in the retail market. However, the customer survey shows that in general customers do not have extensive knowledge about energy efficiency. Two main questions arise from this, is the limited interest amongst owners and managers and particularly among tenants to retrofitting shopping centres to be more energy efficient influenced by the lack of knowledge amongst customers? And are stakeholder groups interested in changing this factor? Amongst informants interviewed, only John Lewis claimed to be influenced by customer interest in sustainability. Data from the questionnaires and interviews will therefore be used to discuss these inefficiencies associated with stakeholder knowledge and actions.

3.2. CUSTOMER CHOICE

In the questionnaires, the customers were asked how important it was for them that a shopping centre is energy efficient. The customers were also presented with an extensive list of factors that can influence a customer's choice of shopping centre, and were asked to choose the five most important influencing factors for them. The factors listed ranged from location to energy efficiency, architecture, prices and so on. Customers were asked to answer "yes" or "no" to whether they were willing to accept measures like higher prices or lower indoor temperature in winters to increase energy efficiency. They were asked about the importance of product origin, the transparency and availability of "organic/bio" and "fair trade" products. Furthermore, customers were asked to rate specific shopping centres according to a long list of factors, many of which were the same as list of factors influencing choice of centre. Customers were asked what they would improve in the specific centre. Finally, customers were asked by which means of transport they usually travel to the shopping centre.

Most customers thought that energy efficiency was important, but few of them let it influence their choice of shopping centre. Interestingly, there was a distinct discrepancy between the customers rating of the importance of energy efficiency in shopping centres (Figure 3), and how much energy efficiency actually influenced their choice of shopping centre. On a scale from 1 (not important) to 6 (very important), nearly 80% of the customers rated energy efficiency in shopping centres as highly important (5-6). However, when asked to pick the five factors that most influenced their choice of shopping centre, less than 5% added energy efficiency to their list (Figure 4).

Figure 3 – Customers questionnaire. Answers to the question "How important is to you that a shopping centre is energy efficient?"

3.2.1 Location, transport and shopping preference

Location had most influence on the customer's choice of shopping centre. Over 60% of customers agreed that the location of the shopping centre influenced their choice (Figure 4).

All factors in the list associated with location and transport scored relatively high in the customer's selection of the five most influential. Free car parking and good access to public transport were chosen by many.

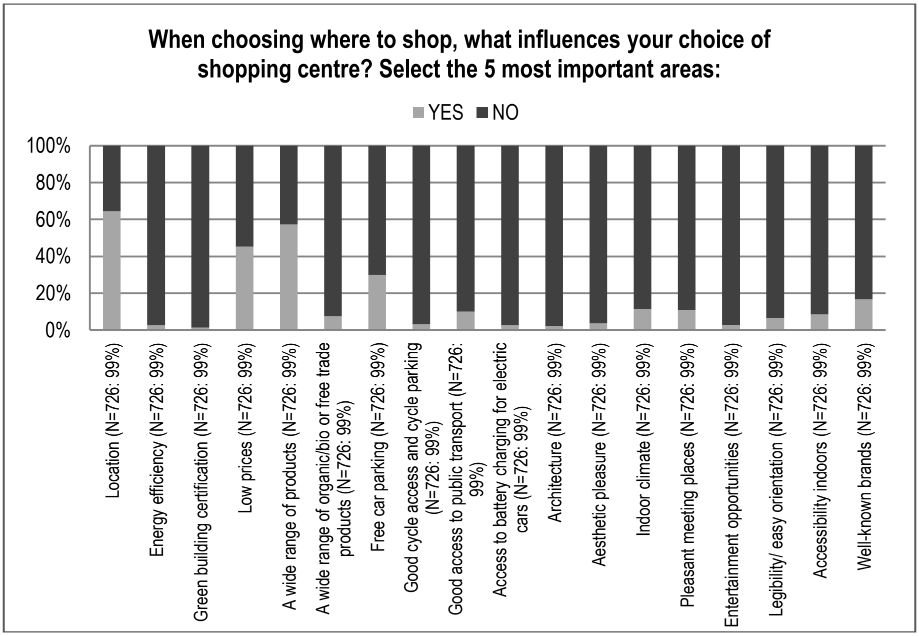

Figure 4 – Customers questionnaire. Answers to the question "When choosing where to shop, what influences your choice of shopping centre?"

Norwegian customers in particular rated free car parking as factor that influenced their choice of shopping centre. When asked how they usually travel to shopping centres, over 70% answered "car/motorbike" (Figure 5). The answers to the questions related to cycle access and cycle parking suggests that this area is not so important to the customers, and very few used bicycles as their main means of transport.

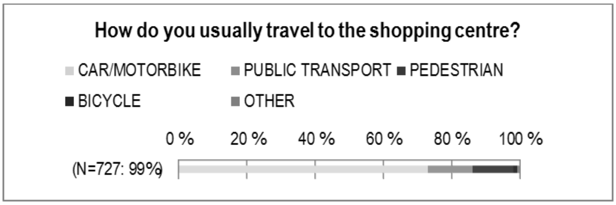

Figure 5 – Customers questionnaire. Answers to the question "How do you usually travel to the shopping centre?"

There are some differences between countries. Over 80 % of Norwegian respondents said that location was the most important. 53 % of Italian respondents replied that location was important. Although location was the most important factor for Italian customers, it is not as important as it is to Norwegian customers. The Norwegian customer survey was carried out by members of the customer club. The Norwegian demo case is a suburban shopping centre which serves a broad catchment area. Shopping is primarily car based and there is free parking. There is bicycle parking which serves the local community, but the majority of customers drive to the centre and this is supported by the results from the survey.

The customer survey in Italy was carried out outside two shopping centres in suburban areas outside Genova and car based travel is also important. Customers are looking for locations which are easily accessible, particularly by car. A town centre survey would potentially have gathered a different response with regard to the means of travel, however we may surmise from its dominance within the existing survey, that location would still be an important factor.

3.2.2 Product availability and price

Close to 60 % of the customers agreed that a wide range of products influenced them in their choice of shopping centre (Figure 4). Norwegian and Italian customers both rated this as having a high importance, almost 50 % of Italians and close to 60 % of Norwegians. Again the use of the Norwegian case for the customer survey influences the response to the questions. The demo case is popular amongst its customers because it allows an one-stop shopping (Woods, 2012). A wide range of products from food and clothing to hardware and pharmacy products, and veterinary services are available to the customer during one shopping trip.

The importance of product availability was also supported by the fact that almost 20% of the costumers answered that well-known brands were among the five most important for their choice of shopping centre. A store manager in the UK suggested that customers are more interested in the price of goods, than they are in energy issues, but that they are also becoming more aware of product origins. However despite the suggested interest in the UK, few customers in Norway and Italy put the availability of organic/bio and fair trade products on the list of five most influential factors for choice of shopping centre. The response in Italy and Norway was similar, under 10 % in both countries. However when asked in a later question about the importance of access to bio/organic products and product origins when doing their shopping in the shopping centre, both aspects rated much higher and, 40% answered "very important" (Figure 6).

The response to this question was different in Norway and Italy. More than 50% of Italian respondents rated availability of bio/organic products as very important (in Norway less than 20 % rated it as very important) and more than 90 % suggested that product origins were important (less than 50 % said this in Norway). The sale of organic products has struggled on the Norwegian market, although the Norwegian Ministry of Agriculture and Food has an on-going focus upon increasing the availability of organic products and their share of the market (Gibalova, et al., 2010) .

The third most popular factor on the list of five influential factors, were "low prices". When asked if they would accept a higher price for a product sold in an energy efficient store, 21% of the Norwegian customers and 45% of the Italian customers answered "yes". Price has traditionally influenced our shopping habits, but consumer response to price is based on an evaluation of the products benefit or utility, which also corresponds to their notion of value (Kyoung-Non & Schumann, 2001). Price is therefore not the only factor which influences shopping habits and the value placed on purchases, and this therefore allows for the possibility of paying more for a product sold in an energy efficient store.

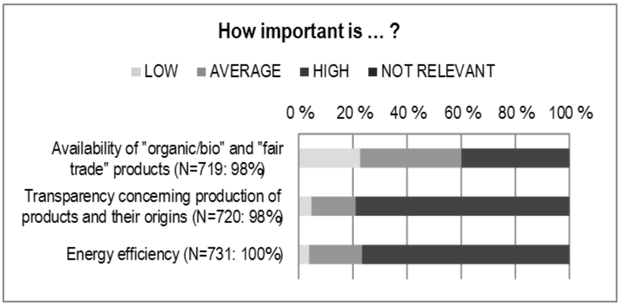

Figure 6 – Customers questionnaire. Answers to the question "How important is…?"

3.2.3 The role of the physical environment

Customer response to the physical environment is important when considering an energy efficient upgrade, because although management systems such as BEMS are important in an upgrade, changes to the physical environment may be expected and this may have implications for eventual customer satisfaction.

Customers were asked to rate the existing shopping centre in terms of a number of physical and environmental aspects, lighting, acoustic comfort, thermal comfort, user friendly design (ergonomics and logistics), meeting places, architecture and design, and aesthetic quality (Figure 7).

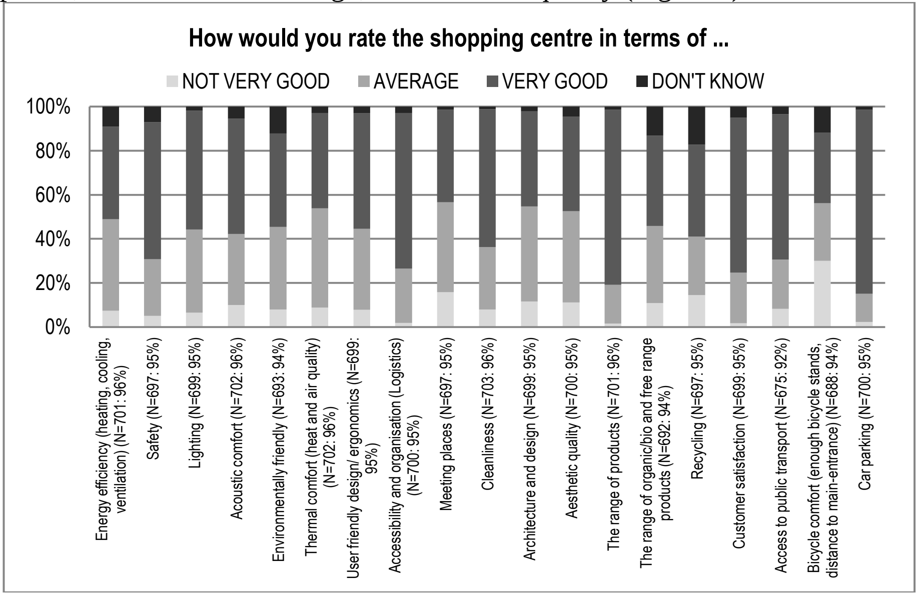

Figure 7 – Customers questionnaire. Answers to the question "How would you rate the shopping centre in terms of…?

The results show that only accessibility and organisation (logistics) score high amongst respondents. Customers were least content with the thermal comfort and meeting places, less than 50 % stating that the shopping centres were very good. Although only under half were dissatisfied, the response does point to a pressing need for improvement in these areas. In general customers in both Norway and Italy were satisfied with the physical environment associated with the three shopping centres who participated in the survey. As mentioned earlier car parking and the range of products are critical factors. Improving energy efficiency in shopping centres has implications for the physical environment; therefore increasing customer awareness/ expectations about the physical environment in shopping centres is relevant. Satisfying shopping centre customers has the potential to be about satisfying their sustainability requirements.

3.2.4 Thermal comfort

When considering energy efficiency in shopping centres, there is a greater willingness amongst customers to accept lower temperature in winters and higher temperatures in summer than to accept higher prices (Figure 8). In fact, 87 % of the customers would accept lower temperature in winters, and many also suggested this in their comments, stating that they would wear their outdoor clothing inside the shopping centre.

66 % of the customers state that they would also accept higher indoor temperatures in the summer, but in this case a significant difference can be noticed between the countries (respectively 79 % in Italy and 43 % Norway).

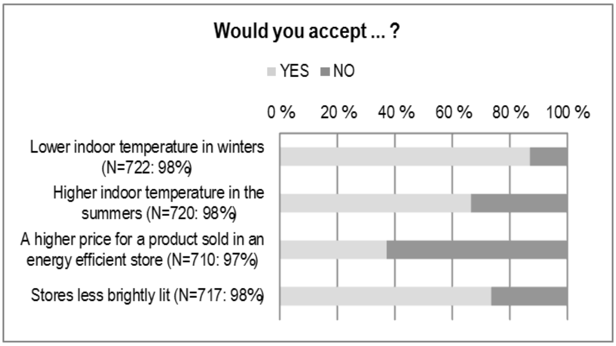

Figure 8 – Customer questionnaire. Four questions relating to lighting, indoor temperature and product price

It is unclear why there is such a difference in the response between the two countries, but it is suggested here that Italian customers are going into shopping centres from a warmer outdoor environment and this affects their indoor expectations.

The use of lighting in stores and shopping centres also has implications for customer satisfaction. The willingness amongst customers to shop in stores less brightly lit is high (73 %), and in this case Norwegians were slightly more inclined (85 %). Lighting was an issue which harvested the greatest number of personal comments during the gathering of questionnaire data. Customers would prefer stores to be less brightly lit for two main reasons, firstly they believe it would help to reduce the in-store temperature, secondly they suggest that a reduction would improve visual comfort.

Although they were less keen on the idea of paying more for goods that were sold in energy efficient stores. Customers are therefore not interested in paying for the cost of upgrading lighting systems in shopping centres. Under 40 % said yes to this.

4. Discussion

The customer survey established that there are three main areas where inefficiencies connected to user behaviour on energy efficiency in shopping centres may be found. These are customer knowledge, customer choice and the role of the physical environment.

Customer knowledge or lack of knowledge is an important factor to be dealt with if shopping centres are to gain approval for actions associated with energy efficiency issues, or if customers are themselves going to demand energy efficient shopping centres. A representative from John Lewis suggested that customer engagement and staff awareness were the most important factors when aiming for in-store reductions in energy use, "You need to tell people what you are doing, if you are going to get them to buy into it. Otherwise they are just going to think that it is very dark and cold (in the store)". It is unclear how customers could actually reduce energy use when visiting a shopping centre, but their interest in energy use and sustainability issues has the potential to influence owners, managers and tenants. Without a customer demand there will be less interest in investing in energy retrofits in shopping centres. However, as with many other retail factors, it is the market, in this case shopping centres which creates the demand. Therefore when working towards energy efficient shopping centres owners managers and tenants should also work at increasing customer focus on these issues.

Customer choice - transport and shopping preference, product availability and price. Energy efficiency does not influence customer choice of shopping centre. Location is the most importance factor influencing customer choice of shopping centre. This is closely associated with the importance customers place on car-parking. Customer's in the survey shop primarily at suburban shopping centres which are convenient to reach by car. However car dependence does not support sustainable shopping, and this may be understood as an inefficiency associated with user behaviour, it is not directly associated with the retrofitting of the physical structure of shopping centre which is the primary focus of the research, but it should considered when working with a broader issue of sustainable shopping centres.

A wide range of products and the price of products also influenced a customer's choice of shopping centre. Customers are less focused on the availability of organic/ bio and free trade products. They do believe that these are important factors when aiming to achieve a sustainable retail environment, but it did not significantly influence their choice of shopping centre. As with car-based shopping, this aspect does not directly relate to retrofitting the physical structure of the shopping centre, but it does point to the level of interest amongst shopping centre customers about sustainable shopping, which in turn has the potential to influence those making the decisions in shopping centres.

The role of the physical environment - thermal comfort. Customers are in general satisfied with physical environment in the shopping centres where the surveys took place. They were not exceptionally critical of, for example the aesthetic quality, meeting places or acoustic comfort. Where the physical framework directly encroaches on their physical comfort or the perceived functionality of the place, customers were more critical and were more aware of inefficiencies in the physical environment. In addition customers were willing to accept changes to the heating and lighting systems in order to save energy, even though these measures would have a negative influence on their physical comfort. They were positive to the suggestion that temperatures could be changed (lower in winter, higher in summer) and that lighting levels could be reduced. Answers from tenants suggest that energy efficiencies will be more easily achieved if there is acceptance on three stakeholder levels.

5. Conclusions

In general customers are satisfied with the shopping centres where the surveys took place. Besides customer satisfaction; safety, logistics, the range of products, access to public transport and car parking received the highest ratings. Most of these aforementioned qualities are also highly appreciated by customers when choosing where to shop. When it comes to architecture and design related considerations, including aesthetic quality, meeting places and thermal comfort (heat and air quality), reception is slightly more mixed, with ratings on the average (3-4) in the same magnitude as very good (5-6). Some customers (at least 10 %) were also less impressed with the current bicycle comfort, recycling and the range of organic/bio and free trade products at the shopping centres. In addition to the general environmental friendliness of the shopping centre, these also stand out as areas, which customers find difficult to assess (meaning at least 10 % chose "don't know" when asked for an assessment). This result implies that a shopping centre is more than what is directly perceivable to each customer and that a fair judgement of i.e. recycling, energy efficiency or environmental friendliness requires more insight in the day to day operation of the centre and behind the scenes management. It also suggests that an environmental friendly profile is not being communicated to the customers. The results show that customers are generally satisfied with the centres which were included in the survey and do not necessarily see a need for improvements, but at the same time they are also keen to improve the energy efficiency of the shopping centres and that this is one of the aspects where they saw the greatest possibility for improvement.

Customer satisfaction is what defines shopping. However customer satisfaction is not achieved by shopping in a sustainable shopping centre. Location and the range of goods are the most influential factors. The shopping centre industry is therefore not being challenged by its main source of income to become more sustainable. Store owner such as John Lewis in the UK do believe that shoppers will in the future become more aware of sustainability issues and demand more sustainable places to shop. However achieving a change in what provides customer satisfaction requires that tenants, owners and managers provide more energy efficient sustainable shopping centres. The change will depend on owners, managers and tenants rather than on customers themselves.

6. Acknowledgements

The research leading to these results has received funding from the European Community Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 608678.

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Rajapaksha.U, et al (eds), 2015, “Making built environments responsive”*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 321–332. ©

AN EVALUATION OF THE CURRENT URBAN DESIGN PROCESS IN ORDER TO DERIVE CRITICAL SUCCESS FACTORS FOR THE CREATION OF A POTENTIAL NEW URBAN DESIGN PROCESS FRAMEWORK

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Abstract
The current urban design process is top-down, i.e., generally the urban designers or planners design the urban environment and at a later stage the community may have some involvement. There are serious criticisms of this process as it may not touch the “ground” level community, and therefore, there is a serious risk these projects will fail to create sustainable environments. Accordingly, in order to overcome the drawbacks of the current top-down process, researches have discussed implementing a bottom-up process in order to deliver sustainable urban designs. In the meantime the current top-down urban design process may have features which may positively affect for the creation of sustainable urban designs. Accordingly, this research paper discusses the critical success factors of the current top down urban design process which supports for a creation of a new potential urban design process framework. The research methodology adopted for this research is case study research reinforced by grounded theory where the researcher has evaluated a live urban design project process in North-West England. The evaluation has resulted deriving seven critical success factors. The “leadership” of the process has been identified as one of the major critical success factors among the other critical success factors.

Keywords: *Sustainability, urban design, top-down process, bottom-up process, critical success factors*

1. Introduction

The current urban design process is mainly top-down. Fraser, Dougill, Mabee, Reed, and McAlpine (2006) state that design processes typically lead by experts simply comply with the funding agencies and this top down process may alienate the community and fail to capture locally significant factors. To overcome the constraints in the top down urban design process, many researches have discussed implementing a bottom-up process in order to deliver sustainable urban designs. C. T. Boyko, Cooper, Davey, and Wootton (2006) states that sustainability issues should be addressed early in the urban design process, and therefore, people who live, work and socialise in urban environments have a fundamental role to play in urban design. Accordingly, Boyko et al. (2006) suggest the constantly changing social, functional, aesthetic and emotional needs should be addressed in the urban design process by providing community engagement opportunities throughout the urban design process. Even though the bottom-up process has been proposed as a potential process for urban design, a bottom-up process has its own weaknesses which can adversely affect the quality of the urban design project or its processes. For an example, as Annibal, Liddle, and McElwee (2013) assert that local people have a unique perspective on their needs, joining up settlements, managing change through community led planning and delivery of innovative services but they have stated that the community needs to be organised, and therefore, a statutory service needs to be engaged which can identify local priorities, secure resources and undertake responsibilities. Therefore, this argument confirms a pure bottom-up process itself may not be a complete solution. Accordingly, based on an extensive literature synthesis which was conducted in a doctoral research, the need to develop a new “balanced” urban design process framework which encompasses features of both top-down and bottom up processes for the creation of sustainable urban designs was established. In order to develop a balanced urban design process framework, the current top-down urban design process as well as a potential bottom-up process were evaluated to examine positive and negative features of both processes and to derive the critical success factors. Based on the derived CSFs from both processes a new community embedded urban design process framework was developed under a doctoral research at the school of Art, Design and Architecture, University of Huddersfield. The specific feature of this new urban design process framework is the process encompasses the features of both top-down process and the features of bottom-up process leading to a creation of a balanced urban design process framework which finally helps to achieve the sustainability issues concerned in the current scope of urban design. The current scope of urban design is focused on achieving sustainability in its triple bottom line which is social, economic and environmental sustainability. However this paper specifically discusses the evaluation of the current top-down process and how this examination has assisted to derive critical successes factors for the new urban design process framework from the current top-down urban design process. A mixed research methodology guided by case study and grounded theory have been used for this study and a live urban design project process in North-West England has been evaluated to derive the critical success factors (CSF).

2. Literature synthesis on current urban design process and its implications on sustainable urban design

This section examines the nature of the current urban design process and how that particular nature has affected for the creation of sustainable urban designs.

2.1. NATURE OF THE CURRENT URBAN DESIGN PROCESS

Roberts and Greed (2001) describe the urban design process occurs in four sequential stages. As they discovered, during the first stage ‘defining the problem’ the planning or design team appraises the study area by conducting surveys associated with the urban form by undertaking an activity analysis. Thereafter, based on the analysis, the team develops a rationale with a summary of development opportunities and constraints. In the latter stage, area strategies and urban design options are evaluated by team members who then finalise an urban design strategy for the area. This indicates that, in practice, the current urban design process is stiff and directly indicates that it is a totally top-down process. Similarly, the four key stages described by Moughtin (2003) in the urban design process in line with the RIBA practice and management hand book of the time, can be taken as another example which emphasises the top-down nature of the urban design process. As explained by Moughtin (2003) in the first phase of the process an architect, planner or urban designer is appointed to identify the problem area and, thereafter, analysis is undertaken; based on the conclusions from the analysis strategies for future development are generated. Once a design is generated, at the latter stage of the process, the client and other stakeholders are consulted. In both these top-down processes, community involvement in the design process is not particularly mentioned nor identified as being an important step in the urban design process and this is indicative of the stiff nature of the top-down urban design process. Based on this stiff top-down nature of the current urban design process, many researchers have argued on its implications for the creation of sustainable urban designs. Some researchers have revealed its positive implications and some researchers have revealed its negative implications. The following literature synthesis identifies the positive and negative implication of the current top-down urban design process for the creation of sustainable urban designs.

2.2. IMPLICATIONS ON SUSTAINABLE URBAN DESIGN

Roy and Ganguly (2009) have stated that a classic top-down process provides early, high level planning which may not deal with the real issues at ground level. As they have explained, a top-down process has no significant understanding of the specific issues, or their cause, at ground level. The Commission for Architecture & Built Environment (2000) argues that a blanket policy of using a top-down process across all locations at all times is not suitable for urban design because each design solution should be distinctive and specific to each context in which it is to be implemented. Carmona, Heath, Oc, and Tiesdell (2003) maintain that the danger of the top down process is the prior formation of the agenda which may lead to the manipulation of local opinion rather than addressing genuine community needs that emerge through effective participation. Supporting the argument of Carmona et al. (2003), and adding to that argument, the Commission for Architecture & Built Environment (2000) has stated that local stakeholders often have particular insight into specific urban design issues affecting a given context and, therefore, urban design solutions developed through a top-down process may not be accepted by the majority of stakeholders. While above arguments discover the negative implications of the current top down process, Larice and Macdonald (2007) have exposed several positive implications of the current top down process. Accordingly, they have asserted that in a top down process development options or proposals are already prepared, therefore, it is easier to focus on the community consultation process. Furthermore, they discovered that a top-down process is less time consuming due to the whole process being predefined and controlled by professional actors. In addition Larice and Macdonald (2007) argue that a top-down process is more effective in terms of resource mobilisation because professional experts mobilise, co-ordinate and interpret community options. Even though Larice and Macdonald (2007) are positive about the current process of urban design, Cooksey and Kikula (2005) argue there are more negative implications in the current process than positive implications. As they discovered the key positive implications are; a top-down approach gives government planners and designers a sense of control and efficiency while donor agencies are keener to invest in projects which have a top-down process because they feel that budgets can be maintained along with pre-established targets and timetables. But as has also been argued there are numerous negative implications to the top-down process and three of the key drawback are, planners and designers proceed as a clean slate design ignoring well-established community social system, analysis generally based on quantitative data or numerical estimations and usually based on poor assumptions of social and environmental behaviour which are often proven to be incorrect because locality and social formations differ. Bell (2005) has argued to achieve good urban design it is necessary to respond to local needs, such as, social and cultural needs, heritage, movement and access, environmental management etc; she has also stated that the current process of urban design often fails to identify such needs in the local context, and therefore, this makes creating a good urban design challenging. Accordingly, she suggests the need for a new progressive process for urban design which has a scope to include the local context. Directly supporting the argument of Bell (2005), Boyko, Cooper, and Davey (2005) have stated that the urban design process must be transformed to create sustainable urban environments. Based on the findings from the literature synthesis the positive and negative features of the top down process can be summarised as follows:

Table 01- Positive and negative features of the current top-down process

Positive Features	Negative Features
•A top-down process gives planners and designers good control over the design project	•Alienates local community members and fails to capture locally significant factors
•Community consultation is easy in top-down process as the plans are al-ready prepared	•Provides early and high level planning which may not deal with the real requirements at ground level
•Less time consuming	•Does not identify specifically the uniqueness of the local entity
•Effective use of resources •Donor agencies are keener to invest in projects which use a top-down approach	•Could leads to manipulation of local opinion rather than addressing genuine community needs that emerge through effective participation
•Donor agencies are keener to invest in projects which use a top-down approach	•Generally based on quantitative and numeric analysis than identifying particular facts in the local context
	•Usually based on poor assumptions of social and environmental behaviour
	•Overlooks the day-to-day life of residents and particularly of family residents
	•May not be accepted by the majority of the community

As revealed in the literature synthesis, the current top-down urban design process has its own positive and negative implications for the creation of sustainable urban designs. Therefore as stated above the current top-down urban design process should be evaluated in order to derive CSFs' to develop a new sustainable urban design process framework.

3. Methodology

The researcher used mixed methodology reinforced by case study research and grounded theory. The research techniques were non participation observation, document review and semi structured interviews. In this study the re-searcher investigated the process of a real life urban design project which was based in North West England. Non-participant observation is one of the key data collection methods in this case study. Accordingly the researcher participated in local design team meetings and other events which were organised to develop the local action plan concerned for this study. Document review was another important method used in this case study to gather much significant information. Several interviews were conducted with community members who live in this particular study area. This has given the researcher a good opportunity to investigate how the community regards the urban design process employed in this project; its drawbacks and any components that should be added to make the process more transparent. Apart from interviews with the community the researcher conducted a detailed semi-structured interview with the Principal Project Officer in charge of the particular project. After gathering data, the researcher qualitatively analysed them by using the NVIVO and Inspiration software where the researcher could derive 07 critical success factors for the creation of new urban design process framework.

4. Discussion and Findings

Based on the positive and negative features of the current top-down urban design process the researcher derived 07 critical success factors which sup-ported for the creation of new community embedded urban design process framework. The derived seven CSF are explained below.

1. CENTRALISED LEADERSHIP AND CONTROL

Centralised leadership and control was one of the leading critical success factor that emerged from this study. The research analysis revealed that the leadership of this particular UD process (top-down urban design project pro-cess) was more centralised to one authority rather than powers being devolved to several authorities or a group of people. Thereafter the researcher investigated, is it a good feature to maintain a centralised leadership? If so how can it be done? Accordingly, based on the analysis the researcher dis-covered, having a centralised leader is a positive feature in a sustainable UD process and it was also revealed that final decisions should be taken by that particular central leader. These empirical findings were strengthened by the literature synthesis as Lang (2005), Carmona (2014)

Cooksey and Kikula (2005) have also described centralised leadership as a positive feature in a UD process. Based on the findings of the analysis, the researcher noted that centralised leadership is needed in order to initiate and execute the UD process in order to complete the UD process effectively within the required time period. Furthermore, it was discovered that the technical and rational decision making should be taken by the project leader.

4.2. COMMUNITY ENGAGEMENT & THE ROLE OF THE COMMUNITY

Community engagement is one of the prominent critical success factor derived by evaluating the negative features of the current top-down urban design process. The analysis indicated that this particular urban design process was a more centrally oriented top down process rather than providing engagement opportunities to the wider community throughout the process. It was clearly identified that community engagement in this process was limited to the latter stage of the process, when the project team conducted a community workshop in order to inform the community about the proposed actions (solutions) for the area and to obtain their comments about the prepared design solutions before finalisation of the plan. The communication process of this project led for many unanswered questions remaining regarding community engagement and the role of the community. These are some of the questions which emerged in the analysis: Is it necessary to engage the community throughout the UD process? If so, when and how is the community to be engaged? Accordingly, the community interviews conducted by the researcher revealed many important information about the community viewpoints about top-down communication process as well as their aspirations to engage in the urban design process. The researcher investigated the communities' asp rations to be engaged in the different stages of the urban design process. Accordingly, the analysis revealed that community can play a strong role at the urban analysis stage in the urban design process. The need for engaging the community for urban analysis has been identified by many authors and re-searchers, among them Boyko et al. (2005), who have stated that the needs of the area should be identified by the community and they should be given ownership to identify the problems and issues of the area. Based on the findings of the study the following mind map (figure 1) was produced informing the influential role of the community in the urban analysis stage.

Thereafter, the researcher investigated the role of the community in the strategy generation stage and it was discovered that the community may have certain interest in engaging in strategy generation but their capability may be limited and not would be greatly influential as it would in the urban analysis stage.

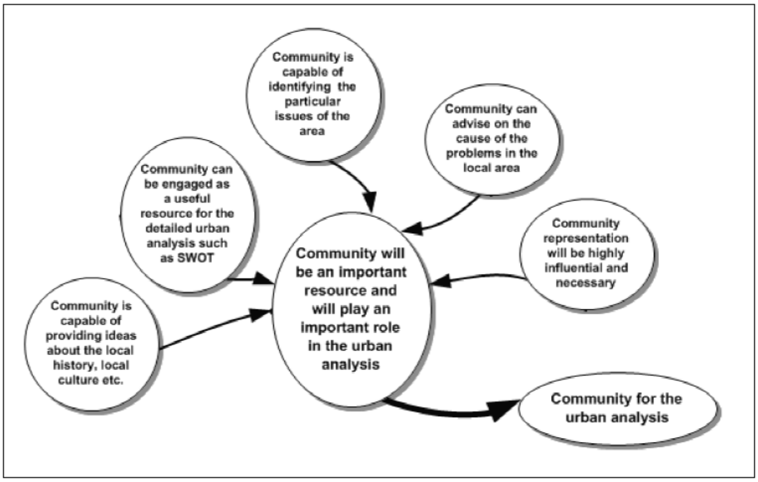

Figure 1, Role of the community at the urban analysis stage

Thereafter, the researcher investigated the role of the community in the strategy generation stage and it was discovered that the community may have certain interest in engaging in strategy generation but their capability may be limited and not would be greatly influential as it would in the urban analysis stage. Figure 2 describes the role of the wider community in drafting strategies. However many authors have supported the engagement of the community in strategy generation, among them, Carmona (2014) has stated powerful play should be enacted by non-designers in this particular aspect.

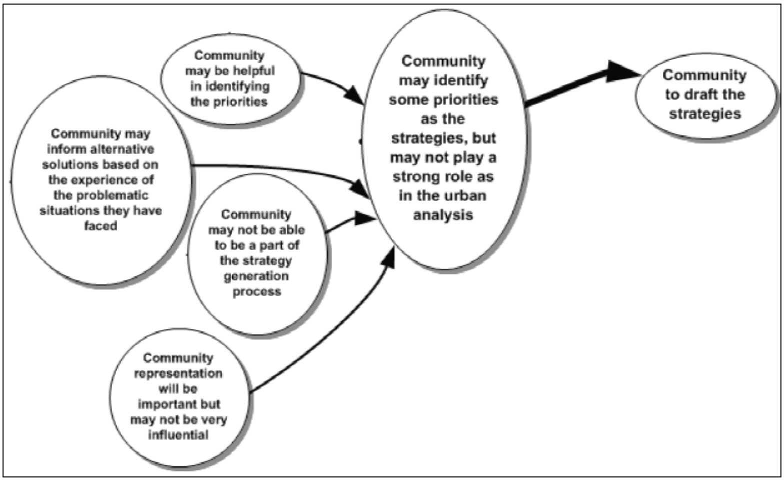

Figure 2, Role of the community at the strategy generation stage

Thereafter, the researcher investigated the role of the community in design development stage. Accordingly the findings revealed that the community does not have a specific interest in engagement in the design development process. Further the results verified that they do not have particular talent to engage in the design development. The analysis indicated that the community can inform the potential designs and they can help to integrate urban analysis findings in the design development, but apart from that, as the analysis indicated, design development is a thing that should be undertaken by the professionals. In addition to the role of the community in the UD process, this CSF informed five conditions which should be maintained in a sustainable urban design process. Those five conditions with its attributes are explained in the table 2 below,

Table 2, Conditions to be met in community engagement

Conditions	**Attributes**
1. Should provide true opportunities for the community	• Community should be given opportunities to actually participate in the process rather than seeking community ideas for already developed plans • Once community ideas are obtained they should be integrated into the final development plan
2. Avoid Over consultation	• Should avoid consulting people about the same issues several times
3. Trust	• Should not consult the community before obtaining and assurance about implementation into the project • Should integrate community ideas after consultation • Engagement should be a transparent process
4. The ability of the community	• The ability of the community to actively engage in the process differs from community to community, therefore it is necessary to change the communication techniques to suit the status of the local community
5. Community should be properly informed about the community consultation	• True intention to inform the consultation workshops to the community • Use of wider tools and techniques to advertise the consultation workshops • Community should be informed in advance

4.3. COLLABORATION WITH OTHER STAKEHOLDERS

Collaboration with other stakeholders emerged as another CSF in this case study. Collaboration with stakeholders is referred to as engaging or obtaining the help of other stakeholders in the urban design process apart from community members. Even though the urban design process of this particular project is top-down a local support group had been established at the urban analysis stage and it operated until strategy generation leading to the creation of the draft action plan. The support group comprised local politicians, building contractors, members of the planning and designing team, and people representing the academic organisations etc. The support group was led by the principal project officer of the city council. The analysis informed that seeking ideas from a wider audience is a positive feature in a sustainable urban design process and the engagement can be undertaken from the urban analysis stage through to the strategy generation stage by establishing a project group or team who represent the wider stakeholders. Furthermore, it was understood that the composition of the stakeholders to be engaged maycomprise the local politicians, representation by people from academia and officers from the construction management discipline such as project developers.

4.4. COMPREHENSIVE URBAN ENVIRONMENTAL DIAGNOSIS

'Comprehensiveness' is an outcome of many factors. All the other CSF identified in this study provide inputs to create comprehensiveness in the urban design process. Even though comprehensiveness is an outcome of many CSFs, in this study a separate CSF emerged on comprehensive urban environmental diagnosis because of two main issues that need to be maintained in the urban analysis of a sustainable urban design process which are non-linearity in the urban analysis and the use of qualitative and quantitative data in the urban analysis. Non-linearity refers to the analysis of urban environment by different parties rather than by only a particular party and use of qualitative and quantitative data in the urban analysis refers that the urban analysis should be conducted by using primary data as well as using secondary data rather than relying only on secondary data. The finding of using qualitative and quantitative data for the urban analysis was strengthened by the findings of Boyko et al. (2006), who state that urban analysis should not only rely on quantitative methods but also needs to focus on the local context.

4.5. EARLY DECISION MAKING VS CEASING EARLY DECISION

This CSF explains the need for avoiding early decisions in the urban design process before actually observing ground level facts and figures. It shows the necessity for urban design process decisions to be taken only after a detailed analysis of the facts and figures and that the initial findings should be considered only as initial findings not as final findings which lead to the conclusions. The analysis revealed three ways to avoid early decisions which are avoid pre identified urban components (analysis), avoid pre developed visions and avoid decisions based on the smaller sample of the community. Strengthening the analysis findings Lang (2005) has discovered that the UD process should be proceeded upon with an open mind by avoiding initial heads of general solutions.

4.6. GROUND LEVEL ORIENTATION

The CSF ground level orientation informs the UD process should be conducted by using ground level facts and figures. This indicates the need to use the community as a strong resource in the UD process and also points towards the need for the project team to collect data and information by visiting the urban area rather than obtaining the information from the previous reports and documents. This CSF is directly related to the CSF ‘community engagement’.

4.7. SPECIFIC FEATURE OF KNOWLEDGE SHARING

The meaning of knowledge sharing in the UD process is sharing knowledge and experience with other partners who are involved in urban development activities. However, it is questionable whether this CSF can become a factor which leads to building a new urban design process framework as this opportunity for sharing knowledge with other project partners is unique to this particular UD project., Not every UD process will get the opportunity to work with project partners.

5. Conclusions

This paper revealed the establishment of potential CSF for the creation of new community embedded sustainable urban design process framework based on positive and negative features of the current top-down urban design process. As described earlier this study was conducted as a part of a doctoral research and therefore after establishing these CSFs, these CSFs were further analysed in order to establish the components for the initial urban design process framework which was derived by investigating the current top-down urban design process. Thereafter, the researcher investigated a potential bottom-up process and derived CSF’s and then further analysed them to develop components for the second initial urban design process framework. Based on the findings from the two initial conceptual frameworks the conceptual urban design process framework was established, thereafter, the framework was critically examined along with the literature findings to ensure the robustness of the conceptual UD process framework. The firmly established conceptual framework was validated by experts in the field of urban design in order to assess the viability of the conceptual framework for use in urban design projects. Finally, based on the experts' opinions, the framework was further shaped and developed to create the final new UD conceptual framework which enhances sustainable urban designs. As described above this paper presents only a part of the findings of the doctoral study.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 333–343. ©

KNOWLEDGE MANAGEMENT IN CONSTRUCTION ORGANISATIONS IN AUSTRALIA USING SOCIAL NETWORK ANALYSIS: A RESEARCH FRAMEWORK

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Abstract

The project-based settings in construction hinder the transfer of knowledge from one project to a future project. Hence, new knowledge created within construction projects should need to pass to the organisation level and then be shared at the organisation level and transferred to other projects. Previous research had found that construction project knowledge is more likely to be disseminated through networks of strong personal relationships. Hence, it is important to build and maintain strong networks within construction organisations to enable wider dissemination of project knowledge. However, little is known on how such networks exist in construction organisations in Australia. Social network analysis provides a method of analysing network patterns. Using social network analysis as a tool for the study of construction management issues has grown considerably in the past decades. However, there have been limited attempts to incorporate social network analysis into the study of knowledge management networks in the construction industry. By using social network analysis, this research aims to identify and measure the key social networks that disseminate project knowledge within construction organisations, through several case studies. In this paper, the literature findings are presented with the proposed research methods. The literature review findings revealed that the organisational structural capital nurtured through network ties and their configuration would effectively enable the project knowledge dissemination process within construction organisations and these could be effectively identified using social network analysis. The literature findings finally led to the development of a research framework. Future research will use this method on an empirical phase.

Keywords. *Knowledge Management, Knowledge networks, Social network analysis, Construction organisations*

1. Introduction

The success of a construction business in today's competitive market place depends critically on the quality of the knowledge it possesses regarding its markets, products, and technologies (Faraj, 1999). Pathirage et al. (2007, p.116) stated, "as a consequence of knowledge becoming a valuable organisational resource within the business community, there is an increased concern in organisations' efforts to deliberately manage knowledge in a systematic manner."

Knowledge gained on a particular project and disseminating lessons learned from problem projects may be used to avoid similar mistakes being repeated (Carrillo, 2004), and prevent 'reinvention of the wheel', and facilitate innovation, increased agility, better teamwork and improved project performance (Kamara et al., 2003). As discussed by Disterer (2002), the transfer of knowledge from projects to the routine organisation is explicitly assigned in project documentation. Further, Disterer (2002) stated that most of the project knowledge is hidden in heads of some project team members, which need to be disseminated within routine organisation before project team disbands.

Knowledge dissemination as a sub process of knowledge management consists of knowledge transfer and knowledge sharing (Hari et al., 2005). It relates to how knowledge is passed between individuals in the environment within which they work (Almond, 2001). Carrillo (2000) showed that failure to capture and transfer knowledge generated within one-project leads to wasted activity and impaired project performance. Hence, existing literature continues that disseminating and application of project knowledge within organisations is a critical area that needs more emphasis.

Some authors (Lang, 2004; Athanassiou and Maznevski, 2002) identified that, complex tacit knowledge is likely to be transferred through social networks and processes. As Lang (2004) contended, much of knowledge is tacit residing in social interactions in team relationships within organisations. The literature suggests that socialisation processes are much related to social capital of organisations. In fact, Bresnen et al. (2003) identified that, process of knowledge transfer and learning in project settings rely very heavily on social patterns, practices and processes within construction organisations.

Nahapiet and Ghoshal (1998, p.243) defined social capital as "the sum of actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit. Social capital thus comprises both the network and the assets that may be mobilised through that network." Nahapiet and Ghoshal (1998) argue that social capital consists of three distinct but closely interrelated dimensions that they describe as structural, cognitive and relational. Structural dimension explains the overall pattern of connections between the actors within a network. Cognitive dimension emphasises the learning process among the individuals. Relational dimension can be described as personal relationships that individuals have developed with each other through a history of interactions.

Recent attention has been directed at structural dimension of social capital. This paper reports mainly on structural dimension of social capital, which focuses on 'social networks,' as an enabler for disseminating construction project knowledge. Next section presents the key literature findings of this study.

2. Literature Findings

2.1. STRUCTURAL DIMENSION OF SOCIAL CAPITAL

The structural dimension of social capital concerns the properties of the social system and it refers to the impersonal configuration of linkages between people or units focusing the overall pattern of connections between actors (who can be reached and how you reach them). The structural dimension influences the sharing of knowledge through ways, which directly affect the condition of accessibility to information and knowledge (Nahapiet and Ghoshal, 1998). Chua (2002 p.376) states, "when organisation members are connected socially through physical means (such as being involved in brain-storming sessions, meetings and task forces) or through electronic means (such as engaging in e-mail and on-line discussions), the opportunity to access information and knowledge among themselves is enhanced." Nahapiet and Ghoshal (1998) described that among the significant features of structural dimension are the presence and absence of network ties between actors, and their network configurations. These key drivers of structural dimension are discussed hereafter.

2.2. NETWORK TIES

Network ties take into account the presence or absence of social ties with other organisation members within the organisation (Nahapiet and Ghoshal, 1998). Chua (2002) emphasised that network ties provide access to knowledge resources. It can be explained as 'who you know' affects 'what you know'. Coleman (1988) explained that social relations, developed for other purposes, constitute information channels that reduce the amount of time and investment required to acquire information. This is also evident by explanation of Hoffman et al. (2005) who state that information channels (social networks) within the organisation are the most obvious example of social capital. They are the directly observable inventory of social capital. Information channels not only contain the formal structure of an organisation but also it consists of personal relationships that people develop with each other. Marouf (2007) notes that formal relationships are documented with job descriptions and organisational charts. Every organisation also has its informal networks – people who know each other and help each other regardless of rank, function, job title and so on.

Further, Marouf (2007) identified two types of ties in a working environment as business ties (based on common business tasks) and social ties (based on emotional relations). Marouf (2007) revealed that prescribed networks and emergent networks are developed through business ties and social ties respectively. Prescribed networks are those that are composed of a set of formally specified relationships between superiors and subordinates who must interact to accomplish an organisationally defined task. Emergent networks, on the other hand, involve informal, discretionary patterns of interaction where the content of the relationship may be work related, social, or a combination of both.

Nahapiet and Ghoshal (1998) described a third feature of structural capital as appropriable organisation, which is grouped here under network ties. According to Coleman (1988), the appropriable organisation is the existence of networks created for one purpose that may be used for another purpose (e.g. development of personal relationships into business exchanges). Social capital developed in one context, such as ties, norms and trust, can often (but not always) be transferred from one social setting to another, thus influencing patterns of social exchange. Nahapiet and Ghoshal (1998 p.253) expressed that: "appropriable social organisation can provide a potential network of access to people and their resources, including information and knowledge and through its relational and cognitive dimensions, may ensure motivation and capability for exchange and combination."

2.3. NETWORK CONFIGURATION

Nahapiet and Ghoshal (1998) discuss that the network configuration properties such as density, connectivity and hierarchy are features associated with flexibility and ease of knowledge exchange through their impact on the level of contact or accessibility they provide to organisation members.

Structural holes (areas of the network not well connected) within organisations hinder information flow and promote competition. One of the benefits of high levels of social capital is the limiting of structural holes within the organisational network (Hoffman et al. 2005). Moran (2005) explained that the contemporary social capital literature is too easily associated with network structure, and even a particular form of network structure (structural holes). The major benefits that a well-developed information channel provides are plentiful and strong ties within the network. These ties, in turn, provide closure (Coleman, 1988). Closure can be described as the existence of sufficient ties within a social network to guarantee the observance of social norms.

Moreover the ‘embeddedness’ (concept that behaviors and institutions are constrained by ongoing social relations) of interpersonal ties within organisation members may be viewed as a continuum ranging from one extreme of high social embeddedness to the other extreme of low embeddedness or arm's length in nature (Lang, 2004). The strength of an interpersonal connection was found to lead how easily knowledge is shared (Hansen, 1999; Uzzi, 1997; Carolan and Natriello, 2006). Recent studies have used frequency of interaction and closeness of ties to measure the tie strength. Frequency of interactions is defined as how often people contact each other for various reasons. Closeness of a relationship is defined as the emotional intensity between two actors Marouf (2007).

Granovetter (1973), a pioneering researcher of social networks, provide a different argument that weak ties are efficient for knowledge sharing because they provide access to novel information and people. Subsequent research has generally supported Granovetter’s (1973) theory, but switched the emphasis to the effective character of strong ties. Consequently, the empirical findings of Hansen (1999) shows that weak ties help the project teams to search for useful knowledge but impede the transfer of complex knowledge, which tend to require a strong tie between the parties to a knowledge transfer.

2.4. STRUCTURAL CAPITAL AS AN ENABLER OF CONSTRUCTION PROJECT KNOWLEDGE DISSEMINATION

According to Nahapiet and Ghoshal (1998), the embedded and available knowledge resources within cohesive social networks which can be derived from the structural dimension of social capital through network ties, network configuration and appropriable organisation, described as ‘organisational structural capital’. Structural capital is owned jointly by the parties to a relationship. Social relationships generally, though not always, are strengthened through interaction but die out if not maintained. Thus, social interaction, socialization processes and social practices are crucial for development and maintenance of dense structural capital (Nahapiet and Ghoshal, 1998). Crucially through high levels of structural dimension of social capital, organisations can gain direct access to economic and other resources privately possessed in the network (Portes, 1998), which leads to better knowledge management within an knowledge intensive organisation (Willem and Scarbrough, 2006).

Literature elaborate that there are four conditions for resources exchange (knowledge sharing/knowledge dissemination) to take place. They are accessibility, anticipation of value, motivation (because of personal benefits) and capability to exchange (Nahapiet and Ghoshal, 1998; Whittaker et al. 2003; Manu and Walker, 2006). Whittaker et al. (2003) revealed that structural capital has a direct impact on these criteria to enable knowledge dissemination process.

There is also very little work that has attempted to explore the effects of structural capital in circumstances such as construction, where work is project-based. In one of the few studies, Bresnen et al. (2005) emphasis that with respect to the structural dimension of social capital, the individuals used each other as a first point of contact for knowing who to contact to access specialist experience and expertise. Expressed differently, Styhre (2008) states that network of relationships are key to the maintenance and development of know-how in the construction industry. According to Bresnen et al. (2005), the cohesive network of individuals through nurturing social capital, provided an important conduit for engineering knowledge dissemination throughout the firm. In other words, these networks of relationships will provide accessibility to individuals to disseminate project knowledge (Manu and Walker, 2006). Moreover, preferred means of contact were by very traditional means, i.e. by direct contact, telephone and e-mail.

Contrary to other industries, construction organisations are paying comparatively little attention to the formalisation of knowledge. Instead, word of mouth and personal contacts play a key role in the ‘knowledge system’ (Styhre, 2008) that dominates within most of the construction organisations). Styhre (2008) notes that, rather than assuming that this is an archaic or outmoded form of knowledge sharing, this embedding of expert know-how in social capital and oral communication is the most effective way to store and disseminate valuable project knowledge within a construction organisation.

Manu and Walker (2006) investigated how lessons learned from a construction project relate to the interaction between social capital and knowledge transfer. They found that the four conditions (access to a social network, anticipation of the value, motivation and capability to exchange) are highly demanding for many traditional construction organisations for disseminating knowledge and these are considered as the influencing factors for the presence of network ties.

2.5 SOCIAL NETWORK ANALYSIS

As discussed in the literature, construction management researchers had found the importance of social networks in wider disseminating project knowledge. Identification of such networks is important in order to enable knowledge dissemination process. In this regard, social network analysis is seen as a useful tool that helps to identify patterns of networks and analyse how strong they are based on their network configurations.

Social network analysis (SNA) is a recently growing method that provides a method of analysing network patterns. Using SNA as a tool for the study of construction management issues has grown considerably in the past decades (for example, see, Ruan et al., 2013, Pryke, 2012, Park et al., 2011, Pryke, 2004, Haythornthwaite, 1996, Chinowsky et al., 2008, Chinowsky et al., 2010). However, there have been limited attempts to incorporate SNA into the study of KM networks in the construction industry.

The analyses of network features using SNA vary greatly from what a traditional individualistic, variable-based approach can achieve. This is because traditional method of analysis calculations takes into account only the individual characteristics of the subjects and ignores the broader context of interactions with the social networks connecting them to other subjects. Hence, SNA is found as a powerful tool that enables to identify and measure network configurations of organisational structural capital. This way it would be possible to find out how the influencing factors lead to differentnetwork patterns.

3. Research Framework

Figure 1 brings together the above literature discussion into a research framework. The heavy reliance on social networks found in construction settings demand that knowledge management approaches in the construction industry should focus on the structural capital of construction organisation. In that, strong network ties with their configurations could be identified using SNA and the factors that affect (for example, the four conditions discussed above) these networks could be determined so that structuralcapital could be used as an enabler for knowledge management in construction. Next section sets forth the research method adopted in this study.

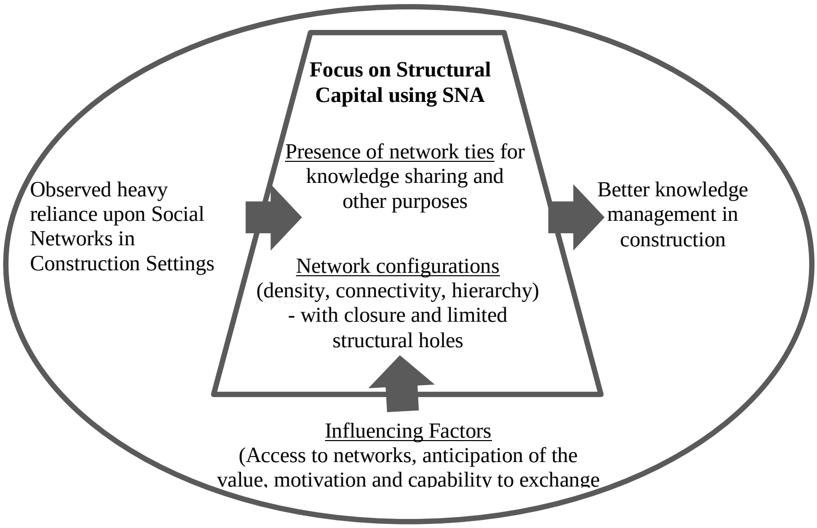

Figure 1, Research Framework

4. Proposed Research Method

The case study research methodology will be used for this research. Accordingly, five contracting firms operating in Sydney region in Australia will be selected for this study. These case studies involves interviewing key management level participants in the selected construction organisations based on a structured interview guide. The data will be used to develop the network patterns using Netminer SNA software. Data analysis will further include a quantitative analysis phase, where the key influencing factors identified through the literature will be compared with the identified network patterns.

5. Conclusions and Way Forward

The aim of the study is to investigate how structural capital could be used as an effective enabler in disseminating project knowledge within construction organisations to improve organisation performance and learning. The literature review indicated that the organisational structural capital nurtured through its key drivers namely: network ties and network configuration and enabled by conditions such as access to networks, anticipation of the value, motivation and capability to exchange would effectively enable the project knowledge dissemination process within construction organisations.

A solid empirical phase that enable to quantitatively analyse the network configurations need to be carried out to identify strong networks and the factors that enabled these. This forms the way forward of this research study as given in the proposed research method.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 344–356. ©

PRELIMINERY PROJECT COST ESTIMATION MODEL USING ARTIFICIAL NEURAL NETWORKS FOR PUBLIC SECTOR OFFICE BUILDINGS IN SRI LANKA

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Abstract

Cost estimating is a critical due to incomplete project details and drawings and has become a similar issue in Sri Lanka. Since, cost of a building is impacted by decisions made at the design phase, efficient cost estimation is essential. Therefore novel cost models have identified as simple, understandable and reliable. Thereby, Artificial Neural Networks (ANN) have established having the ability to learn patterns within given inputs and outputs and the end result was developed as the preliminary project cost estimation model for public sector office buildings in Sri Lanka. To accomplish the above aim, the survey approach was selected and semi structured interviews and documentary review were conducted in collecting data. Then training and testing of the Neural Networks (NN) under ten design parameters was carried out using the cost data of twenty office buildings in public sector. The data was applied to the back propagation NNtechnique to attain the optimal NN Architectures. The empirical findings depicts that the success of an ANN is very sensitive to parameters selected in the training process and decreasing learning rate makes Mean Square Error smaller but with considerably larger number of iterations up to certain point. It has been gained good generalization capabilities in testing session achieving accuracy of 90.9% in validation session. Ultimately, NN has provided the best solution to develop a cost estimation model for public sector as accurate, heuristic, flexible and efficient technique.

Keywords: *Artificial Neural Networks (ANN), Cost Estimation Models, Office Buildings, Preliminary Project Estimate, Public Sector.*

1. Introduction

In early stages unavailability project information was the major problem faced in cost estimation. Therefore, parametric cost estimation models were very useful (Kim et al., 2004).According to Ashworth (1999), cost modeling is the symbolic representation of a system which exists or is planned, and which in terms of its significant cost, features for the reasons of display, analysis, evaluation or control. Therefore, model based cost estimation has become the best to overcome the difficulties faced by the estimators. A wide range of cost forecasting techniques have been exploited in the construction industry namely statistical based analysis techniques and artificial intelligence based technique (Kim, Seo, & Kang, 2005; Elhag, Boussabaine, &Ballal, 2005; Lowel, Emsley, & Harding, 2006; Sonmez , 2008). Currently historical cost data is the most popular source in cost estimating at the early stage of a project since there are incomplete project details.

Yet, the performance of usage of historical cost data in cost forecasting in Sri Lankan consultancy practice is poor. In the meantime, Ferry & Brandon (2000),stated that the private and public sectors are differentiatedin terms of cost targets. In public sectorPreliminary Project Estimates (PPE) are prepared to get the estimated project cost approved from the Cabinet of the government, after completing the preliminary designs. Therefore, the need for an accurate and reliable cost estimate prior to the actual design of the project has been increased in public sector. Although there are number of cost estimating and modeling software in the international market, they are difficult to be adopted for Sri Lankan context.Therefore, those models have limited usage and the availability of the cost models are very much less in number, when applying to current status of Sri Lankan construction industry. Accordingly, main research problem is arising “How to develop a Preliminary project cost estimation model for public sector office buildings in Sri Lanka?”.

Therefore the research aim is todevelopa preliminary project cost estimation model for public sector office buildings in Sri Lanka by investigate different types of construction cost estimation techniques and models and its suitability, current Sri Lankan practices in public sector projects while conducting a thorough analysis of the collected data.

2. Construction Cost Estimating

Cost planning is an attempt used to bridge the gap in cost information between the time of the preliminary estimate and the receipt of the tender (Odeh&Battaineh, 2001). According to the Yu (2007), in preparingan estimate, it is necessary to appreciate the employer’s requirements and how they are translated into substance, the business considerations affecting that translation and the source and nature of the data upon which estimates are based to the form of estimate and its reliability (Cheung et al., 2012). Even though there are incomplete project information at the early stage of a project, it is mandatory to predict the cost since it established the budget and it would be the employer's first impression on the project. Hence, parametric cost estimation techniques are most appropriate for cost estimation at the early stages. Among the cost estimation techniques qualitativeand quantitativemethods are the major categories. There the historical cost data and expert experience is used for the Qualitative cost estimation techniques. While, quantitative techniques not only rely on historical cost data and expert knowledge, hence it can also be analysed project processes, designs, and unique features (Berny & Townsend, 1993). However, systematically analyses cost data of historical projects are highly useful in both qualitative and quantitative techniques and it acts as roots for cost modeling and provides cost controlling at the design stage.

3. Building Cost Estimation Models

Cost modelling is a symbolic development of a structure and enclosed the factors which are affecting to the cost (Holm, Schaufelberger, Griffin, & Cole, 2005). It can be categorized in to two ways, as one based on historical development of the cost models such as first-generation models, second generation models and third-generation models and the other method is according to their characteristics such as traditional cost models, non-traditional cost models and new wave models **(Seo, Park, Koo, & Kim, 2008)**.Traditional and non-traditional Cost Estimation models have briefly listed out in Table 1.Meanwhile, such estimates cater in evaluating project feasibility and effective cost control during detail project designing while preventing re-budgeting, re-designing and project cancellations.

3.3 NEW-WAVE MODEL

Neural Network (NN): NNs are a computer system based on the abilities of the human brain. A group of simulated neurons is interconnected and NNmodels consist of simple computational units organized into a sequence of layers and interlinked by a system of connections (Kim, Seo, & Kang, 2005). A typical parametric NN model includes the parameters in the input layer, and cost in the output layer. It also includes at least one hidden layer between the input and output layers to represent the relations between the parameters and cost (Sonmez & Ontepeli, 2009). Table 2 indicates the Advantages and limitations of neural networks.

Table 1, Traditional and Non-Traditional Cost Estimation Models

Traditional Cost Estimation Models	Non-Traditional Cost Estimation Models
Unit method*:** Cost per functional unit of the buildingto confirm that the costs are reasonable with other similar nature buildings (Seo, Park, Koo, & Kim, 2008). ***Approximate quantities*:**Mmost reliable and accurate under sufficient information. Measurement can be carried out using composite rates to save time. ***Storey enclosure method: Considers thevariations in plan shape and storey height (Seo, Park, Koo, & Kim, 2008). ***Cubic method of estimate***: Relates the cost of a building to its calculated volume (Akinsiku, Babatunde, & Opawole, 2011). ***Elemental cost analysis method***: Unit cost is broken down into elements and sub-elements in a flexible, easily understandable manner (Akinsiku, Babatunde, & Opawole, 2011)	***Regression analysis:*** Statistical computer system approach is utilized in Multiple Regression Analysis to forecast change in a dependent variable on the basis of change in one or more independent variables (Garza &Rouhana, 1995). The equation is used in fitting a curve or line to points of data, such that the differences in the distances of data points from the curve or line are minimized (Bode, 1998). ***Probabilistic Treatments:*** Probability theory and random number generation produce cost models with risk profiles which recognize the inherent variability and uncertainty of design cost modeling, due to its predictive nature (Skitmore& Ng, 2003). ***Simulation Models:*** In Monte Carlo simulation, a mathematical model is constructed based on pre-specified probability distributions, where the possible outcomes of major cost elements are described, and operates to check the

Table 2, Advantages and limitations of neural networks

Advantages	Limitations
• The neural network does not use pre-programmed knowledge base • Suited to analyze complex pattern • Have no restrictive assumptions (Bode, 1998) • Allows for qualitative data (Bode, 1998) • Can handle noisy data • Can overcome autocorrelation User-friendly, clear output, and robust and flexible (Bode, 1998) • The numbers of inputs and outputs are not restricted (Smith & Mason, 1997)	• Requires high quality data Variables must be carefully selected a priori • Risk of over-fitting • Requires a definition of architecture • NNs are in a sense the ultimate 'black boxes' • Time consuming in determining the number of the neurons • Possibility of illogical network behavior • Large training sample required

4. Identification of Suitable Technique for Public Sector Building Projects

Cost models provide a powerful alternative for conceptual estimation of construction costs. However, development of cost models is critical task due to several factors affecting the cost of a project (Sonmez, 2011). NNis accepted as a germane and precise technique used at the preliminary stage based on the available data and it can perceive the relationship and pattern between the inputs which are parameters and the outputs which are costs. However, the details of the project at the early stage are limited to handful ofparameters such as floor height and floor area. Thus, NN delivers an effective output based on the details of previous projects. Even though there are several new wave models, NN is the most appropriate technique for cost estimation due to the complexity of the other new wave techniques (Bode, 1998). In Sri Lanka, there was a considerable development in public sector office buildings in recent years and a critical need for a proper cost model is initiated to estimate project cost at early stages. Therefore, this researchfocuses on public sector office buildings available in the industry. Here the public sector constructions projects are essential to submit an accurate estimate to obtain the Cabinet approval at the preliminary stage, one of the critical issue faced is the prepared estimate is not up to the required standard due to lack of detail drawings and specification. Hence it is clear that, even though some systematic procedures,and models are being used in other sectors, public sector consultancy firms are currently practicing the taking off method using the incomplete drawings, where it is not catering for the accuracy of the estimate using the available set of drawings and specifications. Therefore a question is aroused as, "How to build a preliminary estimating model to cater the current demand in public sector office buildings in Sri Lanka?". Thereby the data collection and analysis is conducted to fulfil the given deficiency.

5. Research methodology

The survey approach is identified as the optimum method and inbetween, document review and semi structured interviews were conducted. the collected data in interviews were analysed using both content analysis and neuroph studio was used as the quantitative data analysis method. training and testing of the neural network is done with the neuroph studio application using six steps. then the findings were geared towards achieving the ultimate outcome by developing a preliminary cost estimation models using the method of nn using the java programming language which carries number of advantages as easy to write, compile, debug, and learn, it is robust, multithreaded and secure.

6. Data Analysis andResearch Findings –

Interviews Semi-structured interviews have been carried out with four key individuals of public sector consultancy organizations in Sri Lanka. Expert opinions were gathered to explore current practice of cost estimation and the necessity of a cost estimation model at the preliminary stage. Further expert opinions were gathered to identify variables for the model preparation and relationships between parameters. Table 3 shows the profile of the respondents.

Table 3, Respondents' profile

Code	Designation	Experience in the construction industry (yrs)
A	Deputy General Manager (Contracts and Quantity Surveying Unit)	16
B	Chief Quantity Surveyor	18
C	Quantity Surveyor	15
D	Quantity Surveyor	10

Majority expressed that the method used for the preparation of preliminary estimate, varies depend upon the availability of data about the project. according to respondent a "*we do predictions up to the maximum level, on the basis of whatever the information we have*". on the other hand majority of the respondents pointed out, that four major items they have readymade analysis prepared by themselves based on the past projects and subjecting to changes they used such estimates for current projects and several mistakes have also been identified by the respondents. accordingly, as emphasized by the respondent a "*if we have reasonable time to prepare estimates with the use of designs developed by architecture and engineering departments of the organization it will result in better estimates*". however, oftenat the preliminary stage of the project architects are reluctant to put their decisions to design since they are not thorough with project details. the necessity of preparing an advanced cost estimation model originated through the importance of obtaining the cabinet approval for the allocated budget for the project especially in public sector projects. even though the probable estimates are prepared by the practitioners based on their skill and experience, there is a possibility of occurring errors in such estimates. therefore majority highlighted that, though it provides the user an easier environment, reluctance to change, traditionally embossed practices and lack of knowledge had become major barriers in the implementation.According to the respondents the parameters were selected for the accuracy of the cost model depending on the availability of data, cost significant items and selection of independent and dependent variable. However the majority commented that for the reliability and accuracy of cost estimation model it is important to used actual rates and costs incurred for the particular works and the respondents further stressed that, to get parametric details it is essential to refer the architectural and construction drawings. However, finding of final bills and related drawings of particular office developments was hard and difficult when it comes to the public sector consultancy organizations, due to poor documentation and unavailability of soft copies of each document.

7. Research Findings and Data Analysis – Document Review

Twenty office buildings, constructed during last 10 years were selected. Most of the them were 2-5 storied having strip foundations with column footings. Only two buildings with the pile foundations were found. According to the opinions of the experts and experienced obtained through documents, cost of main elements and suitable parameters were collected and thereby the data base was developed. The data base developed using the MS Excel Moreover, it easy to feed data from MS Excel sheet to the Neuroph Studio which is the software used for data training and testing. Prior to that parameters which are expected to relate for selected structural elements are selected and presented in the Table 4.

Table 4, Parameters and their Expected Relationship

Element	Expected Relationship (Inputs)
Substructure	Gross Floor Area, Ground Floor Area, Type of Foundation
Super Structure Concrete Works	Gross Floor Area, Ground Floor Area, Number of Stories, Average Storey Height, Building Height
Masonry Works	Gross Floor Area, Number of Stories, Average Storey Height
Water Proofing	Gross Floor Area, Ground Floor Area, Upper Floor Area
Roof structure including, Covering and Plumbing	Ground Floor Area, Roof type
Floor, Ceiling & Wall Finishes including Painting	Gross Floor Area, Wall area, Doors & Windows Area
Doors and Windows	Wall area, Doors & Windows Area

In order to generate most reliable cost estimate, separate NNs was created for each elements. Then the data from projects were trained and tested within each NNs. Each elements were trained and tested with different hidden layers, momentums and learning rates. Ten the results were presented and discussed for each elements separately as shown in Figure 1.

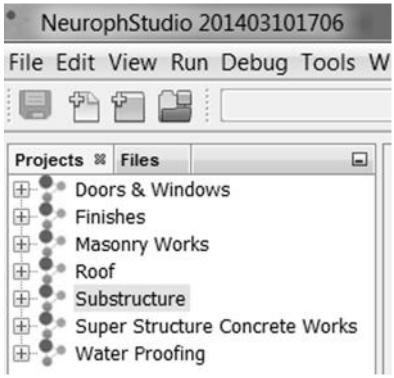

Figure 1, Neuroph Projects Created for Data Analysis

Among the basic elements, sub elements were clearly identified. For an example in substructure, Topsoil excavation, Removal of ground water, Column footings and etc., have identified as the sub elements. Six number of NN architectures were created and tested to obtained optimal NN for sub structure. Number of hidden neurons were taken to range from one to three, while numbers of input and output neurons were three and one respectively.Most of the attempts of training with learning parameters ranging from 0.1 to 0.3, with the momentum rate of 0.6 to 0.7. However, one to three hidden neuron were unsuccessful and some of them were not trained. According to Table5the best combination is the network comprising of two hidden neurons, 0.1 of learning rate and 0.6 of momentum which gives the minimum Mean Square Error (MSE).

Table 5, Sub-Structure Neural Network Training and Testing Results

Training attempt	**Inputs**	**Outputs**	**Hidden layers**	**Learning rate**	**Momentum**	**Iterations**	**MSE**
1	3	1	1	0.1	0.6	10000	-
2	3	1	2	0.1	0.6	8287	0.0140
3	3	1	3	0.1	0.6	3450	0.0159
4	3	1	1	0.2	0.6	10000	-
5	3	1	1	0.3	0.6	10000	-
6	3	1	1	0.1	0.7	10000	-
7	3	3	2	0.1	0.7	10000	-

However, it reads high amount of iterations and it can be identified from the total network error as the graph shown in Figure 2. The relatively high number of iterations indicated that network is hesitant to learn from the data set. This may due to: poor relationship between selected parameters, the cost of sub structure and insufficient data. However it has been trained at certain network architecture, since there is a minor relationship between parameters.

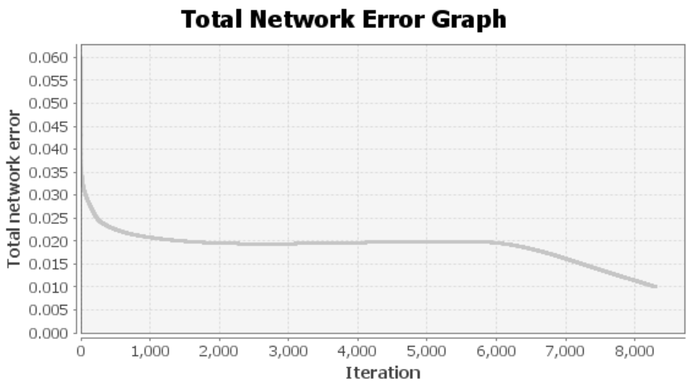

Figure 2, Total network error graph for the optimum neural network

Since the elements coverdifferent sub elements, the relationship between inputs and outputs were hard to identify. The special highlights identified in each basic element is presented in the Table 6.

Table 6, Significant Findings of Each Basic Element

Element	Significant Findings
Sub Structure	Due to several requirements of the design and ground conditions topsoil excavation is not proportionate to the Gross Floor Area (GFA). Type of foundation and ground floor area has the relationship with the cost of sub structure (it is not revealed due to: insufficiency of data set and foundation type).
Super Structure Concrete Works	Quantity of superstructure concrete works are more related to the gross floor area, ground floor area, upper floor area, number of stories, average storey height and building height (Ex: Slabs Concrete Staircases etc.)
Masonry Works	Network shows the relationship between input parameters and the cost of masonry works. GFA, number of stories, average storey height and the building height were used as input parameters
Water Proofing	A relationship between the GFA and the washroom areas in an office buildingis proportionate to the ground floor area (Due to typical shape of most office buildings)
Roof Structure and Plumbing	Area of roof may not related to any of the factors.

Element	Significant Findings
Floor, Ceiling & Wall Finishes including Painting	Wall finishes-kind and quality of internal and external finishes are varied and wall finishes may not directly proportionate to the wall area off the building. Direct relationship is between floor finishes and the GFA, but the cost can be changed due to different types of finishes.
Doors and Windows	Though the door and window areas used as an input parameter, network was not trained properly (Due to varied amount of door and window areas with wide range of types and designs)

8. User Interface of Developed Cost Estimation Model and Validation

After selecting the optimum NN architectures, "Office Building Estimation Application" was built up. According to Figure 3 user interface developed with another two successive windows. Once clicking "Getting Started" in the initial interface, category selection interface appears as in Figure 3. After selecting a category by clicking the selected button the third interface arrives (When selecting a super structure third interface appears. This interface may vary from one another since it has different parameters to enter.

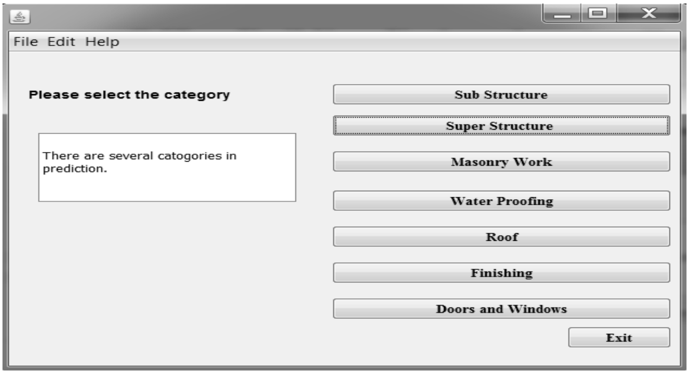

Figure 3, Category Selection Window

After entering relevant parameters then just want click the "predict" button. It predicts the expected cost for the relevant element. This was a user friendly interface and easy to understand.The final step of the NNmodelling was the validation of the model. Since software has already developed in model validation can be done through the developed model. Otherwise, data can be validate with Neuroph Studio by selecting optimum NN architectures for eachelements.

Table 6, Validation of Cost Model

Element	Actual Amount (Rs.)	Predicted Amount	Difference	Percentage Error
Sub structure	3,429,144.00	3,785,265.00	356,121.00	10.39%
Super structure	12,664,566.00	13,828,344.00	1,163,778.00	9.19%
Masonry works	3,878,231.00	4,202,098.00	323,867.00	8.35%
Water proofing works	1,460,808.00	1,360,435.87	100,372.13	-6.87%
Roof	4,552,049.00			
Finishes	57,614,688.00	53,345,987.00	4,268,701.00	-7.41%
Doors and windows	4,375,635.00			

According to the Table 6, when considering all the percentage errors, almost all the percentage errors of each elements were in the range of ± 10.00%. This error value is within the maximum error (10%), which was the initially established percentage. Hence, it can be concluded that ANN model has reached the expected performance in the study.

9. Conclusions

In Sri Lankan construction industry the role of public sector is crucial since preparing a well accurate estimate at the preliminary stage is an essential and transparency of transactions are also vital from the beginning to the end. However, preparing preliminary estimate is crucial since the available data are very less at this stage.Therefore, necessity of a cost model to prepare the preliminary estimate for office buildings in public sector has identified.

Despite drawbacks such as lack of the interpretability of the built model that NNs have, still widely used and included in most data analytics frameworks. However, there are number of advantages in NNs such as data driven, self-adaptive of driven data, approximate functioning - linear as well as non-linear NNs classify objects rather simply - they take data as input, derive rules based on those data, and make decisions. Further, the ability of pattern recognition and generalization of ANN and suitability to predict preliminary project estimates concluded to use NNs. Meanwhile, since the industry is fed up with not having standard practice for preparing estimates at this stage requirement of efficient and reliable cost estimation models were initiated.

Additionally, cost significant items and parameters were selected based on the correlation of variable to the construction cost, retrievable of variables from the past projects and the availability of the variables at the preliminary stage. ANN highlighted as, very sensitive to parameters selected in the training process where the learning rate must not be too high or too low.

Further the decreasing learning rate have made MSE smaller but with considerably larger number of iterations up to certain point. During the testing and training, it was found that each network have obtained MSEs approximate to 0.01 and ANN model effectively learned during training stageand gained generalization capabilities in testing session while achieving the accuracy of 90.9% in validation session. Unfortunately NNs` black box nature may obscure the reason behind the estimate, not display the underlying processes and cost drivers as well as the current cost estimation software. Ultimately all advanced improvements poured in the developments of ANN cost estimation model for preparing PPEs of apartment buildings in Sri Lanka.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8[th]International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 357–368. ©

SPATIO-VISUAL PATTERNS IN RESPECT TO VISUAL EXPERIENCE: AN EXPLORATION OF ARCHITECTURE OF GEOFFREY BAWA

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Abstract The spatial qualities enhanced through his architectural approach are often talked of due to the positive emotional responses from those who experience the spaces. It has been said that spatial progression in Bawa's architecture is a distinct feature in which spatial experience is heightened to its best possibility. While such interpretations are apparently accepted, very less quantitative evidence is to be found that confirm the fact Bawa's architecture acquires those qualitative attributes. Thus there is a lack of research evidence to discuss if Bawa's architecture is actually space specific with having different spatio-visual patterns which are unique to each design or he has unconsciously or consciously occupied similar spatio-visual patterns in his architectural approach which is similar in every design yet is not identified. This paper utilizes Isovist analysis and Visibility Graph Analysis to seek scientific evidence to identify existence or non-existence of similarity in spatio visual patterns in Geoffery Bawa's architecture by analyzing selected domestic architecture in Colombo context. This analysis reveals consciously or unconsciously Geoffrey Bawa has maintained a similar design frame in creating visual experience and visual connectivity in his urban house designs.

Keywords: *Isovist Analysis; Vibility Graph Analysis: Geoffery Bawa; Spatio-visual patterns.*

1. Introduction

The ability of enhancing the experience depends on the creator of the space, in other words on the architect whereas the way of feeling the space depends on the person who experience it. Yet, very rarely architects emerge who can address to the soul of the experiencer through the space by evoking emotional feelings with the spatial qualities. Geoffrey Bawa is one such architect who was and still is praised all over the globe for his unique architectural approach and for his special ability of creating spaces that are memorable. Inspired by vernacular architectural features his spatial arrangement signifies visual axis that enhance connectivity within spaces and the connectivity between inside and outside can be identified to be sensitively achieved (Robson, 2002). His architecture is often taken as examples to demonstrate spatial connectivity and creating eye-catching vistas that append inside and outside. When experiencing the spaces it is felt that Bawa has been sensitive to the site context and his architectural products are place specific and are generated by the context (Robson, 2002).Many literature have been composed in appreciation of the unique spatial and visual experiences created through Bawa’s architecture.

The literature on his architecture defines that he has caught the attention of architects, many related professionals and even thousands of people outside the field and his architecture has been studied widely in terms of quality of space theoretically. It is noted that this appeal in the spaces he has created is obtained from the unique way of connecting spaces visually and physically and giving unhindered vistas from one space to capture the essence of the surrounding. Even though it is said that his architecture is inspired by the context and his architecture has a unique\ approach different to one another it is not proven quantitatively. It is not observed quantitatively if his architectural approach in creating spatio-visual patterns and connectivity has been similar or unique from design to design.

The present paper examines three main spaces Living, Dining and courtyard of six selected urban houses in Colombo context of Geoffery Bawa using isovist and visibility graph analysis. Isovists represents the collected spatial range of all views from a single location within a specific place visibility graph is a more scientific and logical explanation of space arrangement and visual experience and it abstracts the environment into a series of polygons representing the space visible from a series of observation locations. The six VGA used for this paper depicts the highest connectivity point of each house while indicating the distribution of the visual connectivity of spaces. The eighteen isovists represents three selected positions of each house. Three mathematical measures are derived for each house in isovist analysis, which are compared using simple statistical methods as a ratio against the floor area of each house to investigate the level of similarity or dissimilarity demonstrated in Bawa’s designs. While such a study of Bawa’s domestic architecture has never been undertaken before, the paper also attempts to analyze the pattern of connecting interior spaces with exterior views up to a defined limit.

In the coming sections a brief introduction to the relevant aspects of spatial experiences, isovist analysis and visibility graph analysis. Then the research question is outlined. Thereafter the methodology of the research is explained and lastly results are analyzed and discussed.

2. Spatial patterns and Bawa's residential architecture, Isovist and visibility graph analysis

Often literature speaks of Bawa's work in appreciation of aesthetics and spatial experiences. It is always emphasized that Geoffrey Bawa's architecture signifies the spatial progression of a built space with the use of visual connections in between spaces. Links between spaces and the way Geoffrey Bawa creates the visual connection inside the built space can be realized and experienced in real. He has a unique way of giving this visual experience through his architectural practice.

The term "Isovist" denotes to the collected spatial range of all views from a single location within a specific place. It is usually presumed that Isovists are two dimensional and extend all over 360° around a vantage point (Montello, 2007). It is claimed that Isovist analysis reflects the theories of the psychologist J.J.Gibson (1950, 1979) which brings out the necessity of vistas in visually perceiving the environmental layout.

Visibility graph analysis abstracts the environment into a series of polygons representing the space visible from a series of observation locations. The method's origins lie within the work of environmental psychologist James Gibson (1947) where he has proposed that visible space could be represented as a polygon and illustrated the way in which the properties of these polygons changed as the observation location changed position. These polygons were called "Isovists" by Michael Benedict (1979) for the very first time and he developed mathematical measures to describe properties of Isovists. Benedikt explained an Isovist as "**the set of all points visible from a single vantage point in space with respect to an environment**" (Benedict, 1979).

3. Research Question

Geoffrey Bawa's architecture and the spaces created are significant in terms of evoking emotional spatial experiences. When experiencing, it is felt that the quality is unique to the space itself and it holds no resemblance or similarity to any other spaces even created by him. Research question if Geoffrey Bawa has utilized a similar two dimensional approach in connecting and planning spaces in relevance to spatio-visual experience that are different three dimensionally. It is further questioned if there is a similar pattern in creating spatial visual patterns in his architecture to obtain a visual range and visual connectivity.

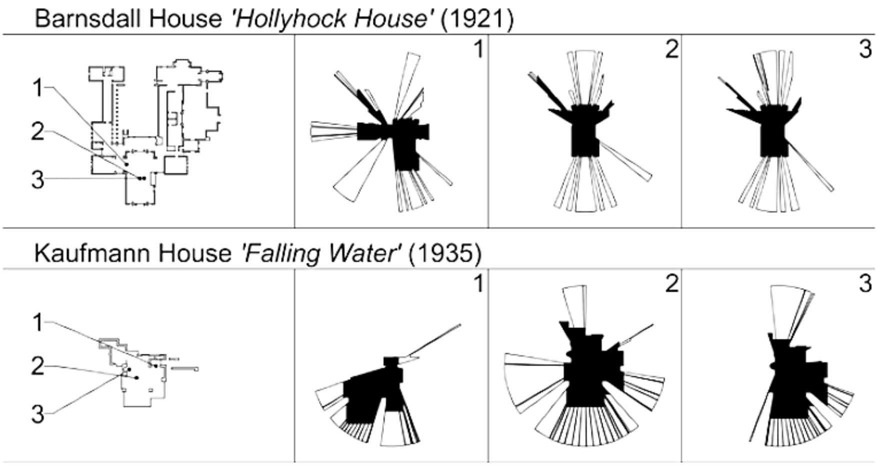

Figure 1: Isovist polygons - 1 threshold, 2 room center, 3 hearth in the living room for two unique house designs by Frank Lloyd Wright

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4. Research Methodology

The houses selected for this study represent urban domestic architecture of Geoffrey Bawa built in Colombo context. The selected houses are Ena de Silva House, Stanley de Saram House, P.C. de Saram House, Dr. Bartholomeusz House, Jayakodi House, Wimal Fernando House. The analysis commences by preparing 2D plans as required for the isovist and visibility graph analysis of the selected houses based on the plan drawings obtained from Geoffrey Bawa trust.

Both floor plan versions are analyzed using UCL DepthmapX with a grid spacing of 250mm and a set of rules is constructed to maintain the accuracy of the analysis. When conducting VGA depending on the floor area of the plan the grid count can be selected. In this study a single grid's size was kept constant as 250mm x 250mm.

For the VGA, all the doors, windows and openings of the perimeter wall of the house (not the perimeter boundary wall) **were considered as closed**. For the computational analysis, house had to be set on a grid, and all the data were taken according to a grid count. So for this quantitative analysis system, it needs a well-defined, enclosed plan form with a limited grid to measure the data (according to the standards of the specific instrumentation). Internal courtyards were treated as rooms/ as internal spaces. Rear gardens/ External courtyards were considered as valid areas for the VGA only if they were covered/ enclosed with walls higher than 1.4 meters (higher than the human eye level.) at least from three sides and should be connected to the house. Louvered opening were treated as windows (as transparent). Car porches/ garages located apart from the house, separately, were not counted for the VGA as they were useless in visual experience wise.

For the Isovist analysis, all the doors, windows and openings of the perimeter wall of the house (not the perimeter boundary wall) were considered as open as they connect the interior with the exterior. 3m offset outer boundary line was created on plans to limit the visibility range towards outside of the houses (View Limit). Isovist measures the visibility area in a 2D plane at eye level to analyze how the interior is connected with exterior (dispersion of the Isovist polygon), so a view limit is needed to create the Isovist polygon at a considered point of a plan. For the comparison of Isovist fields, 3 main common points were selected for all houses. They are,

- Highest Visual Connectivity point found from previous VGA
- Courtyard Center
- Living Room Center

To compare the Isovist result of each house, the size of the Isovist area cannot be considered because it differs in a high range from house to house due to the size of the area of the specific house. Since the Isovist field cannot be compared for different housed Isovist field was calculated as a ratio against the floor area of each house and the ratio was compared to analyze the results. So a ratio between Isovist field area and original plan area was taken and took it as a percentage.

(1)

Isovist field area / VGA plan area x 100 = percentage value (ratio)

If,
Isovist Area (at highest connectivity point) = 268.3 m2
Original Plan Area = 582.9 m2
268.3 / 582.9 x 100 = 46.02 % (Isovist percentage value)

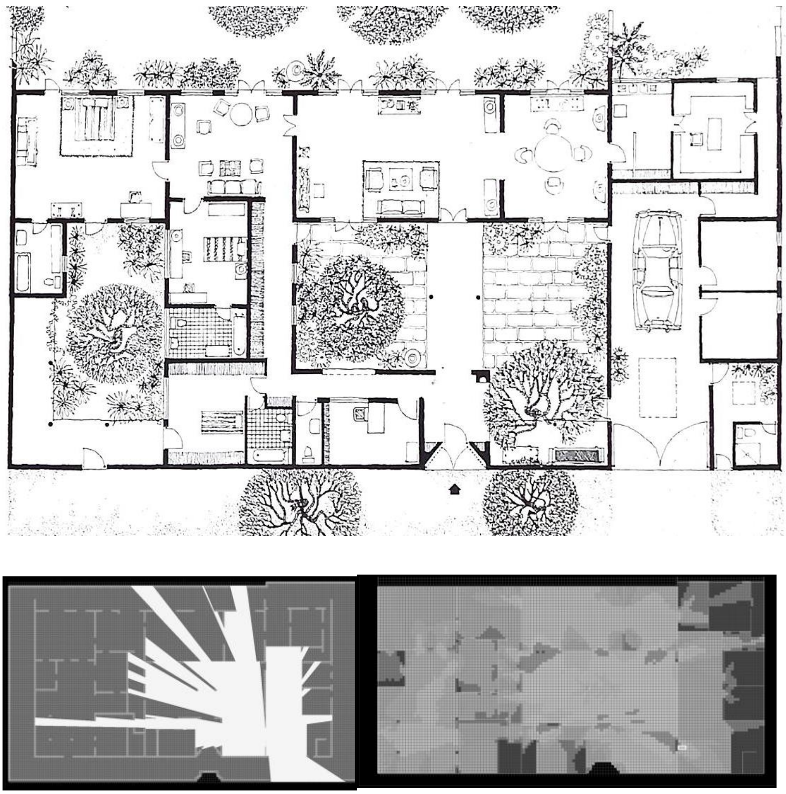


Figure 2: The analysis process

5. Results

Visibility Graph Analysis of selected urban domestic architecture produces results indicating the distribution of connectivity of internal spaces of each house when taken as enclosed entities. The results depict the point where the connectivity is highest as well.

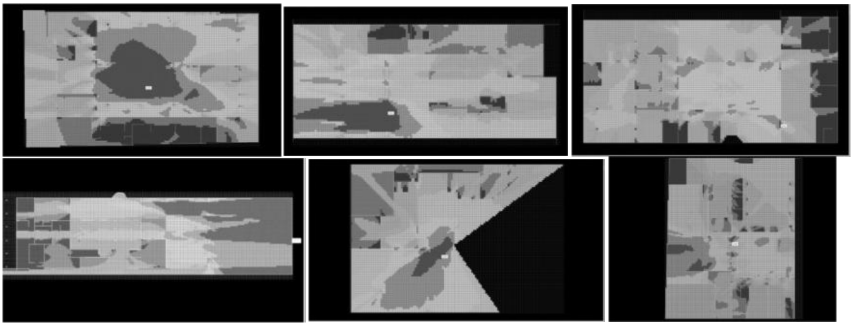


Figure 3: Visibility Graph Analysis results

Table 11: Results summery for VGA

	House	Visual Connectivity Behavior
01.	Ena de Silva House	Highest visual connectivity point is located **adjacent to the center of the main courtyard which is visible to the main entrance door.**
02.	Stanley de Saram House	Highest visual connectivity point is located at the **Entrance point from garage to the center courtyard.**
03.	P.C. de Saram House	Highest visual connectivity point is located at the **Entrance to the Courtyard from the Living Room.**
04.	Dr. Bartholomeusz House	Highest visual connectivity point is located at the **edge of the Rear courtyard, visually covering a large area.**
05.	Jayakodi House	Highest visual connectivity point is located at the **Rear Courtyard in-between the Living and Dining spaces.**
06.	Wimal Fernando House	Highest visual connectivity point is located at **one of the three entrances from Living room to Center courtyard.**

Data for Isovist analysis for all three observation positions indicate the in five of the six cases when the three points are arranged in the descending order according to the visual connectivity there is a similarity in creating visual connection. And the variation of visual connectivity has been maintained within a similar range without reaching higher deviations.

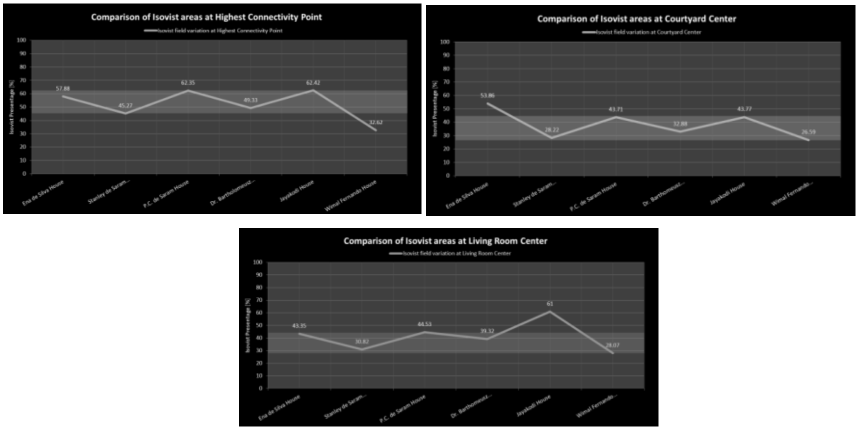
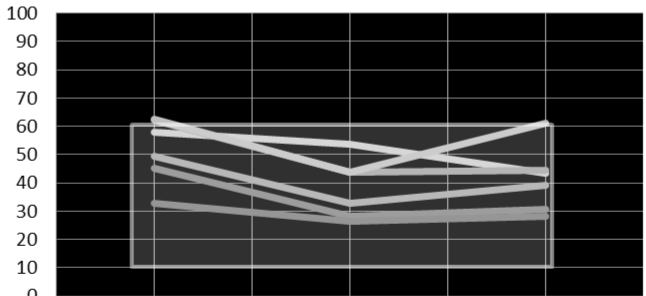


Figure 4: Isovist Analysis results for selected points



	Highest	Courtyard center	Living room center
Ena de silva	57.88	53.86	43.35
Stanley de Saram	45.27	28.22	30.82
P.C. de Saram	62.35	43.71	44.53
Dr. Bartholomeusz	49.33	32.88	39.32
Jayakodi	62.42	43.77	61
Wimal Fernando	32.62	26.59	28.07

Figure 5: Comparison of Isovist Analysis results for each point of selected cases

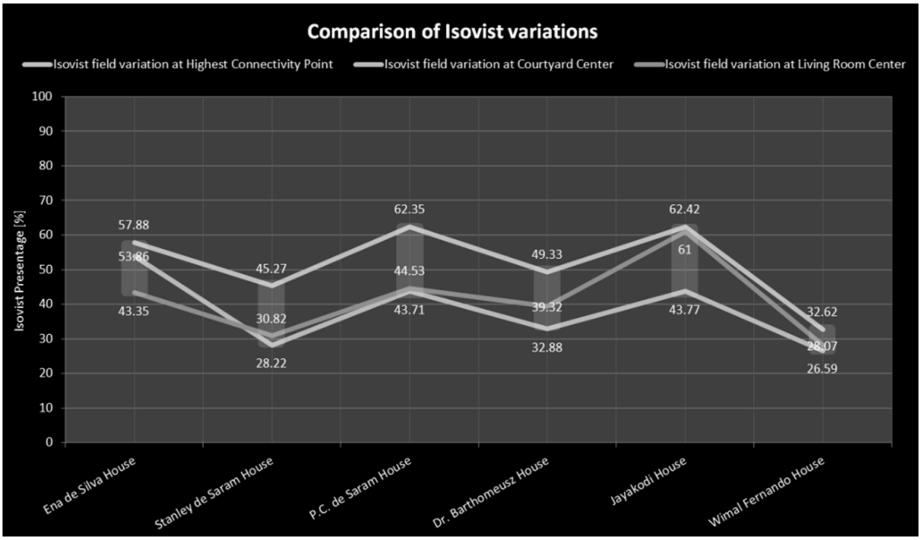


Figure 6: Comparison of Isovist Analysis results for selected points of all cases

6. Conclusion

The results of the analysis cleared the way to identify the characteristics of house designs by Geoffrey Bawa relevance to spatial connectivity and spatial planning when considering the interior spaces. In each case it was clear that highest visible point/ visually connected point were found to be located in a courtyard or at an entrance to the courtyard.Thus it demonstrated that courtyard plays a major role not just as an element but as the main space that connects other spaces. This can be further justified by the radial spreading of the connectivity having the courtyard as the focal point.

Further, highest connectivity point being at an entrance with clear view of courtyard almost in every case indicates that courtyard has made to be the main point of attraction and prominence while common areas such as living spaces have been placed highly connected with the main courtyard. Courtyard of every house seems purely visually active and strongest in visibility. The results of the simulation provide mathematical evidence for this.

Ena de silva house has the strongest visual connectivity rated courtyard out of all the cases. In designing Ena de Silva house the client had requested a traditional courtyard based house with a modern touch which is granted totally through the design while making them not just feature elements but as the binding space of all common spaces. This gives evidence that

Geoffrey Bawa has truly considered visual connectivity of spaces specifically with the courtyard. On the other hand in almost all houses private bed rooms and such spaces and service areas indicated the least connectivity. This denotes that privacy has been a greater consideration in placing rooms whereas service areas have been placed hidden as much as possible.

6.1 Area of Visibility from a Certain Point

In terms of a single house (cases taken separately)

Isovist field taken at the highest connectivity point, center of the living room and the center of the courtyard determined with a decided boundary was calculated against the floor area of each house to obtain a percentage/ a ratio of Isovist field at each point. The resultant percentages were compared against each other to analyze the variation in Isovist fields. Isovist analysis result denotes a contrasting situation than the VGA results. Even though VGA showed a visual prominence in courtyard when the doors and windows of the outer perimeter of the house were closed, when all the openings are concerned as opened, the living room center indicated a higher percentage of interior and exterior connectivity with a larger Isovist polygon.

According to the graphs, all houses taken as cases indicated a similar pattern which showed the Isovist percentage level variation maximum to minimum as, Highest connectivity point > Living room center > Courtyard center (except Ena de Silva house) signifying living room center has more observation capacity with high Isovist field than courtyard center. This can lead to an assumption that though Bawa has made the courtyard as the most visually connected space when considering only the internal planning, he has connected the living room with the exterior giving it more significance in overall planning and higher potential in observation in terms of center point of a space. Since all the houses are planned with living rooms to have higher Isovist field this can be identified to be a similar pattern to create visual experience through spatial orchestration.

6.2 Comparison of All Houses

Isovist field percentages at three selected points of each case were compared with other cases with the purpose of exploring any similarity in between the cases. At highest connectivity point, which is at a courtyard or at the entrance to a courtyard Isovist field percentage of every case shows only a slight variation of 20% (45% - 63%) except the un-built Wimal Fernando house. Isovist percentage at courtyard center has a variation of nearly 18% (26% - 44%) except Ena de Silva house which has the highest connectivity rated courtyard.

At Living room center Isovist percentage of all the case indicate a variation of nearly 17% (28% to 44%) except Jayakodi house which has an odd shaped plot. This variation which is 20%, 18% and 17% in the considered three points respectively highest connectivity point, courtyard center and living room center shows the variation in Isovist field percentage in each case in respect to specific space varies only in a very slight range and the variation range is very similar for all three spaces. And the Isovist ratio of the three considered points varied only within a small range of 20% which was also a similar observation in all houses. This demonstrates that a similarity exists in creating spatio-visual patterns in Geoffrey Bawa’s urban domestic architecture in terms of visual connectivity between inside and outside.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 369–381. ©

INTEGRATION OF REMOTE SENSING AND GIS WITH SLEUTH TO CHARACTERIZE THE URBAN GROWTH OF MATARA, SRI LANKA

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Abstract

Urbanization causes population growth and physical expansion of built-up area in cities and its suburb. It puts immense pressure on natural resources, conversation of agricultural land and degradation of water, air qualities and have profound impact on human lifestyle and health. Since last two decades, Sri Lanka is experiencing speedy urbanization. The urban population of Sri Lanka is expected to reach 60% by 2030 from 14% in 2010. This rapid increase in urban population may cause serious socio-economic disparities. In-order to plan for a sustainable urban future in Sri Lanka, planners are in need of new tools that can be capable to monitor and predict the urban growth under various scenarios. In this paper, we attempted to characterize the urban growth characteristics of Matara city using Geoinformatics and SLEUTH model. SLEUTH is a well-known urban growth model based on cellular automata. Multi-temporal remote sensing datasets from 1980-2010 have been used quantify the urban growth of Matara. SLEUTH model is calibrated using the data sets prepared from aerial photographs, Landsat sensor data and topographical data from Survey department. The derived calibration coefficient are used to project the growth of Matara by 2030 to understand and analyze the areas that are likely to be urbanized by 2030. The model results showing that out of 66 Grama Niladari Divisions 29 (in Matara Divisional Secretariat Division) will be urbanized with a probability ranging from 80% to 90%.

Keywords. *Geoinformatics, Remote sensing, Cellular Automata, SLEUTH , Matara*

1. Introduction

Urbanization is a spatiotemporal process of conversion of rural land into urban. Since, unplanned urbanization involves in breakdown of natural and social cohesion, it often regarded as destructive process as per *Anti Urban* view. On the contrary, a well-planned urbanization empowers the nation’s economic development and provides better access to employment, education and health care to citizens. Sri Lanka experiencing a speedy urbanization since few decades. United Nations Habitat report (2009) has illustrated, the urban population of Sri Lanka will reach to 60% by 2030 from 14% in 2010. This massive growth in urban population unless handle properly, it may create serious socio-economic disparity which is hard to fix. In-order to plan for a sustainable Sri Lanka, planners are in need of new tools that can be capable to monitor historic urban growth and project their city growth into near future under various scenarios. Recent advancement in Geoinformatics and complexity science given birth to new age urban models based on Cellular Automata (CA) and Agent Based Models (ABM). These models are capable to project the city growth into near future both on spatial and temporal scale. KantaKumar et al. (2011) has illustrated, the CA and ABM model are based bottom up approach Geoinformatics used extensively to map and manage the rapidly growing urban areas. Chaudhuri & Keith (2013) are presented, CA based SLEUTH model is widely used to simulate the urban growth of cities all over the world. In this study, SLEUTH model is used first time to simulate the urban growth of a Sri Lankan city Matara. The city of Matara is witnessing rapid urban and socio-economic growth since last two decades. The main objective of the study is to understand the urban growth characteristics of Matara city and projecting its urban growth under business as usual scenario.

2. Study Area & Methodology

2.1. STUDY AREA

The Matara city is located on the southern coast in Sri Lanka. It is situated 160 km south of Colombo. The Matara city is one of the main commercial center in Sri Lanka and administrative capital of Matara District. It was known as “Mahathota" means "The great ferry”. L.H. Indrasiri (2002) has presented it is one of the largest city and in currently the city is second order regional urban center in Sri Lanka. Fig. 1 shows the study area called Matara Divisional Secretariat Division (DSD). The study area bounded between 5°59'9.41"N to 6°00'05.60"N latitudes and 80°30'2.32"E to 80°37'57.62"E longitudes. It falls in the toposheet number 91 on 1:50000 issued by Survey Department. The Matara city historically belongs to the area called Ruhuna, one of the three kingdoms in Sri Lanka (Thun Sinhalaya).The town contains many remnants of Sri Lanka’s colonial period and was dividing by the island’s third longest river the Nilwala Ganga (Blue River).

Figure 1: Study area

Urban Development Authority (UDA) was declared a municipality in 2002 including 18 Grama Niladari Divisions (lowest administrative unit) and recorded immense growth with the higher infrastructure development projects. Information related to population in census 2001 (only Matara DSD) disseminated by urban population as a 40% (Department of Census and Statistics, 2001). As a result of that UDA was decided to expand the municipality in 2010 incorporated with 46 of GNDs (Figure 2). Predicted that by 2030, urban population is gradually increasing from 40% to 68% in the study are.

2.2. METHODOLOGY & SLEUTH IMPLEMENTATION

The research methodology adopted here was actually based on requirement of SLEUTH model (fig. 3). The aerial photographs were used to calculate urban extent in the year of 1980. A time series of Landsat imageries specific to Thematic Mapper, Enhance Thematic Mapper + sensors were downloaded from Global Land Cover Facility website. All the datasets were re-projected to Kandawala Sri Lanka Grid and clipped to the study area. The Landsat dataset was used to prepare urban extent and land use maps of 1990, 2000 and 2010. Maximum likely hood supervised classification method was used to classify the Landsat dataset into five land-use and land-cover classes, i.e. Built-up land (urban), homestead and garden, forest, marsh or paddy and water. Accuracy of the land-use maps were carried out with the help of existing 1: 100000 land use data, 1: 1000 (Survey dpt., 1986 and 2008 respectively) and Google imageries 2011 (Spot image). Digital Elevation Model (DEM) with resolution of 5m prepared by 1:10,000 spot heights data obtained from Survey Department. Hill shade layer was prepared by using

DEM of 5 m resolution. The model required at least two road network. Therefore one road layer was extracted from 1980 aerial photographs and other was extracted from road layers (1:10000) which prepared by the Survey Department in 2008. Fig. 3 shows the methodology of study.

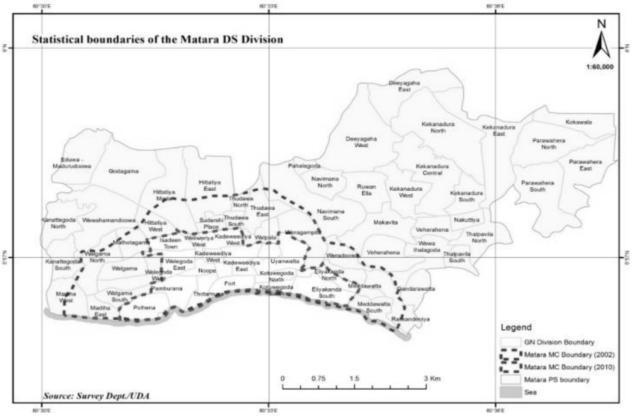

Figure 2. Expansion of City boundary

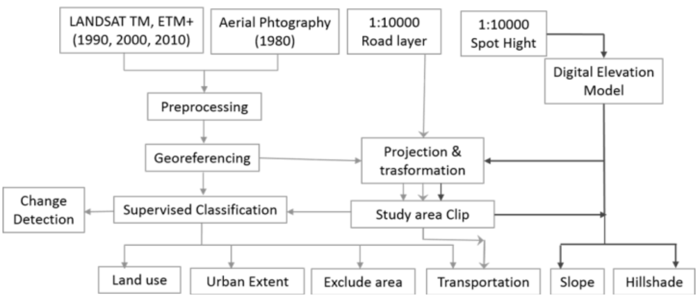

Figure 3. Research Methodology

Format standards for all data layers should be

- Grayscale Graphics Interchange Format (GIF)images
- Images are derived from grids in the same projection (Kandawala Sri Lanka Grid)
- Images are derived from grids of the same map extent
- Images the same resolution [row(471) x column(236) count is consistent]
- Images follow the required naming format <location>.urban.<date>.[<user info>].gif

The model was used here as a tool to project future urbanization pattern in the study area via the calibration under business as usual scenario (continuation existing development condition). To run model required inputs are historic urban extent at least 4 time of period, at least two historic Land use layers, historic transportation network at least two time periods, slope and excluded layers (Water layer). The figures 4 shows the inputs maps use to run the model.

The implementation of the SLEUTH involves three steps called as test, calibration and prediction. Before the Calibration phase test mode is important to verify the input data requirements and their response. The calibration stages are helping to assign best fit values for prediction stage of the study area. By the weighted sum of statistical measures, the best combination is identified. Table. 1 shows the results of each steps of modelling simulation.

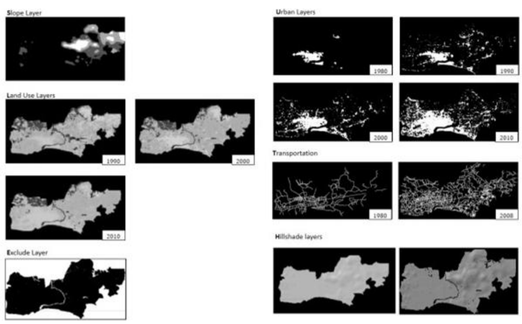

Figure 4. Input maps

Table 1. Model input data test and calibration parameters

Calibration Phase Input	Items	Test	Coarse Calibration	Fine Calibration	Final Calibration	Derived parameters
Model Input Data	Image Resolution	30	30	30	30	
	Slope	mat30.slope.gif	mat30.slope.gif	mat30.slope.gif	mat30.slope.gif	
	Land use	mat30.landuse.1990.gif	mat30.landuse.1990.gif	mat30.landuse.1990.gif	mat30.landuse.1990.gif	
		mat30.landuse.2000.gif	mat30.landuse.2000.gif	mat30.landuse.2000.gif	mat30.landuse.2000.gif	
		mat30.landuse.2010.gif	mat30.landuse.2010.gif	mat30.landuse.2010.gif	mat30.landuse.2010.gif	
	Excluded	mat30.excluded.gif	mat30.excluded.gif	mat30.excluded.gif	mat30.excluded.gif	
	Urban	mat30.urban.1980.gif	mat30.urban.1980.gif	mat30.urban.1980.gif	mat30.urban.1980.gif	
		mat30.urban.1990.gif	mat30.urban.1990.gif	mat30.urban.1990.gif	mat30.urban.1990.gif	
		mat30.urban.2000.gif	mat30.urban.2000.gif	mat30.urban.2000.gif	mat30.urban.2000.gif	
		mat30.urban.2010.gif	mat30.urban.2010.gif	mat30.urban.2010.gif	mat30.urban.2010.gif	
	Transportation	mat30.roads.1980.gif	mat30.roads.1980.gif	mat30.roads.1980.gif	mat30.roads.1980.gif	
		mat30.roads.2008.gif	mat30.roads.2008.gif	mat30.roads.2008.gif	mat30.roads.2008.gif	
	Hillshade	mat30.hillshade.gif	mat30.hillshade.gif	mat30.hillshade.gif	mat30.hillshade.gif	
		mat30.hillshade.water.gif	mat30.hillshade.water.gif	mat30.hillshade.water.gif	mat30.hillshade.water.gif	
Calibration Parameters	**Calibration Mode**	Test	Calibrate	Calibrate	Calibrate	
	Monte Carlo Iteration	1	4	7	8	100
	CALIBRATION_DIFFUSION_START	5	0	0	1	1
	CALIBRATION_DIFFUSION_STEP	1	25	5	1	1
	CALIBRATION_DIFFUSION_STOP	5	100	25	1	1
	CALIBRATION_BREED_START	5	0	25	30	40
	CALIBRATION_BREED_STEP	1	25	5	1	1
	CALIBRATION_BREED_STOP	5	100	50	30	40
	CALIBRATION_SPREAD_START	10	0	75	90	100
	CALIBRATION_SPREAD_STEP	1	25	5	1	1
	CALIBRATION_SPREAD_STOP	10	100	100	90	100
	CALIBRATION_SLOPE_START	95	0	75	75	1
	CALIBRATION_SLOPE_STEP	1	25	5	5	1
	CALIBRATION_SLOPE_STOP	95	100	100	75	1
	CALIBRATION_ROAD_START	5	0	0	1	9
	CALIBRATION_ROAD_STEP	1	25	5	1	1
	CALIBRATION_ROAD_STOP	5	100	25	1	9
Best FIT values	PREDICTION_DIFFUSION_BEST_FIT	20	20	12.5	1	1
	PREDICTION_BREED_BEST_FIT	20	20	37.5	30	40
	PREDICTION_SPREAD_BEST_FIT	20	20	87.5	90	100
	PREDICTION_SLOPE_BEST_FIT	20	20	87.5	75	1
	PREDICTION_ROAD_BEST_FIT	20	20	12.5	1	9

3. Results & Discussions

3.1. DEMOGRAPHIC CONDITION

The impact of rapid urbanization of Matara city is change in the urban environment. Especially increasing population in the study area causes rapid change in land and loss of natural vegetation. Over the last 14 years urban population of the Matara have experienced dramatic growth. Statistics are mentioned in Table 2 that the population is gradually increasing from 40% in 2001 to 68% in 2030 in the study area.

Table 2: Population of the Matara Four Gravets 2001-2030

Year	2001	2009	2020*	2030*
Urban Population	43,442	47,418	89,333	97,707
Rural population	64,796	70,415	40,705	44,520
Total Population	108,238	117,833	130,038	142,227

Source: Department of Census & Statistics report 2001 Resource profile Matara DSD, 2009. *Estimated population

3.2. CHANGE DETECTION

As a result of rapid urbanization process most of the homestead garden and forest lands are converting to the built-up area. Multi-temporal satellite imageries (1990, 2000 and 2010) are showed the changes in land-use in last 20 years (Fig. 5). Supervised classification using maximum likelihood classification was performing with TM and ETM+ Landsat images for the summarized land use change. Training samples were selected with the assistance of land use map (1:10,000), Topographical sheets (1:50,000) data as well as aerial photographs of the study area. Training samples were selected to be detailed as possible in the study area, for example urban, homestead/garden, marsh or paddy, forest and water.

The change detection of land was summarized by using the intersect tool in ArcGIS 10. The nature of change was to analyze land conversions using matrix analysis. This method was use to characterize the land conversions for the periods from 1990-2000 and from 2000-2010 (Table 3 and Table 4)

There are 25 possible combinations for each time period. This study focused on the urban characterization, because only 5 combinations were selected for further analysis related to urban land conversion, such as urban (no change), homestead/garden into urban, forest into urban and water into urban. The other combinations were merged into single (Table

5). The loss of homestead/garden category has contributed to irresistible share of urban growth among other land use categories. During 1990-2000 urban use had a net addition of 556 ha (10%) and 2000-2010 it was increasing to 1046 ha (19%). The urban extents were selected for model calibration phase with slope, land use, exclude, transportation and hill shade.

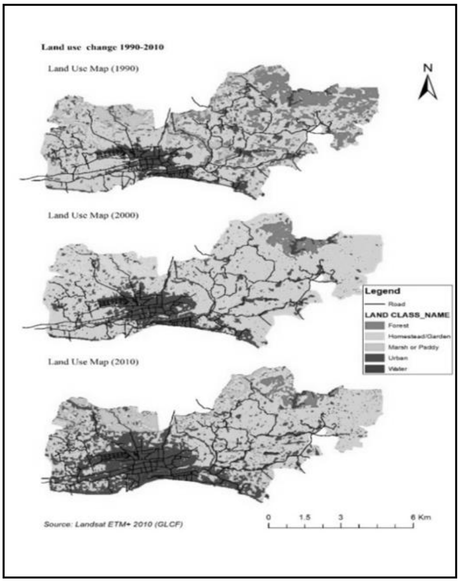

Figure 5. Land use change 1990-2010

Table 3: Transition matrix of land-use change from 1990-2000

Land use category/ Extent (ha)	Urban	Homestead/Garden	Marsh Or Paddy	Forest	Water	2000
Urban	411	416	45	17	33	922
Homestead/Garden	140	2433	248	775	64	3660
Marsh Or Paddy	25	154	341	21	50	591
Forest	1	34	11	202	5	253
Water	16	7	26	8	72	130
1990	593	3044	670	1023	224	5555

Table 4: Transition matrix of land-use change from 2000-2010

Land use category/ Extent (ha)	Urban	Homestead/Garden	Marsh Or Paddy	Forest	Water	2010
Urban	698	863	113	2	20	1697
Homestead/Garden	183	2626	143	111	17	3079
Marsh Or Paddy	31	98	319	6	21	474
Forest	1	54	5	126	14	200
Water	9	19	11	7	57	104
2000	922	3660	590	253	129	5555

Table 5: Urban land conversion in different time period

Nature of change	Urban Land Conversion (ha)			
	1990-2000	%	2000-2010	%
Urban (No change)	411	7	698	13
Homestead/Garden into Urban	556	10	1046	19
Marsh Or Paddy into Urban	70	1	144	3
Forest into Urban	18	0	3	0
Water into Urban	49	1	29	1
Other combinations	4451	80	3634	65

3.3. URBAN GROWTH PROBABILITIES IN 2030

SLEUTH model was used here as a planning tool to visualize and project the urban growth of the Matara city. KantaKumar et al (2011) has illustrated models are often judged by their predictive power. The urban growth was simulation by using the best fit values (fig. 3) which derived from final calibration. Urban extent layer of 2010, slope layer and hill shade layer and road layer in 2008 are used as a seed layers and simulation urban growth during period of 2011 to 2030. The growth parameters are showed that the urban growth of the study area was mainly contributed from the spread coefficient (old or new urban centers spawn additional growth) and Breed coefficient (growing urban centers from spontaneous growth) than the other control coefficients (Table 6).

Table 5: Urban land conversion in different time period

Urban Growth	
Predict Year	Urban Area(km^2)
2011	19
2015	29
2020	38
2025	44
2030	46

Under the business as a usual scenario, the total urban area for 2030 would be 46 sq.km. Furthermore, out of total extent 82% of lands become an urban area in 2030. In order to model results the 3rd order polynomial graph (Fig. 6) is show up required area need by population in 2030.UDA was proposed to extend the urban area towards west part of the study area; from Matara Municipal Council (MC) area to part of Weligama DSD (Fig. 7).That is the key component of this task since the model output similarly displays the trend of urbanization in future.

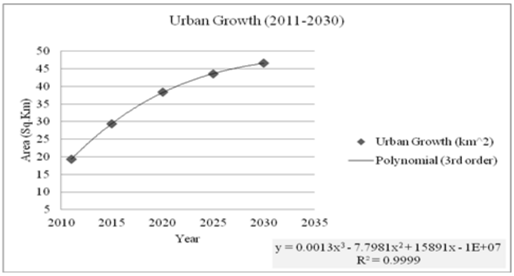

Figure 6: Urban growth (2011-2030)

Table 7: Probabilities of Urban growth in 2030

Condition	Probability	Extent of land (km^2)
Modeled (2010)		16.49
Modeled (2030)	50%-69%	0.25
	70%-94%	2.29
	95%-100%	26.95
Extent of urban area (2030)		45.98
Not modeled Area (Exclude water layer and hilly area)		10.17
Extent of study area		56.15

The spatial distribution of simulated urbanization can be distinguished in fig. 8. It shows that the chances of urbanization of the study are in 2030 and expansion of probable urban pixel of the study area. Except Kekanadura forest reserve and Kiralakele wildlife reserve, rest of the area will be urbanized by 2030. The model results were indicated out of 66 GNDs 29 will be fully urbanized and 26 with in the category of 80%-99%. Kokawila, Parawahera East, Parawahera North Kakenadura East, Kakenadura North and Deeyagaha East were recorded less than 50% of built up area in 2030, because aforesaid area are belong to Kekanadura forest reserve.

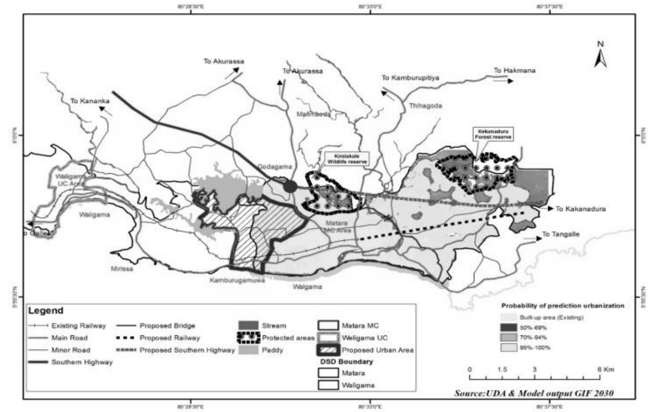

Figure 7: Development proposal of UDA and urbanization trend in Matara

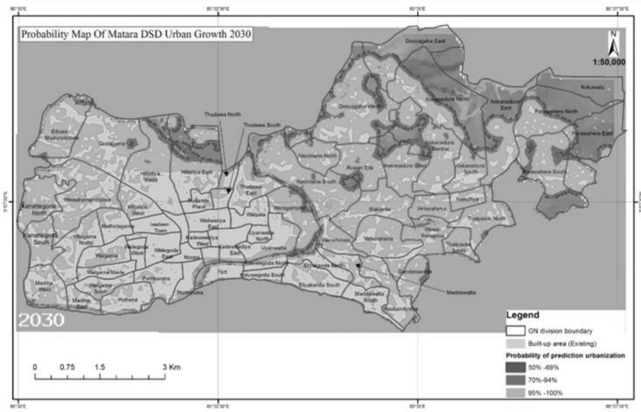

Figure 8: Probability map of Matara DSD urban growth 2030 (by GNDs)

3.4. VALIDATION OF THE MODEL AND SIMULATION SPATIAL ACCURACY

SLEUTH simulation accuracy was analyzed using derive forecasting coefficients avg.log file or last stage of the model calibration process. Urban extent layers which are prepared from Land sat TM, ETM+ by using the maximum likelihood classification method. The urban patterns predicted during the past to future simulation were quantitatively accurate up to 84%

to 100% (Table 8). Furthermore the simulated urban growth is developed from the satellite imageries, and it shows in Fig. 9.

Table 8: Model input data test and calibration parameters (1990-2010)

Based Year	Existing Condition	Calibration results		Accuracy (%)
	Urban Extent (Sq.Km)	Urban Pix	Modeled Area (Sq.Km)	
1990	6.04	6417	5.77	96
2000	9.22	10230	9.21	100
2010	16.97	15763	14.19	84

There are several possible reasons to concern the model precision. SLEUTH model considers a range of various factors controlling new development by most physical factors. But there are some other aspects such as economic and social influence human life. The input images of SLEUTH model during the research were generalized 30m pixel size. The model input images resolution display to cell size because a computational approaches were limiting aspect.

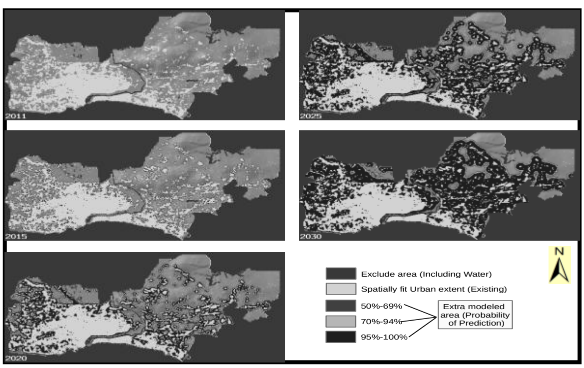

Figure 9: Spatial accuracy (Simulation urban growth, 2011-2030)

4. Conclusion

This paper presents the successful integration of remote sensing data, GIS and an urban model. It also present an approach how urban growth models can be used in planning process. The SLEUTH model is a prediction tool which is useful for decision makers related to urban environment. Basically model output was consisting historical urban extent forecast in pixel based on physical factors like slope resistance and road gravity. The drawback of SLEUTH model is, it doesn’t consider socio economic factors. The whole process of this study has gone to predict urban land change in study area

2011 to 2030. The simulations of SLEUTH are found accurate up to 84% to 100% in this study. Therefore the SLEUTH is accurate and future oriented urban growth model and it consider significant factors which are effect to land use change; urban extent, transportation and slope can be used to model the urban growth and also as an effective tool for the formulate urbanization policies of Sri Lankan cities.

5. An acknowledgement

We wish to express our sincere thanks to Prof. Lasantha Manawadu, lecturer, Department of Geography and Course coordinator of IHRA, University of Colombo (UOC) for providing me with all the necessary assistance and encouragement. This research paper would not have been come out unless Mr. V.B.P. Samarawikrama, GIS and Remote Sensing Analyst, SMEC international. We are extremely grateful and indebted to him. We would like to convey our thanks to Mr. Chinthake Perera, Coordinator Extension Programs, IHRA, UOC.

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ASSIMILATING HISTORICAL CONTEXTS AS LEARNING LABS
Introducing design thinking in the foundation level of design education

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Abstract

Design Thinking is the practice of including and empathizing with people, their cultures, traditions and especially their emotions throughout the problem-solving process of design. In the Bachelor of Design course at the Department of Integrated Design, University of Moratuwa, Sri Lanka, this practice begins by the realization of one's self. While the individual self is realized in varied perspectives in succession, the use of historical contexts as the introductory atmosphere is highly beneficial. Using inherent qualities of the physical context, culturally valued reminiscent structures or ideological attributes given to contexts, students begin the process of questioning the norm for the progression of empathized betterment through history. Empirical data of ten (10) projects spanning from 2001 to 2015 is used to derive the methods of experimentation and evolution of historical contexts as learning labs. The gathered analytical data is used to synthesize necessary inclusions of a historical learning lab and future possibilities. The research has been funded by the Senate Research Committee of the University of Moratuwa under the grant number SRC/ST/05/2015.

Keywords: *Contexts, Learning labs, Design Thinking, Historical contexts, Design Education*

1. Introduction

Design-based Research (DBR) is responsive to inherent natures of contexts yet is structured and systematic as well (Wang & Hannafin, 2005). DBR as a methodology for educational research is highly promising (The Design Based Resrach Collective, 2003). Therefore the research paper begins with the description of the analysis and synthesis methods used for the purpose of 'assimilating historical contexts as learning labs'. The conducted research is compared with the five mandatory characteristics of DBR as characterised by Wang & Hannafin (2005) to define the framework of this research.

With the gained knowledge, empirical data of ten (10) learning labs conducted throughout the years of 2001 to 2015 at the Bachelor of Design course of the Department of Integrated Design, University of Moratuwa, Sri Lanka is used to obtain solutions to the core problem of the research, how and in what ways can varied contexts of history be utilized as an introductory platform for Design Thinking in the foundation level of design education? The hypothesis was developed with the initiation of the first project in 2001. As mentioned below in Table.1 HLL01|DM consisted of using the context of a machinery system that is embedded in historical legendries of Sri Lanka without relating to a particular context. This particular beginning for the introduction for Design Thinking comes with its inherent nature.

Furthermore the paper discusses the research question of; what particular processes or methodologies of design does the foundation student explore and practice upon the introductory platform of history? Finally the future possibilities for the conducted DBR is discussed, developments are inferred and evolution of historical learning labs and the nature of design processes that can be followed by the foundation level students within historical learning labs is realized. Table 1 introduces the prior mentioned ten learning labs with project names, briefly, the nature of the learning lab and the assigned code which will be used in the research paper.

Table 12 - Brief introduction to discussed historical learning labs

No.	**Name of learning lab**	**Nature of learning lab (based on final design output)**	**Code**
01.	*Dandu Monara*	Particular machine without a specific context	HLL01|DM
02.	*Karkataka Yanthra 01*	Particular machine in specific context	HLL02|KY1
03.	*Yaathra*	Connecting system (technical/ structural) in a specific context	HLL03|YTR
04.	*Karkataka Yanthra 02*	Particular machine in specific context	HLL04|KY2
05.	*Yaapahuwa*	System (defence – social/ political/ economic) in a specific context	HLL05|YPW
06.	*Sakwala Chakra*	Design based on physical contextual detail; undefined context of origin	HLL06|RMU1

07.	*Sethu Samudram*	Connecting system (structural/ ideological) in a specific context	HLL07|SS
08.	*Koneshwaram* (Remembrance Rock)	Expression (structural detail) referring to collective contexts in a specific context	HLL08|RR
09.	*Karkataka Yanthra 03*	Particular machine in specific context	HLL09|KY3
10.	*Ranmasu Uyana* (Water celebration)	System for an element in a specific context	HLL10|RMU2

2. Practices of design based research in the progression of historical contexts based learning labs

While Design-Based Research (DBR) is relatively novel than other methodologies of research it provides a sound basis for educational research which has unique situations due to contextual forces. Wang & Hannafin (2005) identifies five qualities that is possessed in DBR; DBR is pragmatic, it is grounded, it is interactive, iterative and flexible, it is integrative and it is contextual. Following the research question of, what are the developed methods of analyzing and synthesizing used for the design based research of utilizing historical contexts as an introductory platform for Design Thinking in the foundation level of design education?, is answered and a structure is developed for the necessary progression of the research.

2.1. APPLICABILITY AND ATTRIBUTES OF DESIGN BASED RESEARCH

Hoadley (2004) identifies that with a simultaneous and comparative progression between designing and the study of it in naturalistic settings can result in a “methodological alignment”. Furthermore, as recognized by Sandoval & Bell (2004) the importance of DBR can be extended and reified through the explicit and conjuncted mapping of research studies. While recignizing the relevance of DBR in such a sence The Design Based Resrach Collective (2003) recognizes particular areas of research that can be funded by DBR to its full pontential. They are;

- Exploring possibilities for creating novel learning and teaching environments.
- Developing theories of learning and instruction that are contextually based.
- Advancing and consolidating design knowledge.

- Increasing our capacity for educational innovation.

With the recognition of the suitability of DBR for the study of how to assimilate historical contexts as learning labs, following is the identification of the prior mentioned characteristics of DBR; as explained by Wang & Hannafin (2005), within the scope of the research.

1. DBR is pragmatic – Pragmatism is identified as the refining of both theory and practice. The value of theory is proportional to the improvement in practice. The preliminary hypothesis for the research was developed at the initiation of the first learning lab in 2001; HLL01|DM. While it began with the broad idea of self-realization for empathy, the nature of the study developed with the years to a precise structure which allowed the relating to contemporary professional practices while having the prior mentioned broad understanding as an underlying layer.

2. DBR is grounded – Gaps in existing theories and or practices are identified to ensure the value of the research. Theses gaps are considered as problems or issues which are continuously revised and refined. This leads to the understanding of "which interventions should (or should not) be introduced and which should be eliminated". Design Thinking has many perspectives of understanding. It is an integrative approach to problem solving (Buchanan, 1992). It is the use of the methodology of problem solving within the practice of design in other fields (Brown & Wyatt, 2010). These continuously developing ideas about the profession of design is integrated in the structure of practice. As it can be seen in Table 1 the change from not relating to a physical context for designing to choosing a physical context to comprehend and use in the design process can be understood as an example.

3. DBR is interactive, iterative and flexible – Interaction occurs with the working together with relevant participants. Iteration occurs with continuous re-evaluation and resultant redesigning. Flexibility occurs with the "insufficiently detailed" beginning to the process. While the initial learning labs were funded by knowledge and practice of direct experts such as architects and archaeologists, the latter learning labs were funded by the knowledge of a broad range of experts including musicians and dancers. While all labs are continuous iterative developments an example of particularized

iteration is the learning lab of *Karkataka Yanthra* which occurred as HLL02|KY1, HLL04|KY2 and HLL09|KY3. The broad understanding used in the HLL01|DM allowed the nurturing through flexibility for all the successive learning labs.

4. DBR is integrative – Methods of research are mixed and changed with iterations to suit the necessities of the existing phase. The learning labs of HLL06|RMU1 and HLL10|RMU2 being located in the same physical context shows the changing of approach to the learning lab while relating to contemporary professional practices.

5. DBR is contextual – Derivations from the initial plan is recorded and results are connected to the context of conduct. For the generalization of and adaptation of the ultimately realized principles, guidance is required. The effectiveness of historical learning labs exists with the relationship to the rich history of the country and its value in the society. When a practicing context differs from similar societal norms the nature of the learning lab may have to be changed.

2.2. METHODOLOGIES OF ANALYZING

As per the requisitions of DBR the research analysis is grounded and uses an analytical inductive approach. The used pre-defined population is the foundation level design students of the Bachelor of Design degree. As sample selection, the selected students to the degree as a result of an aptitude test can be identified. Due to their similar societal practices, the value for history, resultant cultural and traditional practices are used as foundations of the learning labs, thus the foundations of the hypothesis. The progression of learning labs with both similar and adjusted practices serves as key to finalizing statements of the research.

3. History as an introductory platform

In a country with one of the longest written histories in the world and pre-histories nourished with legends and folklore, history plays a far greater role than being a set of past events that affects the present as an underlying layer. Using this contextual force, of Sri Lanka, historical contexts are employed as learning labs to introduce Design Thinking. It begins with the identification of a problem which has a solving process of successive progression as well as lateral progression. Devoid of industrial restraints students explore and develop the ability to realize multiple possibilities using logical imagination and use it for design development. Furthermore in the process of relating to history, students realize the potential of contextual forces such as the in depth knowledge of varied subject matter within the Island (Wickramanayake, 2015).

3.1. POTENTIAL OF HISTORICAL CONTEXTS AS LEARNING LABS

History can be understood as the knowing and acknowledging of events of the past. Thus making the fuel for the existence of history; the present. For Sri Lanka, harbouring millennia of ancient history, it is not merely a cultural attribute but the way of life of contemporary times (Liyanage, 2015). Through notions of collective identity, it is what individuals use to define themselves. Therefore, it can be understood that questioning history would create a platform where the individual self can be questioned.

The necessity of developing a platform where the individual self can be questioned comes with the need of developing a sense of empathy towards the wider society beginning with one’s self. Dissecting history means, the dissecting of the integral belief system of all members of the society as a whole. Hence looking into histories as far as possible stands to mean seeing contemporary times in a different and novel perspective. The knowledge of the possibility of seeing fundamentals of the society anew provides a positive ‘shock’ to the foundation level undergraduate, who has been moulded by didactic education methods of primary and secondary education.

A historical context can be any given scenario of the past, any given reminiscent built environment of antiquarian value or even of more recent historical value. To convert a historical context to a learning lab, activities done in accordance with the curriculum must be based upon a specific context from the above mentioned possibilities. In this conversion of a historical context into a learning lab, positive limitations are induced. The notion of a learning lab suggests that procedures must have the capacity of being reproduced. In these attempts of reproduction students obtain the possibility of scrutinizing the process of design development which fuels successive learning labs. The term ‘lab’ further suggests restrictions, which funds the idea of graspable units of study. In the process of design development all students generate designs within the context of the lab which proves highly beneficial in the process of assessment.

3.2. DESIGN THINKING IN HISTORICAL CONTEXTS

The idea of Design Thinking emerged in the 20th century as a mode of integrative thinking to connect the knowledge of arts and the sciences so that it may better suit the solving of problems and purposes of contemporary times (Buchanan, 1992). In that idea of better understanding the problems and purposes of the present it is mandatory that the professional who follows this ideology has an in-depth understanding of himself (Liyanage, 2015). Thus, creating a learning environment where the student is provided with the space to look deeper in to the roots of the present times whilst questioning and reinterpreting provides the ideal beginning to develop Design Thinking.

Differing from the times of its inception, Design Thinking is currently used as a methodology for sectors of a non-design origin to resolve complex problems in varied fields such as health care, banking and finance, education, etc. by adhering to methods used in the profession of design. While Design Thinking continues to evolve in that manner it also reaches precision as a design methodology which can be used by designers as well.

Design Thinking looks into design problems and seek a solution in five steps.

1. Discovery – a context is converted into a dialogue so that it may present new facets of exploration.
2. Interpretation – the discovered facets are seen in the light of many varied possibilities by the means of relating to people of the context.
3. Ideation – the explored facet and the new interpretation is used to provide a solution for the contextual problem.
4. Experimentation – the solution is put to test and the responses are recorded.
5. Evolution – the responses are taken as feedback for evolving context based iterations.

This procedure can be identified as the method of practice that is used in the historical context based learning lab. While all characteristics of DBR can be identified in the five steps of Design thinking as mentioned above, Figure 1 illustrates distinctively identifiable similarities between the practices of DBR and Design Thinking.

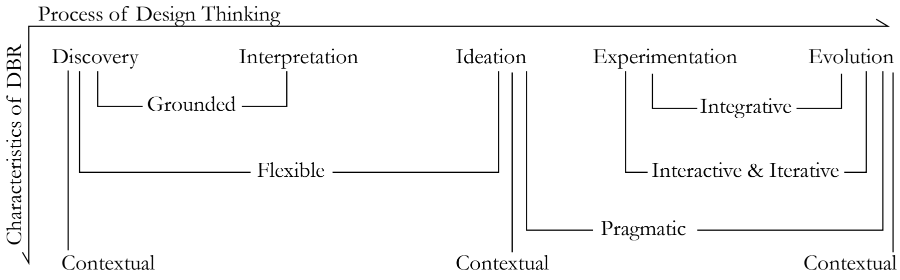

Figure 1, Characteristics of DBR vs. Process of Design Thinking

3.3. IDENTIFYING A PROBLEM-SOLVING PROCESS

Identification of the problem-solving process begins with step one in Design Thinking; ‘discovery’. Prior to converging into a particular context, ‘discovery’ begins by discussing about history in new perspectives. Terminology such as ‘past’, ‘history’, ‘his-story’ is brought forth for discussion to even ultimately discuss broad topics such as time and space. In due-process, basing on facts, discrepancies in chronological data, gaps in historical commentaries are identified as possibilities for reinterpretation. A physical context is introduced at this stage. This creates the necessary convergence to initiate a dialogue which will allow to see the believed norm in different perspectives.

The on-site work begins with the exploration of its physical nature. Following, insights to the context is provided by varied experts allowing the students to gain exposure regarding the context and its histories in varied facets. According to Design Thinking people must be included in the step of ‘interpretation’. Befits of the use of a historical context as the introductory platform can be identified at this stage. Since students explore historical data and design development is devoid of industrial restrictions, foundation level students have the benefit of self-reflection as a source of information for empathic practices.

With gained consciousness of history in varied perspectives with gaps in existent sources of information – both as reminiscent built environments and literature sources – and seeing them through self-reflective empathy, students convert the gaps into problems to which require solutions. The problem is then further dissected so that it may be resolved in a strategic manner. This results in the step of ‘ideation’.

3.4. LOGICAL IMAGINATION AND DESIGN DEVELOPMENT

Logical imagination funds the ‘experimentation’ stage that follows ‘ideation’. Relating to all the previously discussed matter students develop a coherent storyline. As a result of this storyline, a problem is realized according to the nature of the contextual learning lab.

Design development which is fuelled by the logical imagination process begins as team work and gradually shifted on to an individual designing process so that the necessary data for the progression of the coaching process throughout the foundation level maybe properly informed. It is only at this latter stage that the historical learning lab may differ from the precise methodology of Design Thinking due to the inability of an academic process to fund iterations in the stage of ‘evolution’. Figure 2 shows the connection between the progression of the learning lab and Design Thinking.

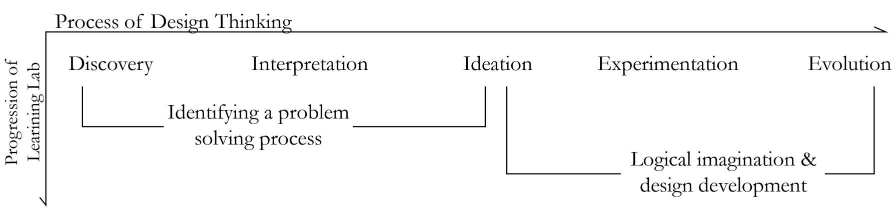

Figure 22, Progression of Learning Lab vs. Process of Design Thinking

4. Curriculum and curricular content of historical learning labs

Design Thinking is a methodology that can be used for developing answers to both the questions of ‘what to be taught?’ and ‘how to teach?’ The answer to the former question lies within the curriculum, which is the development of aims and objectives that encompasses aspects to be taught so that students may begin their learning and exploration process of Design Thinking. The matter of ‘how to teach?’ has its answer in the curricular content, which devices changing content primarily based upon the variations of the physical context of the learning lab. As it can be observed in Table 1 (1.Introduction) a wide spectrum of curricular content can be developed relating to different contexts. Student progression is continuously observed and assessed comparing to the achieved percentage of the objectives of the curriculum.

4.1. CURRICULUM AND DESIGN THINKING

For the purpose of this research paper curriculum is understood as the aims and objectives of the learning lab. Based upon the prior said stages of Design

Thinking the following curriculum was developed through the experimentation of continuous learning labs.

Aim – Gaining the knowledge of the importance in understanding a historical backdrop of a chosen designing context

Table 13. Curricular Objectives and relationship to Design Thinking

Objective	**Relative step in Design Thinking**
Recapturing the epoch of history and establishing awareness	Discovery
Recognition and understanding of built environment etc. by studying and comprehending the unique language and characteristics of a location.	Interpretation
Formulate a creative brief acknowledging the physical context through a process of identification and analysis.	Ideation
Generating a logical conception linking appropriate resources to evaluate and strengthen a conceived abstraction	Experimentation
Execute and refine design ideas using both 2D and 3D methods of rendering in a creative presentable manner.	Experimentation. The stage of 'evolution' can be identified in the development of designs through the individual tutoring process.

4.2. EXPLORATIONS OF CURRICLUAR CONTENT

Curricular content begins with the HLL01|DM where the students developed the famous *"Dandu Monara Yanthra"*; a machine that has been used to fly by King Raavana, a legendary figure in local pre-history. HLL02|KY1 explored the creation of a "*Karkataka Yanthraya*", a machine, with the function of a lift that has being used in the rock fortress of Sigiriya. Sigiriya while being one of the most famous locations of ancient value in Sri Lanka has many derivations with the time period it belongs to. This key factor of derivation, allows a platform for questioning by the context itself. Thus the learning lab is repeated with variations as HLL05|KY2 and HLL09|KY3.

HLL03|YTR was a learning lab created upon the believed ancient sea port of Godawaaya. The intriguing level change in the context was used to create the core of the learning lab where the students developed a connecting system – be it a bridge or a vehicle for transporting vehicles – from sea to inland high ground. "*Yaapahuwa"* is a kingdom in the Sri Lankan royal lineage which was constructed due to foreign attempts of conquering. HLL04|YPW learning lab had as its core, a creation of a defence system relating to social, political and economic aspects. HLL06|RMU1 was based in a location which is popularly known to be a pleasure garden of the kingdom of Anuradhapura. Yet a rock mural with unidentified origins within pleasure garden allows the questioning of the entire context. This evident gap was understood as a design problem and was solved through reinterpreted holistic environments upon the evident physical context of present times.

HLL07|SS, was a learning lab developed in the Northern district of Mannar in the west coast, which is said to have an ancient bridge linking India and Sri Lanka. The learning lab taking into account the ideological value of a bridge – linking – produced either structural or conceptual connections between India and Sri Lanka. The idea of the bridge was socially, politically and culturally made sound with the ruins of a pathway leading from the ancient sea port of *Mahathiththa* in Mannar leading up to the kingdom of Anuradhapura. The learning lab of HLL08|RR, similarly to the prior project used multiple locations to base the output of the learning lab. Namely, the sea port of Mannar in the Northern west coast; *Mahathiththa*, the ancient sea port of Trincomalee in the Northern east coast, *Gokanna*¸ and the adjoining inland location of Sigiriya. The learning lab produced a structural emblem for identity expression upon the Kovil of Koneshwaram in Trincomalee.

HLL10|RMU10, reused the context of *Ranmasu Uyana* yet in a different aspect by focusing on developing a system for the element of water that surrounds the area and the evident water pools in within the context.

5. Future possibilities

Any devised methodology of DBR proves to be successive with the iterations done with changes based upon pragmatic use of prior formulated theories. Thus constructing possibilities of future advancements is of importance. With developed DBR it can be discussed whether novel dimensions for the advancement of the curriculum can be discovered. With an elevated curriculum – aims and objectives – differed methods for students to experience the design process can be realized.

5.1 ITERATING THE DESIGN-BASED RESEARCH AND ADVANCEMENTS OF THE CURRICULUM

A following iteration of DBR can seek to devise a precise methodology of comparing design methodologies in practice and characteristics of DBR. The current method of assessing in the curriculum begins with the assessing of produced work of the group work conducted on-site. The shown work is compared with the degree of success with the related objective. And the individually produced work undergoes continuous assessment with a guiding coaching process.

This process as in the suggested issues of assessing curricular activities such as “what is assessed, what can be assessed, what is the purpose of assessment, who assess and how students experience assessment” by Trede & Smith (2012) can be further developed in iterative processes of DBR. The advancement of the curriculm can be conjuncted to this by creating sub-sections in the practiced design process. As an suggestive example the stage of ‘evolution’ in design thinking can be further understood in segments and used for the purposes of assessment for iterative DBR.

For curricular advancements while Design Thinking as methodlogy proves highly beneficial it can be further improved to cater the modern notions of learning such as constructiveness, self-directedness, collaboration and contextuality (Dolmans, et al., 2005).

6. Conclusion

In conclusion it can be identified that historical contexts with architectural ruins can spark an extensive process of practicing Design Thinking in the foundation level. This explorative learning lab devoid from conventional methods of learning continues to fund the development of empathy in students to become professionals with a focus on social betterment with a deeper realization of self. The notions of educational practices in the present day can be followed and researched using Design-Based Research. Both DBR and the followed method of design practice can be further developed through the further precise detailing of characteristics and design development stages. Figure 3 shows the combination of DBR, progression of learning labs and objectives compared to the stages of Design Thinking.

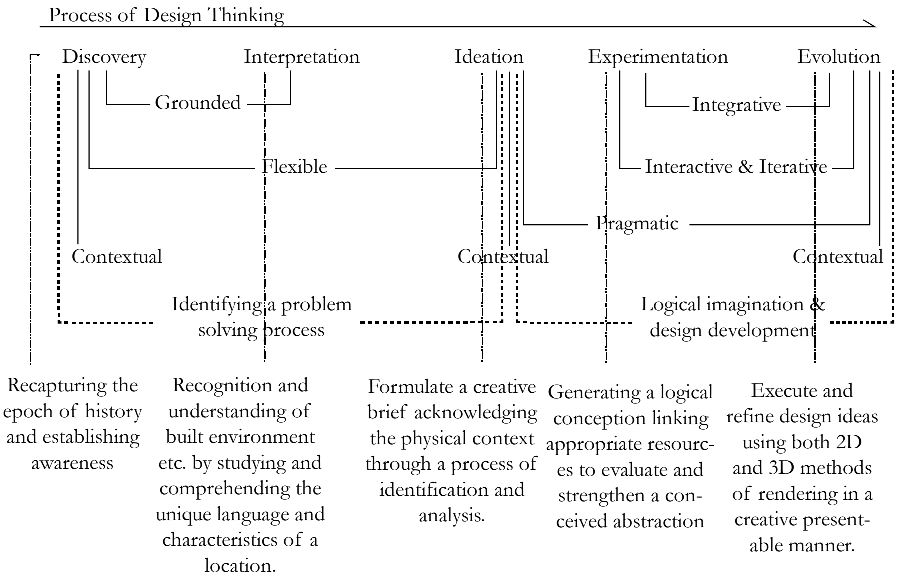

Figure 3, DBR, progression of learning lab, objectives vs. Process of Design Thinking

Acknowledgements

The following members of staff, Landscape Archt./Eng. S. Udalamaththa , Archt. S. Rathnamala, Archt. R. Wickramanayake, Ms R. Rathnayake from the Department of Integrated Design and Department of Architecture of the University of Moratuwa are especially acknowledged for the continuous support in developing the historical context based learning labs additionally to all other members of staff and students.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 396–404. ©

BIM AS AN INSTRUMENT TO MINIMIZE SOURCES OF CONFLICTS IN CONSTRUCTION PROJECTS

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Abstract

It is a general acceptance within the construction industry that the conflicts in projects are inevitable; and it is a regular phenomenon due the unique nature of the construction industry. However, this is not the expectation of the clients of the industry and the society at large. A responsive construction industry should therefore take all steps to minimize conflicts in construction projects. Many sources of conflicts were found to be directly or indirectly related to information and communication. With the introduction of Building Information Modelling it was able to reduce the need for re-formatting or re-gathering information. This resulted in an increase in the speed and accuracy of transmitted information, automation of checking and analysis, unprecedented support of operation and maintenance activities and abatement of limitations associated with a lack of interoperability. It is an expectation in the construction industry that, adoption of BIM therefore will reduce the sources of conflicts in construction projects. This research study was aimed on identifying the modes to minimize sources of conflicts in construction projects with adoption of BIM. A desk study analysis was conducted using various standard publications published by construction stakeholders and the collected data was subjected to content analysis. Through findings of the research, modes which can be used to minimize sources of conflicts using BIM were identified. The findings of the research will provide a guideline for the adoption of BIM to minimize sources of conflicts.

Keywords: *Construction projects; Conflicts; Building Information Modeling.*

1. Introduction

Construction projects are more complex because of their unique nature and involvement of various parties during the construction period, with this conflicts are expected to rise which will affect the flow of the project (Yusof, Ismail & Chin, 2011). Conflicts are apparent in construction projects due to number of objectives and various duties of the parties involved in the goal setting stage (Lueng, Liu, & Ng, 2005). According to Yiu and Cheung (2007) these conflicts are arisen due to various sources. Lueng et al. (2005) explained that clients in construction projects expect completion of woks within the expected time, quality and within the expected cost limit. Further, these expectations can be disturbed due to various sources of conflicts. Among these sources of conflicts main sources of conflicts has been identified by researchers as poor communication (Verma, 1998), collapsing communication chain among the parties (Ogunbayo, 2013), change of site condition, public interruptions, change order evaluation, defective design, excessive variation in quantities, double meaning of specifications (Acharya, Lee & Im, 2006b).

Proper integration of information leads to reduce risks and sources of conflict in the construction projects (The American Institute of Architects [AIA], 2007). Zhang and Hu (2011) emphasized that BIM is a model that is designed to integrate and digitize entire information related to the projects to express every component of building and their relationships. BIM is not a ready-made model therefore; it is changed according to complexity of construction projects. Further, its collaborative process helps to understand every aspect of the construction projects (Sebastian, 2010). The stakeholders are helped by BIM to understand what is to be constructed in a simulation environment to recognize any possible design, construction and operational outcomes. Further, BIM allows to favourable cooperation and support integration of responsibilities of every stockholder on construction project (Azhar, Khalfan, & Maqsood, 2012)

2. Sources of Conflicts in Construction Projects

The sources of conflicts are generally similar although construction projects are unique in nature (Yousefi, 2009). Sources of conflicts exist in many construction projects, whereas they are not always matured into conflicts. Conflicts will arise only if the project participants have failed to come to an understanding or unclearly formulated the provisions regulating the coverage of extra costs by the parties (Yiu and Cheung, 2007). It is somewhat a common case in a construction project, the contractor expects that the client is more responsible for compensation of extra costs, but the client’s point of view is that contractor should obligate to do the additional works at his own cost. Many studies on conflicts and disagreements in the construction projects exclusively deal with the situations characterizing a conflict and tend to ignore the causes thereof or erroneously present related circumstances as sources (Mitkus & Mitkus, 2014). Therefore, he argued that in order to prevent such misunderstanding it is important to investigate the real sources of conflicts in construction projects. Many researchers have categorized sources of conflicts in various ways. But it is difficult to understand each categorization due to overlapping of some sources of conflicts. Therefore, in this research the sources of conflicts were categorized into employers evoked, consultant evoked and contractor evoked sources of conflicts for analysis.

2.1 MAIN SOURCES OF CONFLICTS IN CONSTRUCTION PROJECTS

Through many researches, researchers have identified, that there are sources of conflicts which significantly affected to the conflicts in construction projects. Mitkus and Mitkus, (2014) has hypothetically proved that unsuccessful communication process as a main source of conflicts. Further they have identified that unfair behavior and effects of psychological defenses are also main conflicts sources. Through his research Kumaraswamy, (1997) has identified root (main) sources of conflicts through investigation as, unfair risk allocation, unclear risk allocation, unrealistic time/ cost/ quality targets, uncontrollable external events, unrealistic tender pricing and inappropriate contract type. Acharya et al. (2006a) has revealed the owner as a more responsible party for sources of conflicts in construction project. Acharya, Lee and Im (2006b) confirmed that by identifying six main sources of conflicts which are caused by owner in construction. These are differing site condition, public interruptions, difference in change order evaluation, errors and omission in design, excessive quantity of works and double meaning in specification. Further, they highlighted that through their investigation, differing site condition and public interruptions are the most critical sources of conflicts among those. In addition, they have found that misrepresented shop drawings as the largest source of conflicts in construction projects due to complex nature of the today’s construction projects. Also, delaying of shop drawing and its vague nature will lead to conflicts.

3.0 Building Information Modelling (BIM)

BIM is not just a three dimensional representation. Instead, it is a digital simulation of the capability that can be viewed, tested, constructed designed, and deconstructed digitally. This stimulates iterative design optimization and the ability to rehearse construction before ever moving labor, material, and equipment into the site (Ashcraft, 2008). BIM can be used as proper decision making device for construction projects (Moon, Kim, Kang & Kim, 2012) because BIM provide proper information flow in construction projects (Ding, Zhou & Akinci, 2014), which is an expected improvement exceeding the traditional practice.

3.1 BIM AS AN INSTRUMENT TO MINIMIZE SOURCES OF CONFLICTS

BIM makes integrators, designers, manufacturers benefit in design quality control and efficiency. BIM improves communication within the design and construction participants and the digitally based, virtual and dynamic environment create a well-set database (Linowes, 2009). Apart from the improvement in communication, the collaborative environment where more ideas have to flow between team members in a common platform (Aragon, 2006) is also expected to act as a mode of minimizing sources of conflict. Moreover, the employer and facility manager can avail within the model and in between the residence of the building. Outcome of the information from that model can assist the stakeholders to be more effective and also makes new chances for earning expansion (Nell, Allison & Black, 2010). BIM includes inbuilt sources of information for all stakeholders which governs the smooth flow of project (Volk, Stengel, & Schultmann, 2014). This information sharing mechanism is also expected to minimize the sources of conflict among project participants.

4.0 Research Methodology

In this research, research technique mainly consisted of two processes as data collection and data analysis. Even though the research focus is on BIM, local industry still does not practice BIM and only a handful of local professionals are aware of this system. Therefore data collection methods such as interviews, case studies, or industrial surveys which could have been used are not practicable for the study. Industry experiment is also a possible way of gathering solid data, yet BIM environment is not matured enough in the local context for such a prolific methodology. Therefore considering the impracticability of industry data collection, the data was collected through a desk study which reviewed various different sources of information which are not usually accepted as proper sources for literature review. These included inter alia publications such as manuals and user guides, online blogs and discussion forums. These represented the experience and opinions of BIM experts at various levels. O’Leary (2004) explains the major rule of any form of study is to move from raw data to meaningful understanding. Therefore, data analysis includes the compilation and interpretation of the data collected. Analysis depends on the nature and form of the data which have been recorded. Content analysis was the data analysis technique used to interpret meaning from the content of text data referred.

5.0 Content analysis and findings of the research

Through the content analysis, it was found that out of the many sources of conflicts identified in the literature review, twenty conflicts could be minimized by BIM. Those are five number employer evoked sources of conflict, five number of consultant evoked sources of conflict, ten number of contractor evoked sources of conflicts, one number of third party evoked sources of conflicts and two number of other matters evoked sources of conflicts can be minimized through adoption of BIM for construction projects.

5.1 EMPLOYER EVOKED SOURCES OF CONFLICTS.

Employer evoked sources of conflicts were analyzed under five topics such as delay in getting permits, inadequate contract administration, Inappropriate contract type, Slow current response and Unclear risk allocation.

Getting permits by the government authorities is more time consuming task, it may be due to checking of the codes, guidelines and understanding design parameters. New York City department confirms, code validation software can be integrated with BIM, which reduces the code design errors. It further mentions that since the employer is less knowledgeable in this respect it has to be accompanied by the design team. When it comes to contract administration and inappropriate contract type, many sources mention that BIM has collaborative tools consisting with software packages, 4D models and platform created through web, can be used assisting contract administration.

Addressing the slow response rate, sources explain that BIM visualize construction sequence providing clear understanding about the construction projects, Therefore, it provides information about construction events to employer efficiently, which enables expedite responses. When unclear risk allocation is considered, parties mention that in BIM database it has been clearly defined each participant's tasks and responsibilities. In addition various models can be used to analyze probable risk events.

5.2 CONSULTANT EVOKED SOURCES OF CONFLICTS.

Consultant evoked sources of conflicts were analyzed under four topics such as design failures, drawing errors, inaccurate tender evaluation, inadequate design documentation.

The reason behind many design failures and drawing errors is because of not having a pre analysis technology on the design and drawings before construction. Many sources mention that BIM integrated software package provides best solution for designs with proper solutions. Autodesk states that number of analysis tools and effective 3D models in BIM provides a superior foresight on design. Moreover, many sources identify that drawing errors can happen because different participants making up the final drawings. Coordination among project participants is essential in such a situation, which is provided by the collaborative environment provided by BIM.

Answering the inaccurate tender evaluation, the sources mention that pricing schedules can be produced using BIM, and these schedules can be used to compare BOQ prices as well various analyzing reports can be created compared with the engineering estimate. Moreover 4D models in BIM enhance the correct construction programme and proper resource allocation in selecting the prospective bidder. According to the sources, variations are the common most of the construction projects. These variations change the design of construction projects some extent. Traditionally with each change, a set of design documents has to be submitted to the contractors or subcontractors; the BIM software automatically coordinates the change in the drawings, clashes will be detected and the integrated BIM system will assist in providing adequate design documents

5.3 CONTRACTOR EVOKED SOURCES OF CONFLICTS.

Contractor evoked sources of conflicts were analyzed under five topics such as changes in errors in interim payment applications, lack of knowledge of site conditions, less progress of works, material wastage, misunderstanding of scope of works

Errors in interim payment application are common in construction project. BIM provides favorable solution to overcome such errors because BIM is consisted with fictional software which can generate relevant information. According to the published sources, extraction of accurate quantities, in built pricing schedules and relevant generated information can be assisted to generate error free interim payment application.

The reason for the lack of knowledge of the contractor on the site conditions is twofold. It’s being the contractors and consultants negligence. In addition to that it may be the reason that there is no proper site analysis technology to analyze site condition effectively. But with the adoption of BIM, it provides effective site analysis mechanism. This happens because with the contractors being allowed to work on the model, they become aware of the site conditions in the virtual space.

When the progress of the works is concerned, the sources point out that today most of the construction projects are used pre-fabricated items. It is tends to increase the progress of the work. When BIM is considered it can be connected to the pre-fabrication process. Therefore, more accurate pre-fabricated items can be constructed within less time period. Moreover 4D models enable the scheduling process to expedite work. Material wastage is addressed through BIM, by the selection of material in accurate dimensions from BIM software; also build up of material schedules will reduce the material wastage.

According to sources, visualization offers best solution for the issue of misunderstanding the scope of works. Because BIM integrated software provides clear visualization of model. Most of the parties mention that parametric elements model can be created using BIM. Therefore, each and every construction participants can understand which scope; have to be completed by them.

6. Conclusions and Recommendations

Building Information Modeling is the process of generating and managing BIM during project life cycle by using three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction to produce Building Information Model, which consist building geometry, spatial relationships, geographic information, and quantities and properties of building components. When BIM is used for new construction projects, it is important that having knowledge about what purposes BIM can be used. This study addressed the adoption of BIM to minimize sources of conflicts in construction projects. To achieve this aim, the sources of conflicts, main sources of conflicts and the BIM features were identified using literature. Moreover, sources of conflicts which have potential to be minimizing using BIM were identified. Finally new sources of conflicts which can be minimized through BIM were identified. According to findings of this study it can be concluded that BIM can be adopt to minimize sources of conflicts in construction projects.

Considering the finding of the research, following recommendation can be derived as the implications to the construction projects. If BIM is implemented for the construction projects, sources of conflicts which are evoked by employer, consultant and contractor can be minimized to achieve a successfully completed project within the time, cost and quality originally anticipated. Furthermore, before BIM is implemented for the construction projects it is important to consider on the way of minimizing sources of conflicts which cannot be minimized through BIM. Therefore, it is important having strategic plan to minimize sources of conflicts, when BIM is implemented for construction projects. When software vendors are considered, they can upgrade BIM software and BIM related software to overcome or minimize identified sources of conflicts. Moreover, when software is purchased client can consider which BIM software will facilities minimize or overcome sources of conflicts in constructions projects.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive": *Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka*, pp. 405–416. ©

PUBLIC PERCEPTIONS ON URBAN OUTDOOR CONSTUCTIONS AND THEIR MATERIALS

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Abstract

Human perceptions on their environment are an important aspect that has to be considered in the development construction works to meet the common final goal of a sustainable and satisfactory project. Of the perceptions, those on construction materials are important as it directly links to present day important concerns such as global warming, heat island effects etc. Though extensive research has been carried out on construction materials, the studies are limited on public perceptions on outdoor construction materials. This paper presents the detailed analysis of data collected through a sample of public on their perceptions on the paving materials of outdoor constructions; viz. pedestrian walkways and recreational areas. The methodology included a literature survey to identify the current research status, an on-line questionnaire survey carried out on a sample of public to identify their perceptions and a statistical analysis performed on the collected data. The sample consisted of 149 respondents. Additionally, temperatures were measured on the top surface of selected pavements throughout the day. The outcome of the study indicates clay brick is preferred over concrete and asphalt as the paving material for pedestrian walkways and recreational areas.

Keywords: *Public perceptions, pedestrian walkways, recreational areas, outdoor built environment, paving materials*

1. Introduction

Pedestrian walkways along road sides and recreation areas are two of the prominent outdoor constructions especially in urban areas. In such outdoor constructions the priority received for the viability aspects generally differs from indoor constructions. For example, developers or local authorities seem to be contended by technical and economic viability of outdoor constructions rather than the environmental or user comfort aspects (Scudo and Dessi 2006). Emmanuel and Johansson (2006) claim that urban planners and designers have paid little attention to human comfort in modern outdoor development work. Construction material is one of the important considerations to achieve user comfort. An analysis into the research literature indicates that it is important to develop new outdoor construction materials which are economical, use local raw materials and better suited for contemporary issues such as global warming and urban heat island (UHI) effect in micro climates such as urban open spaces. A preliminary requirement in the development of new materials is to understand the user perceptions on the available materials. This paper presents a detailed analysis of data collected from a sample of public representing a number of cities of Sri Lanka on their perceptions on walkways and recreation areas and the materials used for these constructions.

2. Background

In the recent attempts to modernize the Colombo and other cities in Sri Lanka intense attention has been paid to outdoor constructions, which have become part of everyday life. The following sections briefly present some of the previous research work on the perceptions of outdoor constructions and three artificial materials commonly used in Sri Lanka for such constructions.

2.1 PERCEPTIONS ON OUTDOOR CONSTRUCTIONS

Pedestrian walkways and recreational areas are the most prominent outdoor constructions in the recent city development and modernisation work in Sri Lanka.

Pedestrian walkways: A comfortable environment on the pedestrian pavements makes a journey by foot pleasant and enjoyable. Considerable achievements have been made in this respect with many models and techniques for designing pedestrian walkways around the world. Nevertheless it seems that further attention is warranted during design and planning and also in research to address the issues of pedestrians' safety as well as convenience in our cities. Rahaman et al. (2005) and many other researchers identify safety, security, convenience and comfort as important considerations of roadside walking environment.

Recreational areas: Van der Zee (1990) define recreation as "refreshment of body and mind by activities, or a planned inactivity, undertaken because one wants to do it, without any moral, economical, social or other pressure". Parks and recreation areas are perceived as especially important in urban areas to promote human health and wellness (Garcia et al. 2003).

Additionally, creation of recreation areas in the cities is claimed to have a positive economic impact of the region.

Literature on public perceptions on walkways and recreation areas discuss various parameters; placing of the walkways, route length or the travel distance and shade are often perceived to be important in the usage of walkways (Dayaratne 2011; Giles-Cortie 2005). However, previous studies on perceptions of construction or paving materials were not found in the available literature.

Nonetheless it is a well-known factor that these surfaces of outdoor constructions reflect part of the solar radiation received during the day time. The areas built up with heat absorbing materials such as asphalt and concrete disturb the balance of the natural process with elevated temperatures (Rosheidat and Bryan 2007). This phenomenon of elevated surface and air temperatures due to the retention and emission of solar heat from built-up areas is termed as Urban UHI effect. Heat islands are typically created when either the cities grow or are modified by replacing natural land cover with manmade pavements, buildings and other infrastructure (Wan et al. 2012). Development of heat islands is increasingly becoming a highly-complex environmental issue (Grimmond et al., 2010) and the paving material of walkways contributes to the UHI effect.

2.2 PAVING MATERIALS

In the development of new materials it is important first to understand the researched issues of available construction materials. Here we briefly discuss the research findings on technical aspects of the three artificial outdoor paving materials selected in this study; viz. Asphalt, Concrete and Clay Brick.

Asphalt: Asphalt, which has a lower thermal admittance than concrete, heats up more quickly during daytime and cools down rapidly at night. Halwatura and Jayasinghe (2007), Killingsworth et al. (2011) and Wan et al. (2012) have measured the temperature variations on asphalt-paved roads at different geographic locations and agree that asphalt surfaces can act as heated bodies, promoting higher surrounding air temperature during both day and night. The colour of the material plays an important role; the dark asphalt is the most unfavourable material when taking into account its thermal characteristics (Babic et al. 2012). Though the initial cost of Asphalt sidewalks are low, they are more susceptible to damage from weather and normally require more maintenance, increasing their economic cost over time (Mendoza et al. 2012).

Concrete: Concrete is considered consistent, durable and economic and hence it is the most common type of walkway worldwide (Mendoza et al. 2012; El Nouhy and Zeedan 2012; Killingsworth, et al., 2011). Among the researched favourable characteristics of concrete pavements compared to asphalt pavements are its better skid resistance reducing accidents and increasing safety (Smith, 2000), its ability to tolerate significantly larger deflections without cracking (Soutsos, et al. 2011) and low temperatures which makes it favourable for using in cities for mitigating UHI effect (Babic et al., 2012).

Further, concrete blocks as paving material has the added advantage of using recycled industrial solid wastes (Sukontasukkul and Chaikaew 2006; Gencel et al., 2012; Ling and Poon, 2014) and construction and demolished (C&D) waste in its production (Poon and Chan 2006). They are mostly used as full or partial replacement of aggregate and/or to improve the engineering properties of concrete. Some examples of these materials are fly ash, silica fume, ground granulated blast-furnace slag, porcelain, and clay masonry (Gadja and Van Geem 2001). Rubber and recycled glass too have been researched in making concrete blocks (Sukontasukkul and Chaikaew 2006; Ling 2012). Recycled concrete aggregate and crushed clay brick are the C&D waste used as aggregates in the production of paving blocks.

Bricks: Brick is a popular construction material in many countries due to its durability, relatively low cost, availability, sound and heat insulation, fire resistance, adequate resistance to weathering and attractive appearance. Of the two major types of bricks, the conventional burnt clay brick is the mostly used type for construction worldwide, even though its production requires high energy and emits CO2 gas and causes environment pollution (Deboucha and Hashim, 2011; Reo and Kannaujiya, 2014). The alternative type is made with compressed soil (usually ‘laterite’) stabilized with relatively low percentage of cement (Jayasinghe and Mallawaarachchi, 2009).

3. Objectives and the Methodology

The main objective of this study is to find out the perception of people on outdoor development and the materials used for these developments. Pedestrian walkways along the roads and urban recreational area are thus focused in this investigation to understand the user satisfaction level on walkways and materials used. Questionnaire survey is one of the many methods to understand how persons respond to the outdoor development (Kelly, et al., 2011). An on-line questionnaire prepared on ‘Survey Monkey’ platform was employed to elicit the user perceptions on the research objectives. It is particularly designed to understand (a) the user perceptions on the requirement of pedestrian walkways along the roads and on the importance of having better visual identification between pedestrian walkway and the traffic pathway (b) the preferred material for pedestrian walkways and in recreational areas.

The data obtained through this questionnaire survey was statistically analyzed using Chi-Square test for the following null hypotheses.

a) H_{01}: The public preference to have a separate walkway along roads has no association with the fact whether a person is a pedestrian or a driver.
b) H_{02}: The public preference to have visual separation between walkways and roads has no association with the fact whether a person is a pedestrian or a driver.
c) H_{03}: The public preference to have separate areas for recreation is not gender specific.

Further, five pavement construction materials (three artificial - Asphalt, Concrete, Clay Brick and two natural - Soil, Turf) commonly used in Sri Lanka are selected to obtain the public preferences. The preferences of the surveyed sample were analyzed using percentage plots and with the following two null hypotheses tested using Chi-square analysis to draw conclusions.

a) H_{04}: The public preference on paving material on walkways has no association with the gender.
b) H_{05}: The public preference on paving material on walkways has no association with the experience as a pedestrian or a driver.

In the development of a better pavement material, thermal characteristics play an important role. The comfort of a pavement is impacted by its heat emission which is indicated by temperatures. Therefore, the ambient temperature and the temperature variations on the pavement surfaces were measured throughout the day for two materials viz: concrete and clay bricks, using data loggers on sample pavements. Further, public opinion on discomfort times on the urban walkways was elicited through the questionnaire survey. Perceptions obtained with regard to times of discomfort on pavements are then graphically compared with the temperature variations measured on material surfaces.

4. Results and Discussion

The on-line survey was responded by 149 persons with a response rate of 42%. Of this, 5 responses were discarded as they have failed to respond to all the important questions other than demographic questions. The investigation deliberately focused on main cities in Sri Lanka such as Colombo, Gampaha, Kandy, Galle and Kurunegala. Responded sample consisted of both male and female in a ratio of 71% : 29%. The respondents were categorised into five age groups and the majority (84%) was from age group 20-30 years (Figure 1).

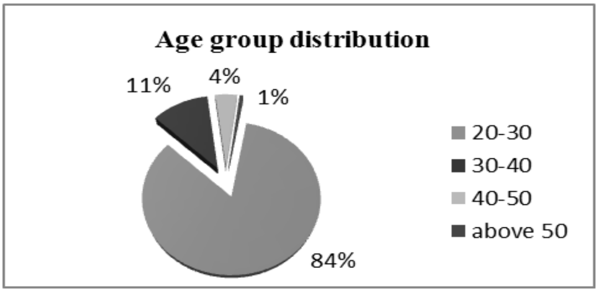
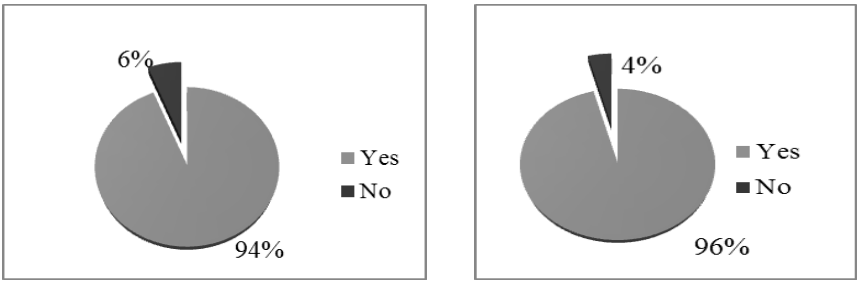


Figure 1, Percentage age group distribution of the sample

The respondents had varying degrees of professions and educational qualifications: 52% were employed and the others were students at tertiary level. The professions of employed respondents included engineers, medical officers, nurses and teachers. Their experiences on the road were three fold; (a) only as pedestrians, (b) only as drivers and (c) with both experiences. For the purposes of this study, the respondents were divided into two groups; those who possess driving experience and those who possess only pedestrian experience whose ratio was 36% (52): 64% (92) respectively.

4.1 PUBLIC PREFERENCES FOR SEPARATE WALKWAYS, THEIR VISUAL SEPARATION AND SEPATARE RECREATION AREAS

Responses were sought to elicit preference for having separate pedestrian walkway along the road and the preference for having visual identification between walkway and the traffic path (road). The analysed results shown in Figures 2(a) and 2(b) indicate that 94% of respondents are in favour of having separate pedestrian walkways and 96% of them wish to have visual identification between pedestrian walkway and the vehicle path.



(a) (b)

Figure 2, (a) separate walkway along the road (b) Visual identification between walkway and traffic path

The three null hypotheses H_{01}, H_{02} and H_{03} formed on the public preference for separate walkways, their visual separation and separate recreational areas were tested using Chi-square tests for the data given in Tables 1 to 3. The Chi-square statistics are shown below the respective table.

Table 1, Association of public preference to have separate walkways with the experience as drivers / pedestrians

Road use / Perception	Driver	Pedestrian	Total
Separation required	51	87	138
Separation not required	1	5	6
Total	52	92	144

Chi-Sq = 1.026, DF = 1, P-Value = 0.311

Table 2: Association of public preference to have visual separation between walkways and roads with the experience as drivers / pedestrians

Road use / Perception	Driver	Pedestrian	Total
Visual Separation required	51	89	140
Visual Separation not required	1	3	4
Total	52	92	144

Chi-Sq = 0.220, DF = 1, P-Value = 0.639

Table 3: Association of public preference to have separate recreation areas with gender

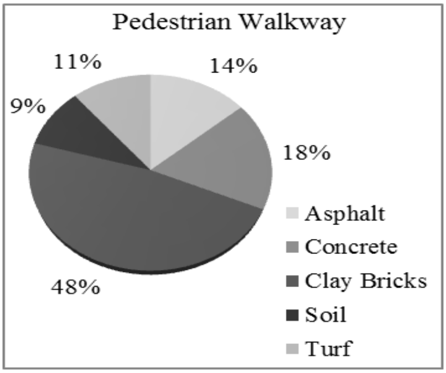
Recreation Area / Gender	Required	Not required	Total
Male	88	8	96
Female	40	2	42
Total	128	10	138

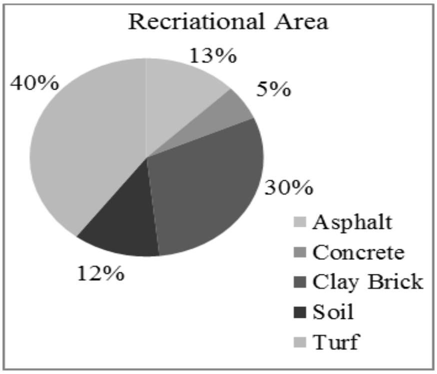
Chi-Sq = 0.554, DF = 1, P-Value = 0.456

For all tests Chi-square values (1.026, 0.220 and 0.554) are less than the table value of Chi-square statistic for degree of freedom 1, (3.84) at 95% levels of confidence and show no evidence to reject the null hypotheses.

4.2 PUBLIC PREFERENCES ON MATERIALS FOR WALKWAYS

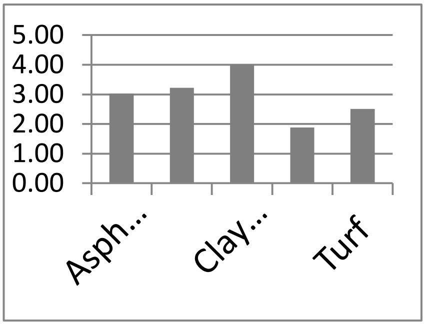
An important aspect of this survey was to obtain responses to understand the preferences among five different materials which are used for pedestrian walkways and in recreational areas, viz; asphalts, concrete, clay brick, soil and turf. Responses were elicited by requesting to rank the five materials in the order of preference of the respondent of their suitability as a paving material first for pedestrian walkways and second in recreational areas. The first preferences converted to percentages are given Figures 3(a) and 3(b) and the weighted average scores (WAS) for the five materials are given in Figures 4(a) and 4(b)

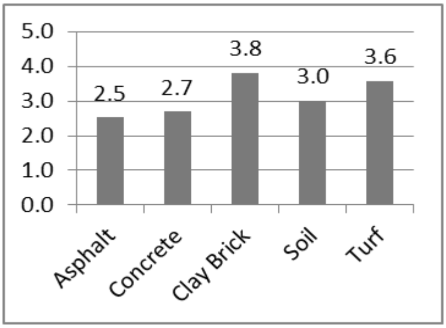




(a) Materials for walkways (b) Materials for recreational areas

Figure 3, Preferred material for walkways and recreational areas





(a) Materials for walkways (b) Materials for recreational areas

Figure 4, Weighted Average preference for paving materials

The survey found clay brick as the highest preferred material with 48% of the respondents placing it as their first choice for pedestrian walkways, followed by concrete, asphalt and turf respectively. In contrast, in the case of recreational areas 40% voted for turf followed by 30% for clay bricks.

Asphalt, soil and concrete were voted less than 13% as paving material. Even if the next best alternatives are considered (Table 4), the highest preferred material is clay brick (WAS = 4.02) and soil was the least preferred (WAS = 1.88) for the walkways on pavements. However, the preferences for the recreational areas showed a remarkable difference where clay bricks, turf and soil were preferred over concrete and asphalt. Further analyses were made to understand the association of gender and road use experience on the public preferences of paving material by testing the two null hypotheses H_{04} and H_{05} for the data presented in Tables 4 and 5.

Table 4: Association of gender with public preference on paving materials

Material / Gender	Asphalt	Concrete	Clay Brick	Soil	Turf	Total
Male	15	14	49	10	15	105
Female	5	12	19	4	1	41
Total	20	26	70	14	16	146

Chi-Sq = 7.999, DF = 4, P-Value = 0.092

Table 5: Association of road experience with public preference on material

Material / Gender	Asphalt	Concrete	Clay Brick	Soil	Turf	Total
Driver	9	4	28	5	6	52
Pedestrian	11	22	40	9	10	93
Total	20	26	69	14	16	145

Chi-Sq = 6.297, DF = 4, P-Value = 0.178

For both tests Chi-square values (7.999 and 6.297) are less than the Table value of Chi-square statistic for degree of freedom 4, (9.49) at 95% levels of confidence and show no evidence to reject the null hypotheses.

4.3 PUBLIC PERCEPTION ON DISCOMFORT TIMES ON WALKWAYS AND THERMAL BEHAVIOUR OF PAVING MATERIALS

The most discomfort times (at one hour intervals from 8.00 a.m. to 7.00 p.m) of the day on public walkways obtained through the opinion survey are compared with the measured surface temperature variations of two paving materials, viz; concrete and clay bricks together with the ambient temperatures (Figure 5). The measurements recorded at the University of Moratuwa premises are considered representative of Colombo city for this study.

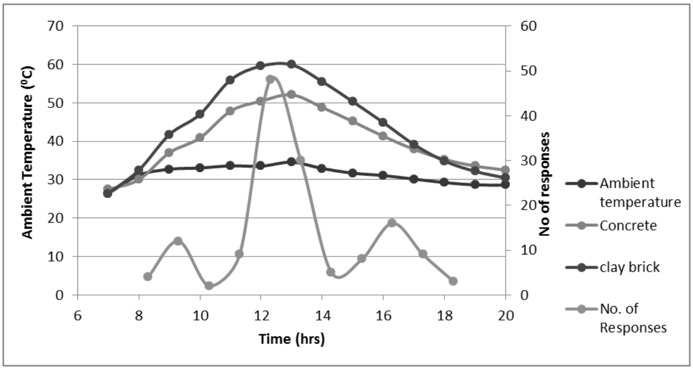


Figure 5, Survey responses on discomfort times with variations in measured ambient temperature and surface temperatures.

4.4 DISCUSSION

The on-line survey responses and their analyses lead to a number of important findings. Among them the first is the Chi-square test results which established that separate pedestrian walkways are preferred by the public irrespective of their experiences as pedestrians or drivers. Second, it is also established that the public preference is to have visual separation between pedestrian walkways and roads irrespective of their experiences as pedestrians or drivers. Thirdly, it is shown that separate recreation areas are preferred by public irrespective of their gender. These three findings emphasize the importance place by the public on separate pedestrian walkways with visual separations as well as separate recreation areas, irrespective of their experiences or gender. Such importance placed by the public warrants investigating into new sustainable and efficient materials for constructing walkways and recreation areas.

The public perceptions received through the opinion survey clearly show the low preference given to soil, asphalt and concrete as construction materials for both walkways and recreation areas. Turf has received mixed preferences with a low preference for walking and a high preference in recreation. In contrast, clay bricks have received the first and the second preferences in both areas indicating any new material developed need to be either based on clay bricks or should closely emulate the positive characteristics of clay bricks.

This paper argues that the public discomfort on walkways mainly arise due to excessive heat emissions from the walkway surfaces. There are also other contributing factors for discomfort such as excessive traffic flow. The expressed perceptions on most discomfort times by the surveyed respondents show three distinctive peaks with one major peak. The major peak coincides with the times where the highest temperatures were observed and this could be attributed to UHI effect as the observed temperatures are even much higher than the ambient temperature. However, a contradiction is observed between the comparatively high heat emission by clay bricks and the high public preference for the same. This aspect needs to be further researched.

5. Conclusions

Separate pedestrian walkways and recreation areas are highly preferred by the public irrespective of their experience as drivers or pedestrians and also of gender. Clay bricks are the most preferred construction material for pedestrian walkways and the artificial material for recreation areas. Therefore, further research in development of new paving materials could either be based on clay bricks or its preferred characteristics. Further, studies are recommended to observe detailed public perceptions on thermal discomfort of walkways and the observed discrepancy between the high heat emission and the high public preference by clay bricks.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 417–432. ©

PLACEMENT OF RAILWAY STATIONS IN URBAN SETTINGS AND THE IMPACT OF LOCATION ON PERFORMANCE OF THE STATION

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Abstract

This research focused on the impact of the city has on the functioning of an urban railway station. Methodology for this study has derived from Node / Place categorization for railway stations introduced by Bertolini, and it has modified to suit the local context. Ten consecutive railway stations along Keleni Valley Line have been selected as case studies after careful consideration. Direct observation, mapping and informal interviews become the main data collection method. Two main performative parameters for railway stations can be derived through incorporating the passenger volume as criteria indicative of a successful achievement. Accordingly the station ability to function as an efficient transport node is considered as a performative parameter and it has been calculated by multiplying the values of 'node index' and number of passenger volume. The second performative parameter is the station's ability in generating diverse urban place. It has been calculated by multiplying the values of 'place diversity index' and the number of passenger volume. From the selected case studies, Nugegoda railway station preformed as the best in both categories followed by Maharagama railway station. Pangiriwaththa station performed as the weakest as a transport node. Considering the perfomative parameter in generating diverse urban place, Udahamulla railway station ranked the last.

Keywords: *City, Railway station, Performance index*

1. Introduction – this is an essential section of the paper

Railway is one of the major transport systems in Sri Lanka and existing railway stations remained in the core of the city's functionality. This research focused on the impact of the city has on the functioning of an urban railway station. All over the world railway stations display a strong co-relationship with the city; the way it functions and also how it has created a public place. Most of the transport nodes in Sir Lanka function only as transit spaces and little social interaction take place in these spaces. It is also recognized that most of transport oriented spaces have no proper linkage with the city and with the surroundings.

Strategic planning authorities of successive governments have identified railway as a sustainable, green and economical mass transportation mode in Sri Lanka. Proposals to extend existing railway network to Katharagama, Palmadulla and Dambulla are already included in the National structure plan for 2030. A study of existing railway stations is timely and will be beneficial for the future establishment of railway stations along the proposed railway lines. It is important to establish the functionality of a railway station to the location and its co-relationship with the city. Spatial and visual forms of public spaces are often discussed in literature, but research on functional performance of railway transport nodes in creating diverse urban public space according to the location is minimal, especially in the local context.

This study attempts to establish the connection between the performance of the railway to the commuters and the placement of station building in the urban context. The research also hopes to contribute to an urban designing solution for station area spatial arrangement and also to an urban planning solution to location of public transport interchanges. It would also be very useful if this study derives a clear classification of railway stations, according to the location and it will be beneficial for the further development of the cities.

1.1 METHOD OF STUDY

The methodology for this study has been influenced from Node / Place categorization for railway stations introduced by 'Spatial development pattern and Public transport' by Bertolini, L. (1999), and has further modified to suit the local context. The percentage of mix-modal passenger transit is considered in this study as the "node index" for the analysis of the performance of the railway station as a transportation interchange. Randomly selected sample of 50 passengers from each station have been interviewed to identify the mode of arrival and departure to and from the railway station.

The percentage of non pedestrian commuter transit has been developed into "node index" represented as*;*

[NQ] α [PT1 + PT 2 + PT3] x 100/2 ; where [PT1] indicates the number of passenger transit to buses, [PT2] indicates the number of passenger transit to privete vehicals and [PT3] indicates the number of passenger transit via three wheeler taxis.

In the analysis of the railway station's performance as generating a diverse urban public place, 'Place index' introduced by Bertolini has replaced by combination of "location index" and "place diversity index" to suite the Sri Lankan setting. "Location index" is derived from the distance to the nearest urban center from the station which is measured through the aid of Google Maps. "Location index" represented as; **[LQ] α [(1000/ (D)],** where (D) indicates the distance to the nearest urban center from the station.

"Place diversity index" indicates the placement of railway station within diverse urban context of different functions and building-use. Survey data and statistics obtained from Urban Development Authority and local authorities together with primary information collected onsite used to compile the building use maps. "Place Diversity index" represented as; **[PQ] α [(N non res B) x (NT)];**Where (N non res B) represented the number of nonresidential buildings in the selected area and [NT] represented the number of different activity types. For this index the selection of the study area is limited to 250m radius from the railway station.

The study proposed to analyse the passenger volume against these three different indexes to review the success of the placement of the railway station. Two main performative parameters for railway stations can be derived through incorporating the passenger volume as criteria indicative of a successful achievement. Accordingly the station ability to function as an efficient transport node is considered as a performative parameter and has been calculated by multiplying the values of 'node index' and number of passenger volume. The second performative parameter is the station's ability in generating diverse urban place and has been calculated by multiplying the values of 'place diversity index' and the number of passenger volume.

1.2 SELECTION OF THE CASE STUDIES

Colombo Fort railway station functions as the main railway hub in Sri Lanka. Three main railway lines, Central Main Railway Line, Coastal Railway Line and Kelani Valley Railway Line radiate from Colombo. Coastal Railway Line was laid parallel to the south western coast and the formation of urban space always limited to the inland direction thus reduced the impact on the city. Hence coastal line was not considered for this study. Central Main Railway Line generates the highest user volume and the main railway stations located in similarly complex urban centers. Kelani Valley line is a single track railway which runs through relatively a compact urban setting and also limited in the commuter volume generation. Considering these facts ten consecutive railway stations along Kelani Valley Railway Line have been selected as case studies.

The Kelani Valley Line was originally built during 1900 – 1902. This line started from Colombo and terminated at Yatiyanthota via Avissawella. By 1912 it was branched off at Avissawella and extended up to Opanayaka. The railway line originally built as a narrow gauge line to serve the rubber plantations in the area. The line between Avissawella and Yatiyanthota was removed in 1942 and the section from Homagama to Opanayaka abandoned in 1973. The services were restarted up to Avissawella in 1978 and in 1992, a project was started to convert the line to broad gauge and completed up to Avissawella (58 km) in 1996. The selected stations are from Cotta Road to Kottawa represented mix of urban and sub-urban settings with varied passenger volumes.

2. Heading Level 1- Format of a typical page and final proceeding book

Heading Level 1 in main text will be in bold 11pt. The page of the final proceeding book measures 170 mm wide by 240 mm high. The text including figures fit into a rectangle of 120 mm by 197 mm. The inside and outside margins of final book are both 25 mm; the top and bottom margins are both 21.5 mm. However, this document is set for A4 paper of which margins are respectively 50 mm and 45 mm.

Left indent when starting a paragraph except the first paragraph of all sections, sub sections etc. There are no footers.

3. Heading Level 1- General paper formatting issues

It is recommended to have at least one paragraph of text underneath each heading. The maximum number of pages should be 12 including images and

Station	Average Daily Commuter Volume
Colombo Fort	
Maradana	
Demetagoda	
Baseline Road	
Cotta Road	1000
Narahenpita	1100
Kirulapona	800
Nugegoda	2900
Pangiriwatta	300
Udahamulla	250
Nawinna	500
Maharagama	1250
Pannipitiya	900
Kottawa	850
Malapalle	
Homagama	

SELECTION

To Awissawella

Fig. 01: Selected Stations along Kelani Valley Railway Line for case study

1.3 SCOPE AND LIMITATION OF THE STUDY

Facilities provided for commuters, proximity to the final destination cost of travel and efficiency of the network are some of the major factors which are not within the scope of this study but encourage public to use the railway transportation.

Catchment area size, quality of space-attractiveness of existing train stations, improvement of connectivity with the other functions, the road network and neighborhoods around the station and legibility of railway stations could have been within the scope was ignored for simplification of the study further.

2.0 Case studies

2.1 CASE STUDY ONE: *KOTTAWA RAILWAY STATION*

Fig. 02 Station Platform

Fig. 03: View from the bridge

Kottawa railway station is located in a residential neighborhood in isolation, approx. 500m away from the town center. The station does not have a clear visual connection with the main road or the town center. Most of the users are the residents in the neighborhood. The station is also functionally isolated within the surrounding.

Fig. 04: Distance between Kottawa station and the city.

Source: Google earth

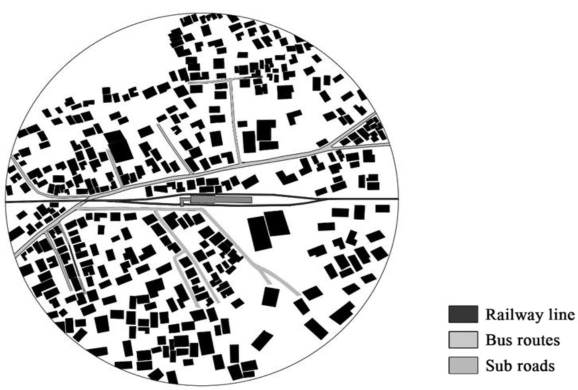
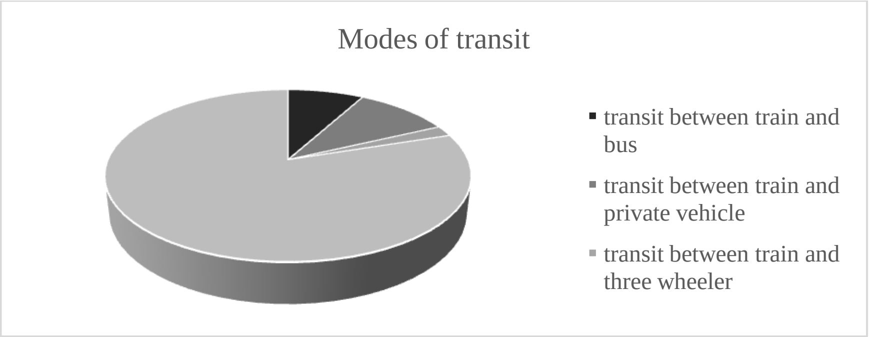


Fig. 05: Kottawa station and the surrounding neighborhood.

There is no direct access from the bus to the railway station and other sub roads leading towards the railway station come from residential areas.

- Daily passenger volume of the station – 850



NODE INDEX

[NQ] α [PT1 + PT 2 + PT3] x 100/2

[NQ Kottawa] α [(4/50) + (5/50) + (1/50)] x 100/2

[NQ Kottawa] α [20]

Fig.06: Modes of transit in Kottawa railway station

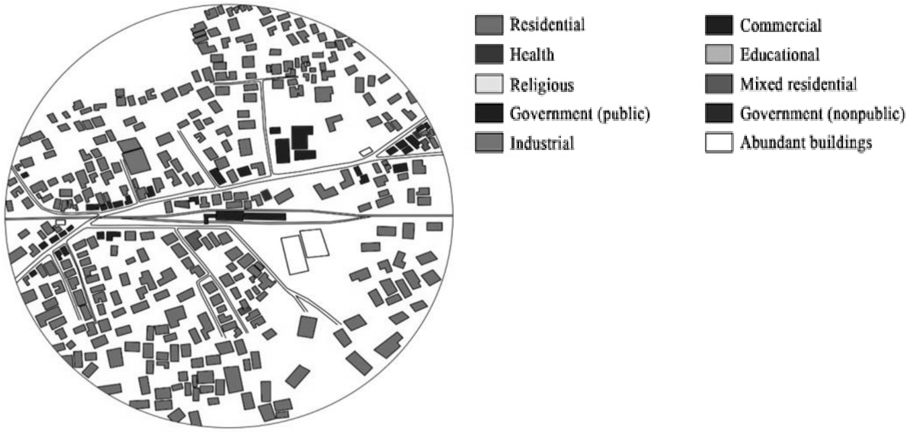


Fig. 07: Building use pattern within the 250m radius area of Kottawa railway station

Within the study area most of the buildings are residential and they have a small amount of commercial building and the surrounding functions did not affect to the functions of the railway station.

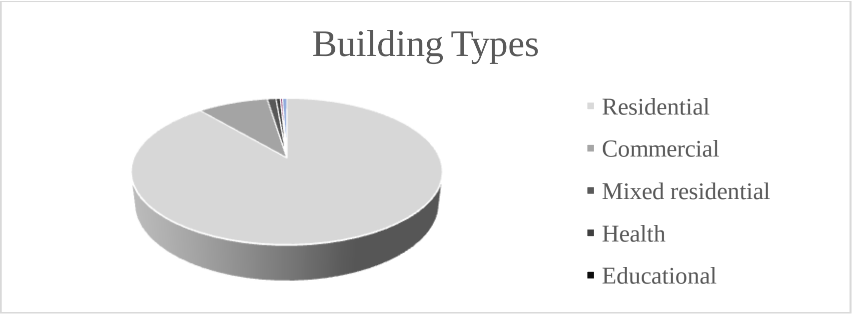


Fig. 08: Building use variation in Kottawa railway station area

PLACE DIVERSITY INDEX;

[PQ] α [(N non res B) x (NT)]
[PQ Kottawa] α [41 x 6]
[PQ Kottawa] α [246]

LOCATION INDEX;

[LQ] α [(1000/ (D)]
[LQ Kottawa] α [1000 / 495] [LQ Kottawa] α [2.02]

Even the area has a mixed development; compared to the residential activity the other developments are insignificant. The surrounding functions are not focusing on the station related activities and the station is not highlighted as an important building in the context.

2.2 CASE STUDY TWO: *PANNIPITIYA RAILWAY STATION*

Daily passenger volume of the station - 900

Node Index	[NQ] α [PT1 + PT 2 + PT3] x 100/2
	[NQ Pannipitiya] α [(24/50) + (5/50) + (9/50)] x 100/2
	[NQ Pannipitiya] α [76]
Place Diversity Index	[PQ] α [(N non res B) x (NT)]
	[PQ Pannipitiya] α [120 x 6]
	[PQ Pannipitiya] α [720]
Location Index	[LQ] α [(1000/ (D)]
	[LQ Pannipitiya] α [1000 / 585]
	[LQ Pannipitiya] α [1.71]

2.3 CASE STUDY THREE: *MAHARAGAMA RAILWAY STATION*

Daily passenger volume of the station - 1250

Node Index	[NQ Maharagama]	α	[(34/50) + (7/50) + (3/50)] x 100/2
	[NQ Maharagama]	α	[88]
Place Diversity Index	[PQ Maharagama]	α	[340 x 7]
	[PQ Maharagama]	α	[2380]
Location Index	[LQ Maharagama]	α	[1000 / 150]
	[LQ Maharagama]	α	[6.66]

2.4 CASE STUDY FOUR: *NAWINNA RAILWAY STATION*

Daily passenger volume of the station - 500

Node Index	[NQ Nawinna]	α	[(20/50) + (10/50) + (4/50)] x 100/2
	[NQ Nawinna]	α	[68]
Place Diversity Index	[PQ Nawinna]	α	[108 x 7]
	[PQ Nawinna]	α	[756]
Location Index	[LQ Nawinna]	α	[1000 / 350]
	[LQ Nawinna]	α	[2.85]

2.5 CASE STUDY FIVE: *UDAHAMULLA RAILWAY STATION*

Daily passenger volume of the station - 250

Node Index	[NQ Udahamulla]	α	[(12/50) + (6/50) + (9/50)] x 100/2
	[NQ Udahamulla]	α	[54]
Place Diversity Index	[PQ Udahamulla]	α	[25 x 6]
	[PQ Udahamulla]	α	[150]
Location Index	[LQ Udahamulla]	α	[1000 / 1175]
	[LQ Udahamulla]	α	[0.85]

2.6 CASE STUDY SIX: *PANGIRIWATHTHA RAILWAY STATION*

Daily passenger volume of the station - 300

Node Index	[NQ Pangiriwaththa]	α	[(4/50) + (6/50) + (2/50)] x 100/2
	[NQ Pangiriwaththa]	α	[24]
Place Diversity Index	[PQ Pangiriwaththa]	α	[90 x 6]
	[PQ Pangiriwaththa]	α	[540]
Location Index	[LQ Pangiriwaththa]	α	[1000 / 260]
	[LQ Pangiriwaththa]	α	[3.85]

2.7 CASE STUDY SEVEN: *NUGEGODA RAILWAY STATION*

Daily passenger volume of the station - 2900

Node Index	[NQ Nugegoda]	α	[(23/50) + (8/50) + (5/50)] x 100/2
	[NQ Nugegoda]	α	[72]
Place Diversity Index	[PQ Nugegoda]	α	[245 x 7]
	[PQ Nugegoda]	α	[1715]
Location Index	[LQ Nugegoda]	α	[1000 / 200]
	[LQ Nugegoda]	α	[5]

2.8 CASE STUDY EIGHT: *KIRULAPONA RAILWAY STATION*

Daily passenger volume of the station - 800

Node Index	[NQ Kirulapana]	α	[(3/50) + (10/50) + (14/50)] x 100/2
	[NQ Kirulapana]	α	[54]
Place Diversity Index	[PQ Kirulapana]	α	[68 x 6]
	[PQ Kirulapana]	α	[408]
Location Index	[LQ Kirulapana]	α	[1000 / 1540]
	[LQ Kirulapana]	α	[0.65]

2.9 CASE STUDY NINE: *NARAHENPITA RAILWAY STATION*

Daily passenger volume of the station - 1100

Node Index	[NQ Narahenpita]	α	[(15/50) + (12/50) + (5/50)] x 100/2
	[NQ Narahenpita]	α	[64]
Place Diversity Index	[PQ Narahenpita]	α	[191 x 8]
	[PQ Narahenpita]	α	[1528]
Location Index	[LQ Narahenpita]	α	[1000 / 590]
	[LQ Narahenpita]	α	[1.69]

2.10 CASE STUDY TEN: *COTTA ROAD RAILWAY STATION*

Daily passenger volume of the station - 1000

Node Index	[NQ Cotta Road]	α	[(24/50) + (8/50) + (6/50)] x 100/2
	[NQ Cotta Road]	α	[76]
Place Diversity Index	[PQ Cotta Road]	α	[98 x 8]
	[PQ Cotta Road]	α	[784]
Location Index	[LQ Cotta Road]	α	[1000 / 500]
	[LQ Cotta Road]	α	[2]

3.0 Observations

The selected railway-stations can be classify into, main three groups according to the location and distance to the town center or main commercial hub. Railway in an urban center (eg.Maharagama, Nugegoda) performs differently to a station in the periphery (eg. Narahenpita, Cotta Road, Pannipitiya, Pangiriwaththa, Kottawa, Navinna) or a station in suburban neighborhoods or countryside (eg.Udahamulla, Kirulapana). Table 1 discloses a summary of index values and passenger number for the selected case studies.

Table 1 – Performance of Railway station according to Node, Location and Place Diversity indexes

Railway Station	**Passenger Volume**	**Node index**	**Location index**	**Place Diversity index**
Kottawa	850	20	2.02	246
Pannipitiya	900	76	1.71	720
Maharagama	1250	88	6.66	2380
Navinna	500	68	2.85	756
Udahamulla	250	54	0.85	150
Pangiriwatta	300	24	3.85	540
Nugegoda	2900	72	5.00	1715
Kirullapona	800	54	0.65	408
Narahenpita	1100	64	1.69	1528
Cotta Road	1000	76	2.00	784

Two main performative parameters for railway stations can be derived through incorporating the passenger volume as criteria indicative of a successful achievement. Accordingly the station ability to be function as an efficient transport node is considered as one performative parameter and it has been calculated by multiplying the values of node index and number of passenger volume. The second performative parameter is the station's ability in generating diverse urban place. This has been calculated by multiplying the values of place diversity index and the number of passenger volume.

Table 2 – Performance criteria calculation for the selected railway stations

Railway Station	**Passenger Volume (V)**	**Node index (NI)**	**(V)x(NI) /1000**	**Passenger Volume (V)**	**Place Diversity index (PI)**	**(V)x(PI) /1000**
Kottawa	850	20	17	850	246	209
Pannipitiya	900	76	68	900	720	648
Maharagama	1250	88	110	1250	2380	2,975
Navinna	500	68	34	500	756	378

Udahamulla	250	54	13	250	150	37
Pangiriwatta	300	24	7	300	540	162
Nugegoda	2900	72	208	2900	1715	4,973
Kirullapona	800	54	43	800	408	326
Narahenpita	1100	64	70	1100	1528	1,680
Cotta Road	1000	76	76	1000	784	784

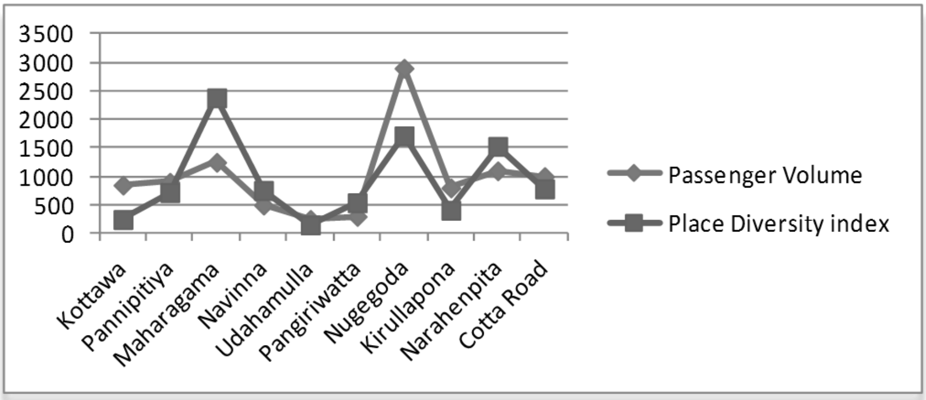
From the selected case studies as indicated in the table 3, Nugegoda railway station preformed as the best in both categories followed by Maharagama railway station. Pangiriwaththa station performed as the weakest as a transport node followed by Udahamulla railway station. Of the perfomative parameter ranking in generating diverse urban place, Udahamulla railway station ranked last behind Pangiriwaththa station.

Table 3 – Ranking of selected railway stations according to the performance criteria

	Performance of the railway station as a transport node		**Performance of the railway station in generating diverse urban place**
1	Nugegoda	1	Nugegoda
2	Maharagama	2	Maharagama
3	Cotta Road	3	Narahenpita
4	Narahenpita	4	Cotta Road
5	Pannipitiya	5	Pannipitiya
6	Kirulapana	6	Nawinna
7	Nawinna	7	Kirulapana
8	Kottawa	8	Kottawa
9	Udahamulla	9	Pangiriwaththa
10	Pangiriwaththa	10	Udahamulla

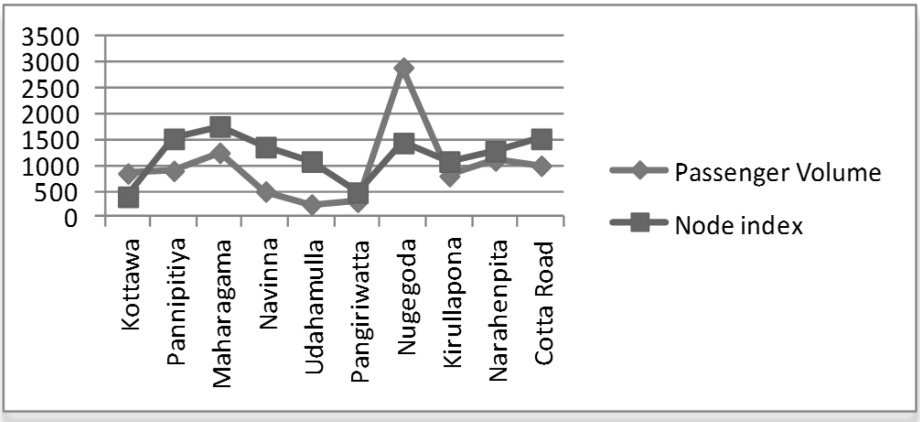
Another important finding is that all three indexes are positively responded to passenger volumes throughout the selected study area which can be observed in charts 01, 02 and 03. As indicated in chart 03, passenger volume is highest in the stations located in the town centers and lowest at the sub-urban areas. Since the railway stations were formation catalyst for these urban centers, it can safely assumed that the variety of urban activities, uses and functions concentrated in the surrounding area, caused the place diversity pattern indicated on chart 01.

Chart 01: Passenger Volume vs Place Diversity index



This study also demonstrated that when stations are well connected with the other modes of transit the passenger volume increases as indicated in chart 02.

Chart 02: Passenger Volume vs Node index



It should be also noted that Kirulapana station has ranked high as a transportation node due to the high demand from commuters to the neighboring Open University premises in Nawala, even though it is located reasonable distance away from the town center.

Chart 03: Passenger Volume vs Location Index

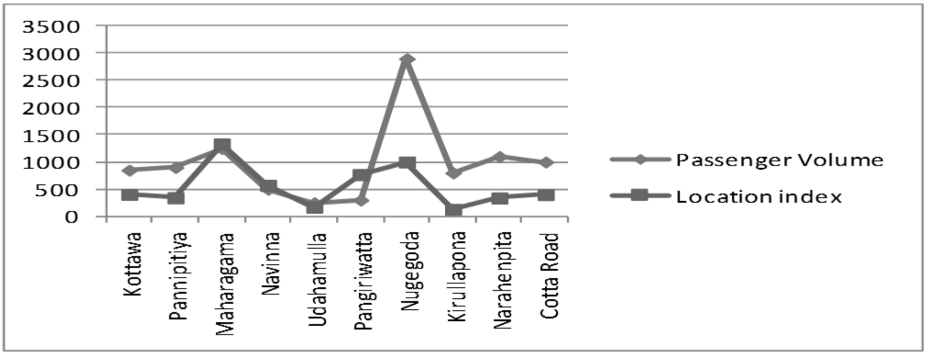
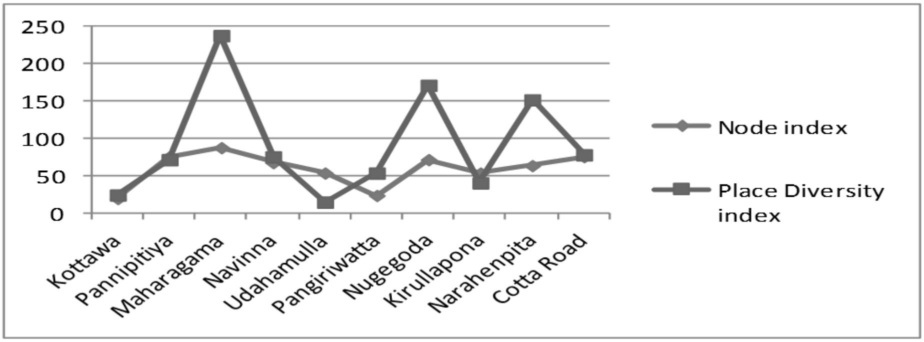


Chart 04: Place Diversity Index vs Node Index



4.0 Conclusion

A railway station placed in an urban center performs differently to a station in the periphery or a station in suburban neighborhoods or countryside. There are many factors to consider when establishing of new railway station or redeveloping of an existing railway station.

When the railway station is located in the city center it has a significant potential to develop as proper “Transport Nodes” and “Diverse Urban Public Places”. When the distance between the railway station and the city increases, it shows the remoteness from the development.

When the cities become smaller the location of the station has a high potential to be, in the periphery of the city. Even though if a station is proposed for the periphery of a city, it should be locate in a place, which has high pedestrian accessibility and also has access through the other modes of transportations. The location should provide incentives and stimulus to the commuters to be at the station, so there should have diversified activities within the immediate surroundings.

Four potentials strategies to mitigate, the frequent inadequacies identified during the research, recommended below, which can be applied during design task for establishing of new railway stations or redevelopment of existing stations.

- Transform the station itself into multimodal hubs including bus station, taxi ranks and car parks. (This strategy focuses on increasing the performative parameter based on the 'Node index' value.)

- To reduce the barrier effect and enhance the visual relationship with the city center. (This strategy focuses on minimizing the effect by 'location index' by increasing the visual proximity.)

- Transform the station itself into multifunctional place including shopping and recreational activities. (This strategy focuses on increasing the performative parameter based on the 'Place diversity index' value.)

- Involve of wider area other than the station itself in the development activities. (This strategy focuses on increasing the performative parameter based on the 'Place diversity index' value.)

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Rajapaksha.U, et al (eds), 2015, “Making built environments responsive”*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka*, pp. 433–446. ©

INTEGRATING UNIVERSITIES WITH THE BUILT ENVIRONMENT PRACTICE AND THE COMMUNITIES IN DISASTER MANAGEMENT EDUCATION

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Abstract

Built environment (BE) practitioners have a key role to play in developing societal resilience to disasters. In doing so, various interactions are needed between BE disciplines and other stakeholders engaged with the disaster management process. Therefore universities conducting courses on disaster management need to consider the needs of these stakeholders in their programme design and delivery. This requires building partnerships between universities, BE practice and other stakeholders engaged in disaster management who are referred to as ‘community’ in this research. Previous research has highlighted the lack of integration between practice, community and university (PCU) in contributing to the societal resilience to disasters and therefore it is very important to strengthen the integration between PCU. Development of such partnerships is a complex task and it is important to identify how PCU integration can take place and how the effectiveness of such integration can be measured. Accordingly, the aim of this paper is to present the initial PCU framework developed as part of an EU funded project, aimed at developing a professional doctorate for disaster resilience in the built environment. The methodology adopted for this research comprises of a literature review and brainstorming. The paper presents several mechanisms to integrate universities with the BE practice and communities in developing meaningful partnerships in the proposed professional doctorate, some of which include, collaborative programme design, delivery, research and supervision.

Keywords: *Disaster resilience; professional doctorate; built environment practice; stakeholders; partnerships*

1. Introduction

Education is one of the key elements in reducing the risk of natural disasters (Shaw et al., 2009). Education builds knowledge, skills, understanding and confidence to, prevent, mitigate, prepare for, respond and recover from the impacts of natural disasters. The importance of disaster education was formally recognised by the Hyogo Framework for Action (HFA 2005-2015) where 'education, training and capacity building' was identified as one of the main pillar of the framework. As a result of ever increasing threats of natural disasters, Sendai Framework for Disaster Risk Reduction (2015-2030) (SFDRR) has re-emphasised the importance of educational measures in reducing the disaster risk and called for "*integrated and inclusive educational measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience*" (UNISDR, 2015).

There is a growing recognition on the Built environment (BE) professions' role in disaster management (Max Lock Centre, 2009, Bosher and Dainty, 2011, Haigh and Amaratunga, 2010), and it is important that they possess relevant professional skills and expertise to strengthen resilience. As such, disaster management education and training is considered essential in making BE professionals more responsive to disaster events (Siriwardena et al., 2013). Education and training on disaster resilience can be provided in numerous ways and SFDRR highlighted the importance of promoting the incorporation of disaster risk knowledge, in formal and non-formal education, as well as in civic education at all levels, as well as in professional education and training (UNISDR, 2015). Hence, it is important that we design educational and training programmes for BE professionals in disaster resilience in order to enhance their capabilities in dealing with disaster related matters.

Education and training for BE professionals are usually provided by Higher Education Institutes (HEIs); vocational education and training providers; built environment professional bodies; construction organisations, and training and development authorities (Thayaparan et al., 2015). Out of these, contribution made by HEIs in enhancing BE knowledge base is widely recognised in practice as well as in the academic literature (Witt et al., 2014, Thayaparan et al., 2015). HEIs mostly offer organised programmes which are recognised by a qualification or part of a qualification and hence the learning opportunities provided by the HEIs are normally classified as formal learning (OECD, 2004). Number of drawbacks yet exists in formal learning opportunities of disaster management provided by HEIs, some of which are, complexity and multi-disciplinary nature of the subject; lack of industry involvement and the lack of research and development activities on disaster management by construction sector professionals (Siriwardena et al., 2013).

In supporting the concept of lifelong learning and in overcoming the above-mentioned challenges, EU funded CADRE (Collaborative Action towards Disaster Resilience Education) project intends to develop a professional doctorate (DProf) in disaster resilience in the built environment. By developing a professional doctorate, it is expected that challenges such as, complexity and multi-disciplinary nature of the subject; lack of industry involvement; and lack of research and development activities on disaster management by built environment professionals, could be tackled successfully (Malalgoda et al., 2015). A key component of the proposed professional doctoral programme is the identification of the relevant parameters, which will help to establish a framework that defines the integration of Practice, Community and University (PCU) within the context of the construction industry to increase societal resilience to disasters. Recognising the fact that interactions among PCU stakeholders is complex, the PCU framework will then identify the nature of the PCU integration which helps the development of the proposed programme, creating the necessary intra PCU feedback and feed-forward mechanisms to enable effective lifelong learning. The dynamic nature of such interactions is complicated; hence it is also necessary to establish measures to monitor the effectiveness of such integration. Accordingly, this 'framework' identifies how such integration should take place, and how the effectiveness of such integration can be measured. Accordingly, the aim of this paper is to present the initial Practice, Community and University (PCU) framework developed as part of the CADRE project.

The methodology adopted for this research comprises of a literature review and brainstorming. The outcomes of the literature review provided a basis for the brainstorming exercise. The framework was developed based on the outcomes of two brainstorming exercises conducted by the project partners. Brainstorming sessions were conducted as part of two organised workshops. Before the start of the brainstorming, initial literature findings were presented to the audience and the ground rules were set. 12 participants attended the first brainstorming exercise and 9 participants attended the 2nd brainstorming exercise. Participants comprised of academics, researchers and representatives of non-government organisations relating to built environment and disaster management.

2. The PCU framework

The need for collaboration between industry and higher education was highlighted by various authors such as Williams (2005), Siriwardena et al. (2013), Thayaparan et al. (2015) and Ozansoy et al. (2009). Since the Lambert Review (2003), there has been a growing debate on the need for collaboration between industry and academia and a huge change in both quantum and quality of such collaborations has been observed (DL, 2012). Williams (2005) argued that the engagement of the construction industry with higher education is critical to the future success of the UK economy and highlighted the importance of aligning teaching, learning and assessment with the requirements of professional bodies, industry and universities. Similarly, Ozansoy et al. (2009), argued that in engineering education university/industry/community projects are beneficial to all parties and useful in helping students to develop work-related skills.

There has been a widespread agreement between academic literature on the importance of developing disaster resilient and management capacities. In supporting academic literature, Sendai Framework has identified the need of enhancing the capacities of relevant stakeholders and industries. Accordingly, the framework suggested to "*build the knowledge of government officials at all levels, civil society, communities and volunteers, as well as the private sector, through sharing experiences, lessons learned, good practices and training and education on disaster risk reduction*" (UNISDR, 2015). The intension of the current research is to address this capacity gaps by developing a professional doctorate in disaster resilience in the built environment. Teaching disaster resilience and management require, multi-sectoral and multi-stakeholder engagement (Thayaparan et al., 2015) and thus, designing and delivery of education programmes catering built environment practitioners require collaboration between all disaster related stakeholders, BE practice and the university. However, Siriwardena et al. (2013) observed a significant lack of collaboration between HEIs, industries, professional bodies and communities in the context of disaster resilience in the built environment. Thus, it is very much important to develop mechanisms to integrate all disaster related stakeholders, BE practice and the university in order to ensure success in the DProf programme development and delivery. Accordingly, a key component of the proposed professional doctoral programme is the identification of the relevant parameters, which will help to establish a framework that defines the integration of Practice, Community and University (PCU) within the context of the construction industry to increase societal resilience to disasters. The initial framework is depicted in Figure 1. The next section elaborates the key components of the framework.

2.1. KEY COMPONENTS

2.1.1 Practice (P)

Construction sector has an enormous role to play, before, during and after a disaster (Bosher and Dainty, 2011, Haigh and Amaratunga, 2010, Ofori, 2004) and as such, it is important that built environment professionals to engage more widely in disaster risk reduction and response and to address the problems of building, infrastructure and land (Max Lock Centre, 2009). Accordingly, in this research, the term ‘practice’ refers to the practices associated within the built environment. According to Max Lock Centre (2009), main practices associated within built environment are, architecture, engineering, planning and surveying.

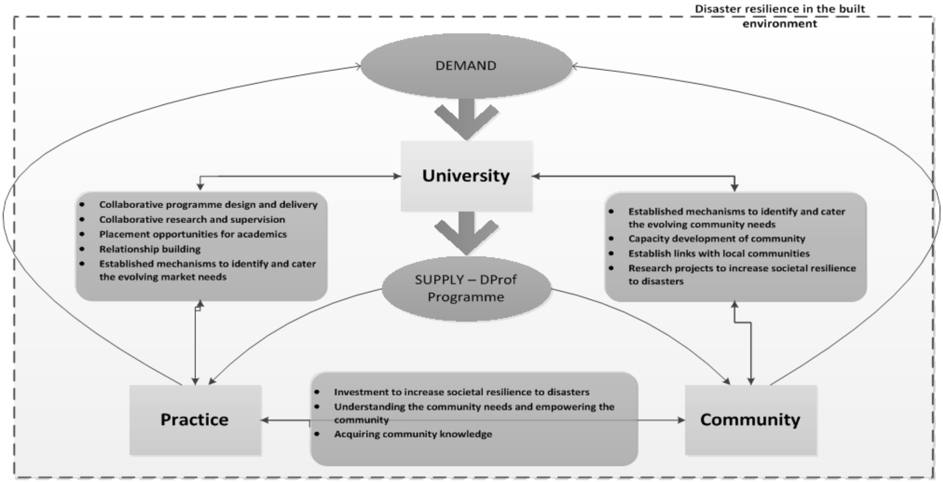
2.1.2 Community (C)

Disaster resilience and management is a complex task which requires numerous efforts of various stakeholders such as; local government decision makers, city officials and departments, central and provincial governments, the private sector, civil society, non-governmental organisations, community based organisations, research institutions and institutions of higher learning (Niekerk, 2007). All these stakeholders engage with built environment practice in increasing societal resilience to disasters. Therefore, with reference to the PCU framework, the term community refers to all these stakeholders except for the research institutions and institutions of higher learning as these stakeholders are separately identified under the category of ‘university’.

2.1.3 University (U)

There are various definitions associated with the term universities. More commonly, universities are referred to as Higher Education Institutes (HEIs). According to the UNESCO (2007), higher education includes ‘*all types of studies, training or training for research at the post-secondary level, provided by universities or other educational establishments that are approved as institutions of higher education by the competent State authorities*’. Accordingly, these institutions are entitled to deliver certificate/ diploma/ degree/ masters and doctoral level awards. Since the current study aims at developing a professional doctorate, the study define universities as an institution which is approved as an institution of higher education by a competent state authority and has the capability and authority to deliver doctoral level programmes.

Figure 1, PCU framework



2.1.4 Demand

Before developing the proposed DProf programme, it is important to improve the understanding of the experiences, needs and expectations of BE practice and community partners. As such, current and emerging demands for disaster resilience and management need to be captured and it is referred to as ‘demand’ in the framework. In this instance, the demand was captured by an extensive primary and secondary data collection and an analysis process. Accordingly, the first phase of research involved, capturing the needs of 5 stakeholder groups associated in disaster resilience and management, as well as current and emerging skills and competencies, applicable to built environment professionals towards enhancing societal resilience to disasters. The primary and secondary data generated a long list of needs and skills with respect to the property lifecycle stages under the respective dimensions of resilience. Finally, the identified needs and skills were combined ‘like-for-like’ to produce broader level of competencies. In parallel an extensive policy analysis was conducted to capture the emerging policy level needs in the disaster resilience in the built environment. Accordingly, it is expected to develop the professional doctorate integrating these needs in order to make it more attractive to the practitioners and to increase the relevance to the community and policy needs. Capturing demand is not a one off task, and this need to be done regularly in order to make sure that all current and emerging needs in the market are considered.

2.1.5 Supply – DProf programme

After capturing the current and emerging needs, the next step is to develop a professional doctorate in disaster resilience in the built environment. Due to shortcomings of the traditional doctoral programmes in addressing the needs of the industry and professionals, professional doctorates have become increasingly recognised (Kot and Hendel, 2012). The UK Council for Graduate Education has defined a professional doctorate as *'a programme of advanced study which, whilst satisfying the university criteria for the award of a doctorate, is designed to meet the specific needs of a professional group external to the University, and which develops the capability of individuals to work within a professional context*' (UKCGE, 2002). Accordingly, it is intended to develop a structured professional doctorate, which reflects how the construction sector and its professionals could contribute in achieving resilience for increasing threats from natural and human induced hazards.

3. PCU integration

Importance of integrating universities, practice and communities were undoubtedly evident in various academic literature (Williams, 2005, Ozansoy et al., 2009, Strier, 2011). However, only little evidence was found in relation to disaster resilience in the built environment. Authors such as Thayaparan et al. (2015) and Siriwardena et al. (2013) have discussed the importance of integrating universities, industries and communities in the construction to develop societal resilience to disasters but none of these were directly related to a development and delivery of a professional doctorate. Nevertheless it is important to analyse existing methods of collaboration in proposing the integrating mechanisms for proposed professional doctorate. Hence this section provides a synthesis of existing mechanisms of integrating, universities, practice and communities.

According to Williams (2005), industry–university collaboration can operate at different levels ranging from individual modules, to entire courses informed or sponsored by industry partners. It is believe that these types of collaboration will help to bridge the gap between supply of graduates and the demand by the industries. Similarly, Ozansoy et al. (2009) have identified industry and community partners as key players of all programmes and courses at Victoria University, Australia and explored the matters related to collaboration of academics and industry professionals in engineering education. Accordingly the authors have discussed about the key roles and responsibilities that the practitioners can play in the design of the courses, facilitation of the projects and the assessment of student learning. Some of the key suggestions were, identifying industry/community partners and engaging them in university programmes, selecting appropriate projects for students with varying backgrounds and capabilities, team formation, developing curriculum to suit changing career needs in the industries, encouraging industry experts to actively participate in teaching, project supervision, facilitation and assessment (Ozansoy et al., 2009). Adding to these, Williams (2005) highlighted the importance of engaging employers in the development of the content and structure of the course. In addition,inviting industry experts for lectures and workshops are highly regarded in educating engineering students (Miau et al., 2001). According to DL (2012), there are good practices in business-university collaborations in degree programme design, delivery and sponsorship which displayed clear advantages for the students, company and university. DProf programmes usually consist of taught and a research components and all of these mechanisms are directly applicable for the design and delivery of the proposed DProf programme where partnerships are sought with the built environment practitioners and all stakeholders related to disaster resilience and management. Another possible engagement strategy proposed by Williams (2005) was by sponsoring students to meet their organisational needs. This strategy is very much applicable to the context of the DProf programme where companies can sponsor their employees to research on a topic, which is of particular interest to the practice. Both companies and universities would benefit from such an arrangement, which facilitate practice-oriented research. As emphasised by Ozansoy et al. (2009) in such an arrangement, industry/community partners can help students throughout their course and can act as mentors together with the academics of the university. Besides, industry/community partners can engage as part of the assessment panel in evaluating the student outcomes. Accordingly it is clear that a PCU integration framework will be a useful tool in ensuring the needs of practice and community are considered in the programmes delivered by HEIs. During the brainstorming sessions, a number of concepts came up on integrating practice, communities and the university within the proposed DProf programme in disaster resilience in the built environment. Accordingly, the next section highlights the main findings of the brainstorming sessions.

3.1. PRACTICE – UNIVERSITY INTEGRATION

This section elaborates the nature of practice and university integration. Number of mechanisms have been identified through brainstorming to strengthen such integration in the proposed DProf programme and are detailed below.

One of the important means of integrating practice and university is via collaborative programme design and delivery. DProf programmes are usually consisting of taught and research components. In terms of taught components, input of practitioners could be sought in identifying emerging market needs in disaster resilience in the built environment; developing and upgrading of curricular and syllabuses of disaster resilience and management; developing teaching materials; teaching; organising industry placements for students; and, assessments and student feedback. Another important means of integrating practice and universities is to organise guest lectures from BE practitioners. In doing so, students can be benefitted from industry specific knowledge and understanding in the point of view of various disaster related stakeholders. They can bring in real life examples and data and therefore this provides a valuable means for universities to formally integrate with the practice and to capture the industry specific knowledge and understanding. Universities can also organise other formal, non-formal and informal learning opportunities for practitioners with the developed modules to enhance their knowledge and skills in disaster resilience and management. As such it is clear that, collaborative programme development and delivery is one of the means of integrating universities and practice.

The next component of the DProf programme is the research component. The proposed DProf programme facilitates students to research on a topic, which is directly relevant and linked to their professional practice. Accordingly, collaborative research plays an important role in integrating universities and practice and provides opportunities for universities to design and implement research activities directly relevant to the professional practice. This provides opportunities for universities to provide valuable contributions to the practice. However, it is important that these contributions are disseminated via appropriate means, which is reachable and understandable to the practice. Moreover, cross university/ practice supervisory teams can be formed in order to ensure high quality research and mutual learning. In integrating practice and universities in developing societal resilience to disasters, it is also important to provide industry specific knowledge and experience to academics. In doing so, industries have to play a vital role in terms of providing career, placement and training opportunities to academics. Accordingly, it is important to build formal links between practice and universities to exchange knowledge and skills.

As explained earlier, universities and practice could be integrated via various methods, such as, collaborative teaching; collaborative research; career, placements and training opportunities; guest lectures etc. All these provide opportunities for the two sectors to collaborate and to build formal relationships. These relationships need to be strengthened via organising various forms of engagement activities, social events and establishing formal links between the university and practice. Commitment of the parties is an important element in sustaining these engagement activities and it is important to ensure mutual benefit. In doing so, it is also important to lay down how these said activities could be sustained in the longer term.

Disaster resilience and management is an evolving discipline, which requires enormous efforts of various stakeholders. On the other hand, practitioner needs are dynamic and evolving, and as a result universities need to establish formal as well as informal mechanisms to capture the evolving needs of the BE practice. Accordingly, within the proposed DProf programme, the universities need to ensure that they are conducting and delivering appropriate teaching and research to cater the dynamic and evolving needs of the practice. It is very clear that universities cannot work in isolation and they require support from the BE practitioners and as a result BE sector needs to get involved with the universities to ensure the effectiveness of this exercise. Accordingly the integration of practice and universities are of paramount importance to identify and cater the evolving needs of the practice.

3.2. COMMUNITY – UNIVERSITY INTEGRATION

This section elaborates the nature of community and university integration. Number of mechanisms have been identified to strengthen such integration in the proposed DProf programme through brainstorming, and are detailed below.

Community represents most of the stakeholders attached to disaster resilience and management including, government, non-government, community and voluntary based organisations, private sector and disaster affected and other vulnerable population. It is obvious that these stakeholder groups have dynamic needs in relation to developing societal resilience to disasters. Accordingly, they expect BE practitioners to possess with required knowledge and skills to fullfill their dynamic needs in relation to disaster resilience in the built environment. Hence, universities are required to capture the needs of the community and consider them in the design and delivery of the proposed DProf programme. In doing so, universities need to establish formal as well as informal mechanisms to capture the evolving needs of the community. Universities need to work with all related community groups to understand their needs and social settings. Accordingly, the universities need to ensure that they are delivering appropriate teaching and research in the DProf programme to cater the needs of various forms of community groups. It is very clear that universities cannot work in isolation and they require support from the community stakeholders and as a result, communities needs to get involved with the universities to ensure the effectiveness of this exercise. Accordingly the integration of communities and universities are of paramount importance in the development of the proposed DProf programme.

Universities can effectively engage in developing capacities of communities. These can be done via organising and facilitating, training programmes, counselling, capacity building workshops etc. and particularly through the proposed DProf programme. By engaging in such programmes, universities can provide an enormous service to communities to better prepare them for future disasters. In doing so, universities will get an opportunity to engage with communities and will be able to learn the community needs and wants and other ground level conditions. These engagement activities in turn would help universities to effectively align the DProf programme to emerging needs of the communities.

Another important way of integrating the community is by establishing links with the local community. Universities can organise public lectures for the local community, which provide an important opportunity to integrate with local communities and community leaders. On the other hand, universities can participate in community level programmes and share their knowledge and experience with the local community. All these will help universities to integrate with the community and to understand what community really wants from the BE practitioners and in turn these will help to align the DProf programme with the needs of the community.

Universities can also integrate with the communities via various research projects. Universities can invest in research which directly address the community needs and which facilitate enhancing the societal resilience to disasters. In conducting these projects, universities will get an opportunity to integrate with various community stakeholders, in preliminary investigations, data collection and research dissemination.

3.3. PRACTICE – COMMUNITY INTEGRATION

This section elaborates the nature of practice and community integration. Number of mechanisms have been identified to strengthen such integration in the proposed DProf programme through brainstorming and are detailed below.

BE practices are expected to invest in disaster resilience and management programmes to increase societal resilience to disasters. Since due to the multi disciplinary nature of the subject, it is of paramount importance to engage communities in such programmes. Communities need to be consulted in advance to identify their needs and wants and the investments need to be aligned with what community really wants in terms of making societal resilience to disasters. In doing so, it provides opportunity for the BE practices to get involved with the community and work together to make more resilient cities and local environments.

Communities need to be empowered to take shared responsibility in coping with disasters. BE practices have to play a vital role in empowering the community, especially the disaster affected population. In doing so, it is very important to understand the needs of the community and to develop their capacities to make them empowered. In terms of capacity building, BE practices can organise, capacity building workshops, provide livelihood support, and, assist them to rebuild the properties etc. In doing so, BE practices get the opportunity to work with the community and to understand their needs and wants. These will facilitate the integration between the community and the BE practice.

On the other hand, during the brainstorming, there was a special attention to the local communities. Local communities are more knowledgeable on ground level conditions and vulnerabilities. As such they are more aware of the local geology, the hazard context, and the livelihood options and therefore they must be involved in disaster management programmes conducted by the BE practices. By engaging communities in such programmes and with community centred approaches, BE practices would be able to acquire local knowledge and to make more informed decisions with regard to enhancing resilience of cities and communities. In doing so, it is very important to promote community participation and to make all the community groups involved in order to make this initiative a success.

4. Conclusions

Paper elaborates how the integration of practice, the communities and the universities should take place in the proposed DProf programme. Accordingly, a PCU framework has been developed as shown in Figure 1. The framework is subject to further refinements as the project progresses. Due to the complex and dynamic nature of PCU integration, it is also necessary to establish measures to monitor the effectiveness of such integration. Accordingly, continuous feedback and feed forward mechanisms are established to ensure the applicability of the professional doctorate to the needs of the BE practice. Accordingly, findings of the labour market needs, skills and competencies are first reviewed by project partners and the steering committee. After the initial refinement, number of stakeholder seminars and validation seminars are proposed to further refine the identified list of competencies. Accordingly, the programme's direct applicability to the needs of practice and communities can be ensured.

5. Acknowledgements

CADRE research project has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use, which may be made of the information contained therein.

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LIFE CYCLE ASSESSMENT FOR HISTORIC BUILDING REUSE: IS EXISTING BUILDING THE GREENEST BUILDING?

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Abstract
Until now, little has been known about the climate change reductions that might be offered by reusing and retrofitting existing buildings rather than demolishing and replacing them with new construction. This life cycle analysis of Bent's house building was carried out as an exploratory study to find out whether preserve historical building will have quantifiable environmental impact beyond the cultural benefit that have been known and agreed by public. This research paper provides a comprehensive analysis to date of the potential environmental impact reductions associated with building reuse using Bent's opera house as a study case. Utilizing a Life Cycle Analysis (LCA) methodology, the study compares the relative environmental impacts and primary energy consumption of historical building, building renovation and new construction over the course of a 75-year life span. Also, this research project illustrates a framework of integrating variety BIM tools in life cycle analysis.

Keywords. *Life Cycle Assessment, Historical Preservation*

1. Introduction – this is an essential section of the paper

Every year, approximately 1 billion square feet of buildings are demolished and replaced with new construction in the United States. The Brookings Institution projects that some 82 billion square feet of existing space will be demolished and replaced between 2005 and 2030 – roughly one quarter of today's existing building stock.1 Yet, few studies to date have sought to examine the environmental impacts of razing old buildings and erecting new structures in their place. In particular, the climate change implications of demolition and new construction, as compared to building renovation and reuse, remain under examined.

Life Cycle Analysis (LCA) is an internationally recognized approach to evaluate the potential environmental and human health impacts associated with products and services throughout their respective life cycles. " LCA requires life cycle inventory (LCI) data for all materials and processes, a life cycle impact assessment (LCIA) method, and a software tool to do the work. LCI data is the inventory of all flows to and from nature due to a product or process – it's a long list of substances and quantities which involves complex considerations in boundary, allocation methods and so forth. The LCIA method translates those flows into environmental impact potential.." 2

2. Approach and Methodology

According to ISO 14040 standards, and LCA is conducted in four phase. "The first phase, goal and scope definition, establishes the boundary conditions of the systems, defines a functional unit for the system, and enables equivalent comparisons with other products or processes. During the second phase, life cycle inventory (LICI), data is aggregated to determine aggregate inputs and outputs. In the case of a building materials study, this is often the quantity of materials used as well as the emissions associated with the production of those materials. In phase three, Life cycle impact assessment (LCIA), the LCI is translated using characterization factors, into impact categories, such as global warming potential. The fourth and final phase is interpretation, where data and results are analyzed to determine areas of relatively high environmental impacts and recommendations are made for improvements to the system. The four phases often occur in an iterative nature." 4 Quite a few LCA tools and software exist that can be used to assess buildings, for example, BEES, ATHENA, Gabi and Simpro. The USGBC has also started to incorporate LCA into their newest version of LEED through pilot credits, including Pilot Credits 1: Life Cycle Assessment of Building Assemblies and Materials and Pilot Credit 63: Materials and Resources – Whole Building Life Cycle Assessment. 5

2.1 STUDY OBJECT DESCRIPTION

Located in the heart of Median, New York, Bents' Opera House stands prominently at the corner of 444 main street and center street. Completed in 1865, the opera house was built from the now famous medina sandstone, which can also be found in places such Havana, Cuba and was used for London's Buckingham Palace. 6 Named after the property's original owner Don Carlos Bent, the Opera House has a rich and varied history. Given the building's name, it follows that the opera house's main feature was historically its performance space located on the third floor. This was home to variety of uses including plays, shows, commencements, elections, and other public functions. The building has also served as a gathering space for the local men's fraternal order as well as a Bank of America branch. Over time the building fell into disuse but is still considered a significant architectural landmark for Medina. In 1995 it was included in the National Register of historic places as a part of Medina's main street historic district. Bents' house has total 4 floors with square footage of 23000.

2.2 LCA BOUNDARY DEFINITION AND LCI INPUT

The boundaries for this study include material extraction, product processing, delivery, demolition and transportation. Benefit and loads beyond the system boundary such as steel recycling was excluded. This LCA include the environmental impacts of Bent's house's building materials and operational expense. Three models have been built: the first model is based on the original material of historical building (no additional thermal insulation were added); the second model is based on keeping original historical building external walls and roof materials with additional thermal insulation; the third model is based on rebuilding entire building with the same square footage, functions and meeting current international green construction code (Igcc code). Building mechanical, electrical, plumbing system is excluded from material calculation since in the original historic building none of those modern systems existed.

Transportation of the building materials to the construction site, construction waste, and materials used for construction itself (e.g., temporary materials) are included. The functional unit of this study is defined as the entire Bent's Opera House. Operational expenditure includes energy spent on heating, cooling, ventilation, water heating, lighting, and others. The major components of the material analysis, ranging from structural elements to interior flooring are included. "Not included in the study were landscaping elements; interior finishes such as carpet tiling and paints were also not included in this study as they represent a small quantity of the building's total mass. Paint and interior finished represented only 2%- 4% of energy and global warming impacts in previous building LCA studies." 7

Figure 1 Building Materials and Assemblies included in LCA

The analysis take a closer look at the initial materials involved with the Bent's house and also account for replacement materials that included in life cycle B6 stage. (refer to figure 4)Material inventory data was obtained through plans and project information provided by Bero architect and site survey conducted by the researcher, including plans, elevations, sections, code analysis and Revit models. Materials were extracted from material schedule in Revit models, then converted into a excel database. The operational expenditure was obtained through benchmarking method based on CBECS(Commercial Building Energy Consumption Survey) building 2003 database. 8 The operational expenditure's measure unit is KBTU/sf-yr.

2.3 IMPACT ASSESSMENT METHOD

The LCIA phase was conducted using the combination of two impact assessment methods. The material side life cycle primary energy consumption is analyzed using Athena IE4B. The Athena sustainable material institute is the pioneer of whole---building life cycle assessment (LCA) in North America. In 3.3 tools and data, IE4B will be explained in details. The operational side of primary energy consumption is assessed using benchmarking method. The benchmark database is CBECS 2003 survey; the sets of data used in the study include offices and public assemblies.

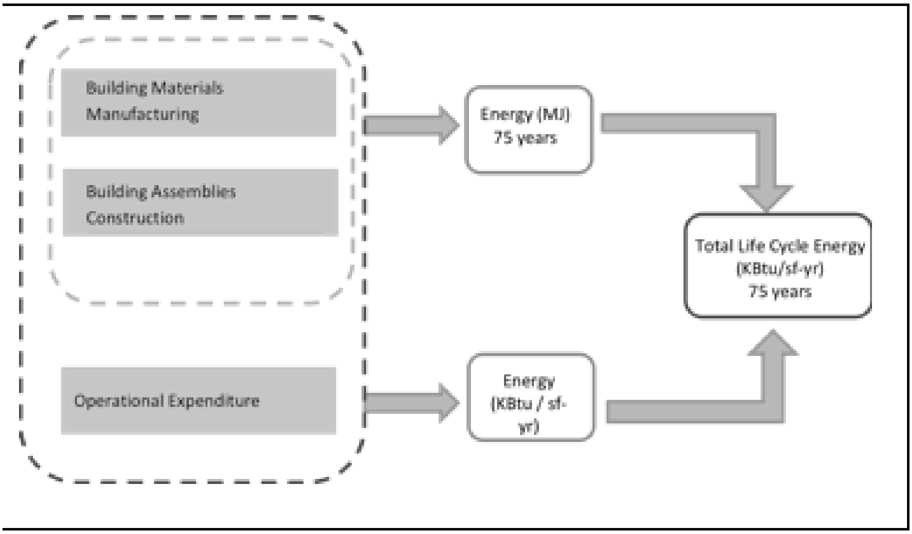

Figure 2 Impact assessment method

The impact assessment categories reported from Athena included global warming, acidification potential, HH particulate, Ozone depletion potential, smog potential, eutrophication potential, energy consumption, air emissions, water emissions, resource use, land emissions. In this study, the researcher focuses on global warming, HH particulate, Ozone depletion potential, smog potential.

3. Goal and Scope

3.1. GOAL

There are no original drawings for the historic building; however there are multiple alterations have been done to the interiors. None of the alternation and renovation is well documented. The base of this study is the survey drawings done by Bero Architect and Revit model reconstructed based on the survey drawings and filed measurement conducted by the researcher. Most building assemblies are based on field assessment. The main outcomes of this LCA study are the establishment of materials inventory and environmental impact references of the Bent’s house. Exemplary applications of these references are in the assessment of future reconstruction or renovation of the historical buildings similar to Bent’s house. Furthermore, the comparisons of environmental impact between preserving historical building with upgraded exterior wall insulation property and reconstructing a new building according to Igcc, can be seen as an essential part of the formation of a powerful tool to help inform the decision making process of policy makers in establishing quantified sustainable development guidelines for future historical buildings renovation, reconstruction and demolition projects.

3.1. TOOLS AND DATA

Two main software tools are utilized to complete this LCA study: Revit model to takeoff the materials and the Athena sustainable materials institute's Impact Estimator for Building (IE4B) to assess the life cycle impact. The materials quantify takeoff from Revit model constructed based on survey drawings and field measurement. Using the physical model, the schedule within Revit extracts the three dimensional data and then materials takeoff schedule has been exported out from Reivt as xcel file. The researcher has to simplify the schedule to edit out the non-useful information and made a clear spreadsheet. The useful data include: external walls, interior walls, columns, floors, roofs, foundations. Then the data have been manually inputted into Athena IE4B.

Using the formatted takeoff data, version 5.0.0125 of IE4B software, the only available software capable of meeting the requirements of this study, is used to generate a whole building LCA model for the Bent's house. Three models were generated based on geometrical information from the same Revit model: 1) The historical building; 2) The renovated version with added insulation in external wall the roof. (The added insulation has a value of R30 on external wall and R40 on roof); 3) New constructed Bent's house.

Table 1 Building Assemblies Included in LCA

Assemblies Makeup			
	Historical Building	Renovation	New Construction
EXTERNAL WALL	Natural solid Sand stone	Natural solid Sand stone with additional fiberglass batt insulation R30	Brick cladding concrete backing with air barrier and fibreglass batt
WINDOWS	Unclad wood window frame double pane glaze no coating air	PVC window fram double glazed no coating air	Fiberglass window grame double glazed sofr coated argon

DOORS	Solid wood door	Solid wood door	Fiberglass exterior door
FLOOR	Plywood decking @15mm with 3.6 kPa	Plywood decking @15mm with 3.6 kPa	Concrete hollow core floor with love load 2.4kPa
COLLUMNS	Softwood lumber with live lad 2.4kPa	Softwood lumber with live lad	Precast concrete with live lad
BEAMS	Glulam	Glulam	Precast concrete
ROOF	Plywood decking @ 15mm without insulation	Plywood decking @ 15mm with R40 insulation and waterproofing	Precast concrete decking with R40 insulation, EPDM cellulose and
FOUNDATION	Concrete @ 200mm with average flyash %	Concrete @ 200mm with average flyash %	Concrete @ 200mm with average flyash %

3.3. BUILDING MODEL

In order to compare preservation, renovation and new construction, three models have been created with reasonable accuracy.

The first step in creating a reasonable building model is to carry out a takeoff of the materials used. The takeoff for Bent's house was based on Revit model we created based on survey drawing provided by Bero Architect. Unfortunately, due the age of the building, many of the actual building assemblies are hard detected, and the researcher made multiple assumptions. The takeoffs for Bent's house were done using scheduling tool in Revit. The area condition is used to compute the surface area and building basic geometry. The count condition is used to compute the number of times the same instance occurs. A few major assumptions were made to complete this project and the assumptions are: the foundation are raft foundation made of caste in place concrete; all floors are same in terms of assembly and load; all columns on all floor are the same.

3.3.1 Columns and Beams

The column and beam takeoffs were completed mainly using Revit count condition. The floor to floor height and live load were taken from

Bero's code analysis document. The supporting span and supported Span are both 4 meter. (refer to table 1)

3.3.2 Floors

All floors within the building are wood trust made of plywood. The surface area of the slab was computed using the area condition in Revit. The computed areas were then convert into rectangular slabs of equivalent surface area with spans of 4 meters and 8 meters as those are close to the IE4B span limits. The length and span of the idealized rectangular slabs were then inputted into the IE4B. A rectangular slab 20 meters by 10 meters results in an equivalent surface. The concrete strength and live load were taken from code analysis document and entered into the IE4B. (refer to table 1)

3.3.3 Roofs

All roof in Bent's house are assumed to be made of plywood as well since we could not get onto the roof top. Decking thickness assume to be 15mm with love load at 2.4kPa, then those date have been manually put into IE4B. Other assumptions include: the bitumen was standard modified, the insulation were not added when the building was originally being constructed.

3.3.5 Walls

The external wall types used in Bent's house are as follows: natural sandstone walls. The lengths of the external walls are calculated by scheduling from Revit model. There are no rebar in the exterior wall. Interior partition wall are excluded from the material takeoff due to the lack of historic documents on interior layout and multiple alternation through the years. The windows for all walls were modeled as being unclad wood window frames double glaze even though many of the windows are, in fact, wood frames. The window schedule in Revit model was used to find the number of windows relate to a specific wall, in the schedule the researcher was able to schedule window counts per each wall. The number of windows was then put in Athena with related square footage of a single window in order to compute the total window area relate to a given wall. Like windows, the number of doors within each respective wall was calculated using schedule function in Revit model, then manually input the data into Athena. Exterior doors were assumed to be solid wood frame door.

3.3.6 Assumptions

It is important to put in perspective that there is some uncertainly related to the accuracy of the Bill of Materials due to the assumptions mentioned in the previous section. Firstly, the roof material and construction is based on the assumption from similar building built around same period since it is difficult to get on the roof without professional equipment. Secondly, the live load is assumption based on the current building code. This might lead to many of the live loads being overestimated. This, in turn, likely led to a slight over estimation. Thirdly, due the lack of choice in Athena, all windows are chosen as double pane which is different from actual single pane glass. This led to overstatement the materials use and environmental impact in the end.

3.4 ALTERNATIVE OPTIONS

After the base building---historic building data has been manually put into Athena, two alternative sets have been created based on the baseline building: Renovated building; New constructed building update 2012 Igcc standard.

In the renovated building version: external wall were added with additional R30 insulation; windows were replaced with fiberglass window frame with double pane glass; roof were added additional R40 insulation; floors, columns and foundation were kept the same as base line building.

In the new construction: external wall were added with additional R30 insulation; windows were replaced with fiberglass window frame with double pane glass; roof were added additional R40 insulation; wood columns have been replaced by precast concrete columns; floors and foundation were kept the same as base line building.

3.5 BUILDING OPERATIONAL EXPENDITURE (ENERGY USAGE)

Benchmarking method has been used to determine the total site energy intensity. The data set is coming from U.S. National CBECS (Commercial Building Energy Consumption Survey) 2003 version; the location is set to has =<2000 CDD, 5500-7000 HDD; size as 0-25000 sqft; operation hour as 0--90 hours/week and building was built before 1920. In order to capture as much as buildings that comparable to Bents' house, during benchmarking, the building type has been set as Administrative/professional office, Bank/other finical, Culture, Mixed-use office, and other public assembly, recreation, social/meeting. Total 19 buildings have been found in the CBECS database with median energy usage intensity (EUI)at 66.7 kBTU/sf---yr. And this number is being used to calculate the total site energy consumption for the historical building in the life span of 75 years. The same benchmarking process has been

4. Results and Findings

4.1 LIFE CYCLE ENERGY CONSUMPTION

The researcher compared the results from the three models with the goal of providing information related to building reuse and renovation benefit. IE4B produce results for the following mid---point impact measures: total primary energy consumption, non---renewable energy consumption and fossil fuel consumption. In this study, researcher only focuses on primary energy primary energy consumption. Total Primary energy consumption is measured in mega---joules (MJ). The primary energy includes all energy, "used to transform or transport raw materials into products and buildings, including inherent energy contained in raw of feedstock materials that are also used as common energy sources." 10 In addition, the impact estimator also includes indirect energy such as processing, transporting, converting and delivering fuel and operating energy.

In general external walls of the historical Bent's house represented the highest total primary energy consumption; nearly accounts for 85% of energy consumed through life cycle stage A through C. The secondary is floors assembly, accounts for 6%. In renovation building, external wall accounts for 78% total primary energy consumption and roof assembly rise to the second, consume 12% of the total energy. In the new construction, the external wall assemblies still rank the first, however it only account for 54% of the total primary energy consumption, all other categories have substantial increase in percentage: Beams and columns assembly rank the second representing 32% consumption; roof assembly account for 8% and it is third highest energy consumption category.

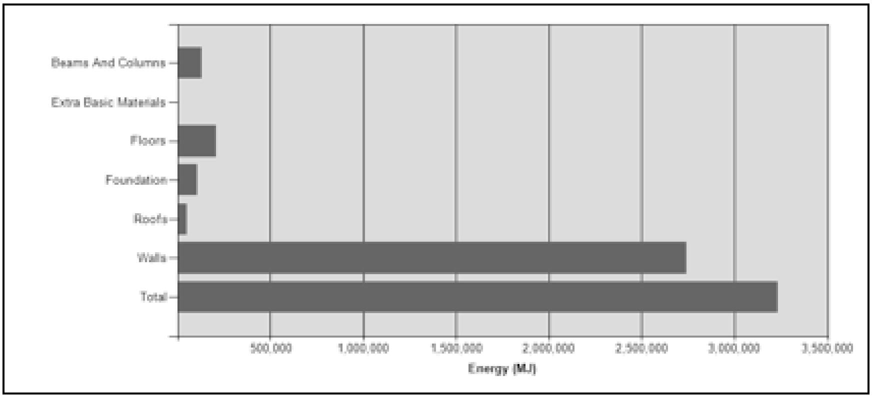

Figure 3 Total primary energy summary for Historical building by assembly groups

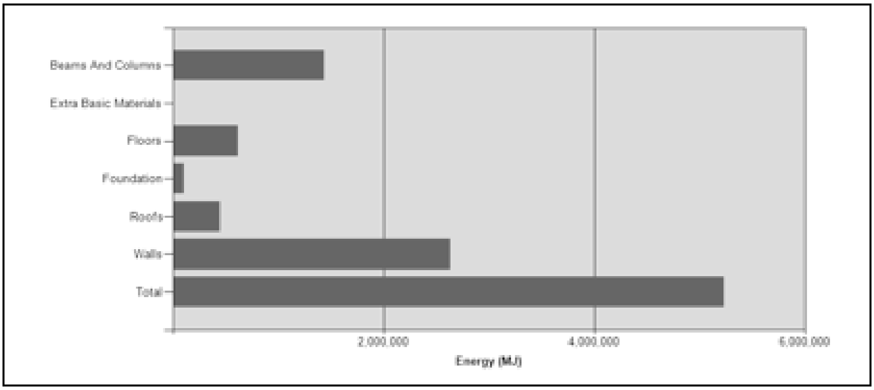

Figure 4 Total primary energy summary for new construction by assembly groups

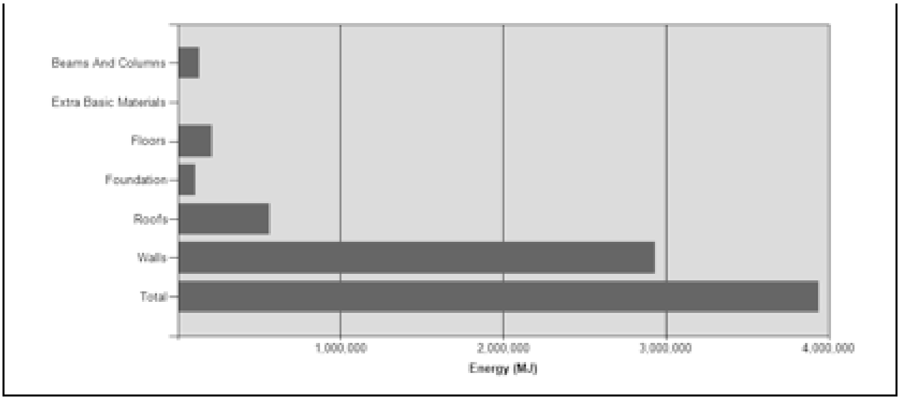

Figure 5 Total primary energy summary for renovation by assembly

And consistently, within material primary energy consumption, operational energy is much higher than embodied energy. In terms of total operational energy(in life cycle stage B6),[11] the historic Bents' house consume almost twice the energy in the entire life span compare to renovation and new construction building. And in the stage A1---A3, the new construction has slight higher energy consumption compare to historic building and renovation building. In IE4B operational energy is refer to B6 stage and include: energy primary extraction, production, delivery, and use. And those usages are only related the building materials and assemblies. We need make very clear the "Material operational energy" is different from "Building Operational Energy Use" which we described in 3.6. "Building Operational Energy Use" includes the energy used to provide space heating, cooling, ventilation, water heating and etc. for the occupancy.

Through the comparison result, the researcher has three major findings: Identifies the operational cost is most important the stage through the entire building material life span in terms of total primary energy consumption.

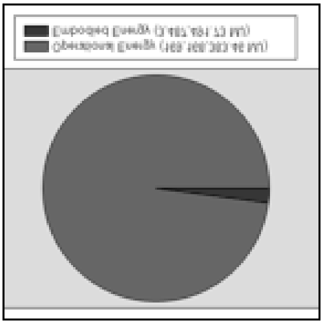
Figure 6 Historic Bent's House

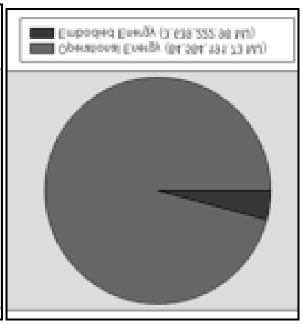
Figure 7 Renovation

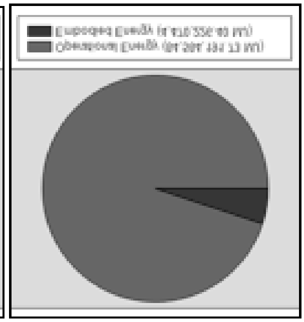
Figure 8 New construction

From stage A-C, historical building has slightly higher material primary energy use in end of life stage C and A4-A5 comparing to renovated building. Beside those stages, historical building has lower primary energy consumption throughout entire life cycle, only 87% comparing to new construction and 97% of renovated building. New construction material has sustainable high primary energy beyond building life span of 75 years that is almost 21 times of historic building. It represents a high waste of new construction materials after the building use life has been terminated.

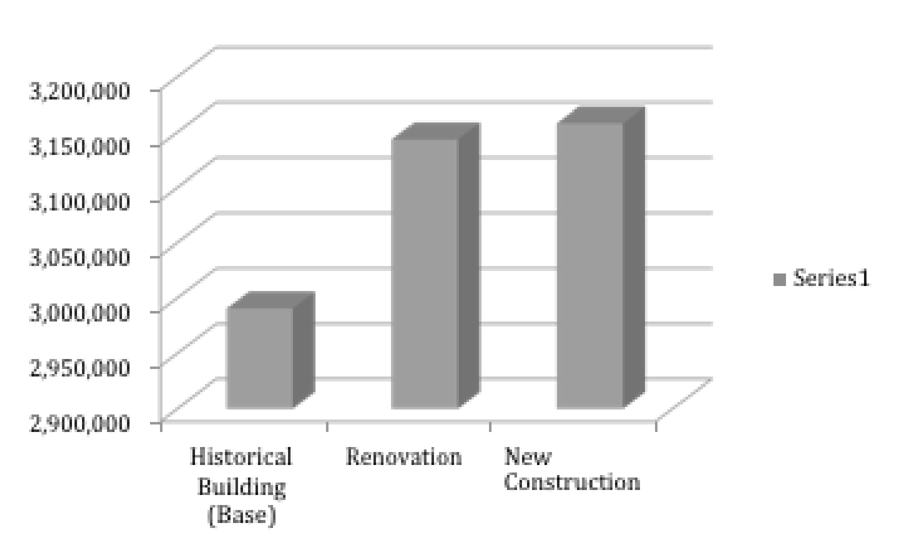

Figure 9 Comparison of Total Primary Energy By Life Cycle Stage

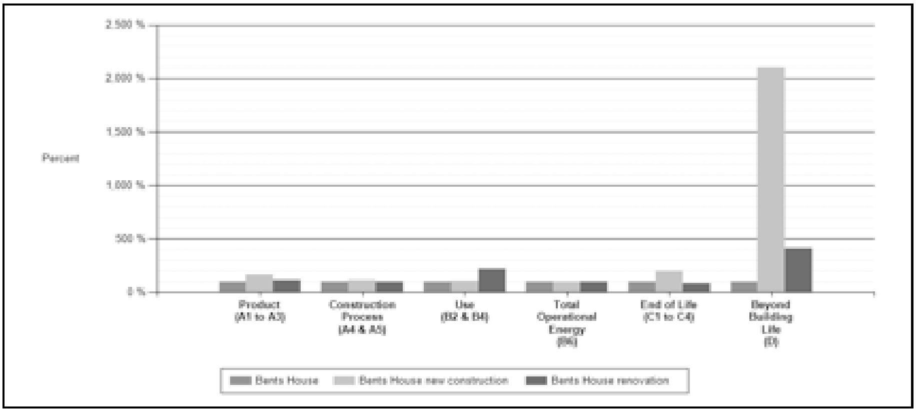

Figure 10 Overall Energy Consumption per year in life span of 75 years

4.1.4 Material primary energy consumption + Building energy expenditure
Due the insufficient thermal properties of historical building exterior building envelope and long heating period in Rochester, NY, historical building consume more building operational energy. However, because of the higher embodied energy embedded in the new construction materials the overall energy usage of historical building is still less than renovated building and new construction.

4.2. LIFE CYCLE ENVIRONMENT IMPACT

In this study, researcher focus on the following mid-point impact measures: global warming potential, human health particulate, ozone depletion, and smog potential. In global warming potential (GWP): New construction has about 1.3 times potential than historic building and 1.21 times than renovation building through A-C life cycle stages. In smog potential: New construction has about 1.45 time potential than historic building and 1.44 times than renovation building through A-C life cycle stages. In HH Particulate Potential: New construction has about 3.0 time potential than historic building and 1.78 times than renovation building through A-C life cycle stages. In Ozone Depletion Potential: New construction has about 1.1 time potential than historic building and 1.19 times than renovation building through A--C life cycle stages.

5. CONCLUSION

This study looked at both embodied energy of major building materials and assemblies and building operational energy consumption in building life span of 75 years in upper state New York. The study was done as the comparison between three different models: Historical, Renovated and New construction. It is important to note the result is consistently: the new construction will have bigger primary energy consumption even though the advanced HVAC system might offset some building energy consumption in operational phase. The assumption is: the longer the building life span and closer three model estimation will become, the payback period of using modern advanced materials in order to reduce operational cost will most likely exceed the building functional life span, that is typical 60 years.

As more and more buildings are target to become more energy efficient, we should not disregard the primary energy of the materials and building assemblies play important role when we decide whether to retrofit or reuse an existing historical building verse demolishing old building and building a new one. Many studies in the past have large focused on operational phase energy, as that building life cycle phase typically dominated analyses. We now need to reconsider the important interplay between building materials and use phase performance to truly design and operate any buildings.

This study analyzed the life cycle environmental impacts of the materials phase of three models: Historic Bents' house, Renovated version and New construction compare the impact results. New construction has more negative impact in all aspects studied in this research: Global Warming Potential, Smog Potential, Ozone Depletion Potential and HH Particulate Potential. Life cycle assessment is necessary aspect for evaluation for building reuse to understand how the embodied energy of materials is allocated during a building's use phase and whether building a new high-performance building could have even bigger and negative environmental impact.

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AN ANALYTICAL STUDY OF THE VALUE OF URBAN OPEN SPACES IN PROMOTING ENVIRONMENTAL IMPROVEMENT AND SOCIAL WELLBEING

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Abstract
According to current projections, more than 75% of the human population will live in cities and urban areas by 2050. This will lead to overcrowding of the cities that will lead to conversion of much needed open spaces to meet infrastructure needs. Loss of urban spaces will contribute to physical inactivity which together with unhealthy diets will contribute to a rapid increase in the non-communicable diseases among the urban populace. Therefore modern cities must incorporate urban parks to provide aesthetic, social, physiological and psychological benefits to urban societies. In Sri Lanka, an initiative has been taken to create urban parks, multi use trails and wetland nature parks to encourage active and passive recreation as well as social gathering. This research project was formulated to test the hypothesis that *"created parks have generated improvement in physical environment such as quality of air and aesthetics and has made an impact on sociological wellbeing of the user community".* The research focused on four open spaces created in Sri Jayewardenepura Kotte, Diyatha Uyana, Parliament green, Japanese friendship road walk path and model paddy field walk path. One environmental parameter, air quality and visitation patterns to these parks were investigated with the aim of identifying level of exposure of the visitors while spending time at these sites and visitor preferences. The air quality of the four sites is well within National air quality standards, especially during the peak use hours of these sites by general public. The parks attract a multitude of users mainly between 29 and 49 years of age. The users show site tenacity based on the type of activity they engage in while using these parks. These parks have positively contributed to social and physical well being of park users.

Keywords : *Urban open spaces, urban health, environment improvement, social well being*

1. INTRODUCTION

The world is undergoing an unprecedented urban expansion and according to current projections more than 75% of the human population will move to the cities and urban areas by 2050 (UN, 2012, UNFPA, 2011). This will be accompanied by an ever increasing demand for urban public services. Further, this will lead to overcrowding in the cities forcing city dwellers to become restricted to minimal spaces for living. In most Third World cities, the enormous pressure for shelter and services has resulted in the conversion of much needed open spaces of the city to dwellings or other facilities. Loss of urban spaces in turn has contributed to physical inactivity of people. Lack of exercise and unhealthy diets are considered to be the main drivers that are contributing to a rapid increase in the non-communicable diseases (Lee et al., 2012), especially among the urban populace.

There is mounting evidence that urban parks provide important aesthetic, social and psychological benefits to urban societies, which enrich human life with meaning and emotions (Arnberger, 2006; Chiesura, 2004; Sugiyama *et al*., 2008; Takano, *et al*., 2002). As emphasized by McRobie (2000) and Christiansen, *et al*., (2001), urban parks, designed primarily for recreation can provide enormous benefits to the community by improving health, social well-being and enhancing enjoyment of the local environment. Similarly, benefits of leisure also cover physical health, psychosocial well-being, self actualization, spirituality, self-identity, family bonding, child development, environmental education and social skills development (Veal and Lynch, 2001). Therefore, multifaceted services of urban open spaces and urban greenery are of crucial significance for the livability of modern cities and the well being of urban dwellers. Also due to its capacity in controlling the effects of Climate change, the role of urban open spaces is been greatly valued and appreciated in the global cities today. Considering these factors, urban regeneration, retrofitting parks and open spaces into cities have come into the forefront of city agendas to promote healthy living and creating healthy cities.

The open space requirement stipulated for Sri Lankan Cities to maintain a healthy environment is 1.4ha per 1000 population. However, majority of the cities fail to meet this requirement. Therefore, an initiative has been taken to transform cities into much more environmentally friendly entities. The pockets of greenery in cities are turned in to urban parks, water front developments, streetscape improvements, multi use trails and wetland nature parks to encourage urban dwellers to engage in active and passive recreation and also social gathering. A study conducted by Marawila and Thibbotuwawa (2010) has estimated that such a newly created urban park, Diyatha Uyana alone attracts more than 100,000 visitors per year with a recreational value of 3,890 million Rupees (UDS 35 million) per anum.

Although these created urban open spaces seems to be successful in attracting large number of visitors with a high recreational value, an attempt has not been made to ascertain whether the anticipated objectives are achieved in the fields of environmental improvement and social wellbeing. While these urban parks encourage people to engage in physical activity, due to their proximity to busy roadways the users may get exposed to air that carries high loads of vehicle emissions. Further, since physical exercise enhance the respiratory rate that may further increase the exposure rate. Accordingly, this research project was formulated to test the hypothesis that ***"created parks have generated improvement in physical environment such as quality of air and aesthetics and has made an impact on sociological wellbeing of the user community".*** The research has focused on the open spaces created in and around Sri Jayewardenepura Kotte at the fringes of Diyawanna Lake. The issues investigated included the quality of air in newly created open spaces, people's perception regarding these urban parks, the emotional dimension involved in the experience of nature and its importance for *people's* general well being.

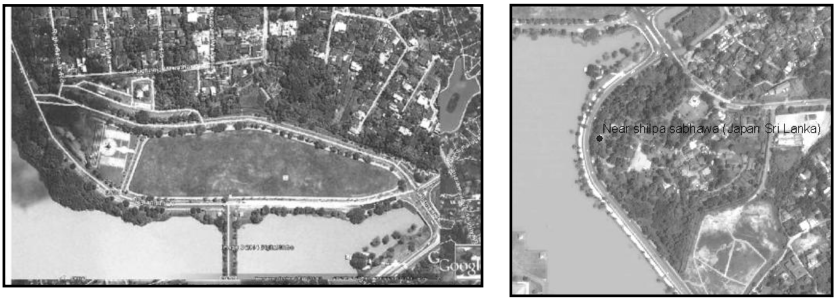
2. METHOD

2.1 *Description of the study area*

Altogether four sites, Diyatha Uyana Park, Model farm Parkway, Parliament Green and Japanese Friendship Road Parkway were selected for this study within the Kotte Municipal Council area. All 4 sites are located in the vicinity of the New Parliament Complex and are waterfront developments. Out of the four sites selected, three have physical links with the water mass of Diyawanna Lake while the other has only a visual connection. Each site contains facilities and picturesque setting which has contributed to their popularity.

Diyatha Uyana Park

Model farm Parkway



Parliament Green   Japanese Friendship Road Parkway

Figure 1: An aerial view of the four sites selected for the study

Diyatha Uyana Park**:** The land area once belonged to the Water's Edge premises and was not open to general public. Since September 2012 the edge of water and a substantial area was opened to the general public. The long paved walkway along the edge of Diyawanna Lake is used by the joggers while ample seating is provided for family outings. The interior section of the wetland accommodates the nature lovers and the artists. The park also has food court, an aquarium and sales centers. Therefore, it can be describes as park that offers a multitude of recreational opportunities.

Model farm Parkway**:** The site contains logging path along the outer periphery of a paddy field. The jogging path is purposefully designed with a level difference to the busy road so that the walkers are relaxed in their own entity. The exercise area opposite the path equipped with colorful exercise equipment is used by all age groups.

Parliament Green: The 13 acre area in front of the Parliament Complex is developed as a parade ground as well as a public open space. The Jogging track along the periphery of the green is approximately 2km long. The boundary of the jogging track is made into tiers so that people could sit and relax under a row of shady trees. A food court is provided across the park along with a parking area.

Japanese Friendship Road Parkway: This parkway is created along the newly constructed Sri Lanka Japan friendship road. The walk path with shady trees is constructed a level below the highway and it has created a much needed buffer from the busy road. This parkway also contains a parking area and the seating and a rest area built on stilts. A restaurant is made available across the parking area.

2.2 Methodology of the study

Two main methods were used, one for the environmental study and the other for the sociological study. The environmental study focused on the air quality of the environment in parks and neighborhoods located adjacent to the park to ascertain the level of exposure of park users to vehicular emissions. Three main parameters, concentrations of SO_2 (Sulphur Dioxide), NO_2 (Nitrogen Oxide) and fine particulate matter (PM_{10}) were measured (Atkinson and Anderson, 2001). A total of 10 permanent sampling locations were selected for the study. These 10 locations were selected based on the level of park usage and the difference in environmental settings. Approximately, a quarter-mile (approx. 0.4km) distance from the edge of each site was designated as the adjacent neighborhoods. This is the widely used distance criteria in the urban park literature to define urban park catchment areas, based on behavioral studies. On site sampling and air quality testing was carried out by the National Building Research Organization (NBRO). The samples were collected weekly and tested in the laboratory of the NBRO.

Active and Passive sampling techniques were used to collect the sampling. At each site passive air sampling devices were installed to measure long term exposure levels. Active monitoring was also conducted at critical locations for short term (1 hr, 8hr and 24hr) sampling to cover peak traffic hours and maximum visitation hours in the parks.

At each location passive sampling apparatuses were installed in an open area with a minimum distance of 3m from ay permanent structure and at a 3m height from the ground level using holding clips. The sealed end caps were removed on site before installing in the samplers. Each set of passive samplers, installed at selected sampling points were collected at weekly intervals for testing. They were sealed with the end caps and were taken to the laboratory for analysis. Samples for the following week were installed at the time of collecting the previous set of samplers. The measurements were carried out during calm wind and cloudless conditions. There were no rains during the sampling period. The sampling was carried out for 24 hrs to ascertain the quality of air with respect to Sulphur Dioxide (SO_2), Nitrogen Oxide (NO_2) and PM_{10} concentrations in a daily basis. Eight hours in the morning, eight hours in the evening and the peak traffic hour were considered.

The results were compared with National Ambient Air Quality Standards stipulated by the Central Environment Authority, of Sri Lanka which is considered as the national air quality standards to ascertain the quality of air in the parks.

For the sociological study a questionnaire survey method was used on a randomly selected sample from all 4 parks. More in depth interviews were done with a selective group of park users through personalized interviews.

In order to get a representative sample of users, 200 questionnaires were distributed among the selected users in each of the locations. Most of them were completed through a face-to-face discussion made between the user and the data collector, and some were filled by the users and was returned later. The questionnaire targeted users on weekdays and weekends as well as mornings, afternoons and evenings to capture temporal variations. Data was directly entered from the questionnaire into the SPSS database for analysis.

The questionnaire contained a series of questions designed to capture the current use of the green space, perceived quality of green space, attitudes to potential green space interventions and finally how these initiatives have influenced their health and wellbeing. Validated existing scales (for health and wellbeing) and questions that have been cognitively tested and demonstrated in the world to conduct such surveys in parks and open spaces were also referenced as a guideline.

The sampling was done using a selective method. The sample was selected to cover all age groups, gender balance and also to obtain a cross section of activities happening in these parks. The survey was conducted among a mix category of respondents from ages 15- 19, 20-24, 25- 34, 35-44, 45-54 and smaller percentage of persons that are more than 55 years of age. *Apart from the semi- structured questionnaire survey, in depth interviews were conducted for a selected group of users to ensure that different age groups, professionals and vendors are captured in the sample.*

3. RESULTS AND DISCUSSION

3.*1* *Air quality of the four selected urban parks*

Four locations (L1 - L4) were selected to for the active sampling to ascertain the concentrations of NO_2, SO_2 and PM $_{10}$ on a daily basis. They were strategically located within the parks and within the neighborhood of parks.

Table 1: Results of the active sampling for air quality

Locations	**SO_2 Conc. μgm/m^3**		**NO_2 Conc. μgm/m^3**		**PM_{10} (μgm/m^3)**
	Observed	Standard	Observed	Standard	
L1 Day 8Hr	23	120	21	150	0.021
L1 Peak 1Hr	82	200	100	250	
L1 Night 8Hr	24	120	23	150	
L2 Day 8Hr	13	120	13	150	0.007
L2 Peak 1Hr	66	200	58	250	
L2 Night 8Hr	8	120	10	150	
L3 Day 8Hr	21	120	25	150	0.027
L3 Peak 1Hr	102	200	149	250	
L3 Night 8Hr	14	120	14	150	
L4 Day 8Hr	7	120	12	150	0.016
L4 Peak 1Hr	43	200	40	250	
L4 Night 8Hr	5	120	15	150	

Sampling locations**:** L1 - Diyatha Uyana (near Min Medura); L2 - Diyatha Uyana (Near the boundary towards Waters edge); L3 - Japanese Friendship road park (Near the Parking area); L4 - Model farm park (Near the Temple)

The results of active sampling indicate that the concentrations of SO_2 and NO_2 are not higher than the values stipulated in the National Environmental (Ambient Air Quality) Regulations as declared in the Sri Lanka gazette No 1562/22, which are the Standard guidelines for Sri Lanka under the Ministry of Environment. At each location peak values were much higher compared to morning and evening hours. Further, SO_2 and NO_2 levels are lowest at the Model Farm park and the section of the Diyatha Uyana facing away from the traffic. The location L3 had the highest values compared to the other three sites as it is located next to a busy intersection (Kimbulawala Junction) which receives a very high traffic flow during peak traffic period. However, the peak time concentrations are still less than the standard concentrations. Active sampling done throughout a period of 24 hours in the four parks and their surroundings, demonstrates that the morning and the evenings had very low concentrations of SO_2 and NO_2 and therefore, the most visited hours to the parks are safe and healthier to use.

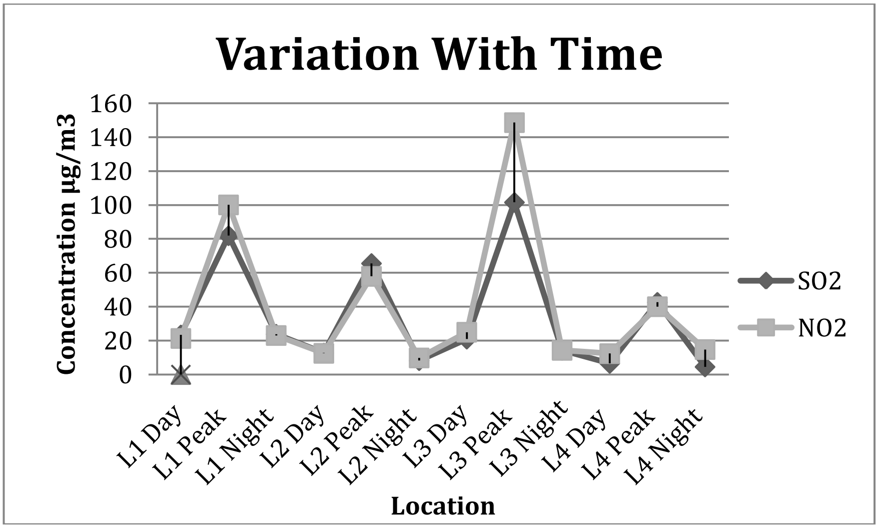


Figure 2: Daily average SO_2 and NO_2 levels (µgm/m^3) observed at the 4 sampling locations.

Passive sampling was conducted at 10 locations in the 4 parks for six weeks continuously to ascertain the weekly concentrations of NO_2 and SO_2 levels. Weekly exposure levels of SO_2 and NO_2 were analyzed to obtain trends and spatial variations. Figures 3 indicates the concentrations of NO_2 and SO_2 at each of the ten sampling location. Each concentration was compared with the ambient air quality standards published by CEA to ascertain the quality of air at the 10 different locations.

Other than the site L3, L7 and L8 the weekly average NO_2 levels were below the permissible air quality standard throughout the study period (Figure 3). Average NO_2 levels showed temporal fluctuations during the study period with some weeks yielding high values. The fluctuations were consistent across the 10 sampling locations. At site L3 and L7 the standard value was exceeded only during one out of the six weeks during which measurements were taken. However the average NO_2 levels at site 8 exceeded the permissible value 50% of the time. All three sites showing high values were located in close proximity to the road while site 8 is located at the Kimbulawala junction where traffic stalls considerably, especially during peak hours resulting in high level of emissions.

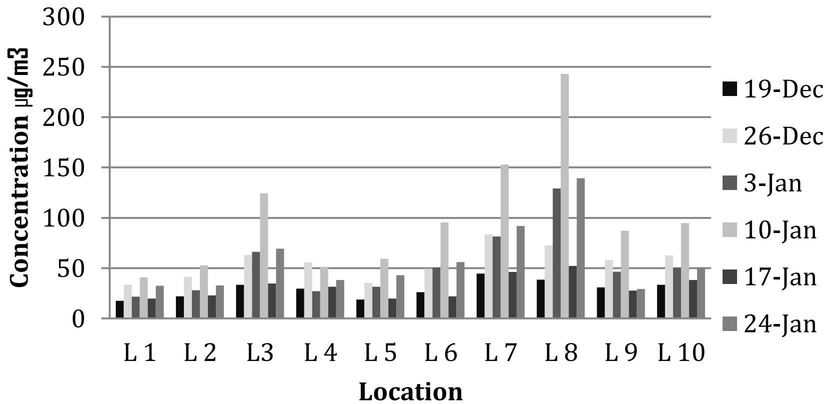
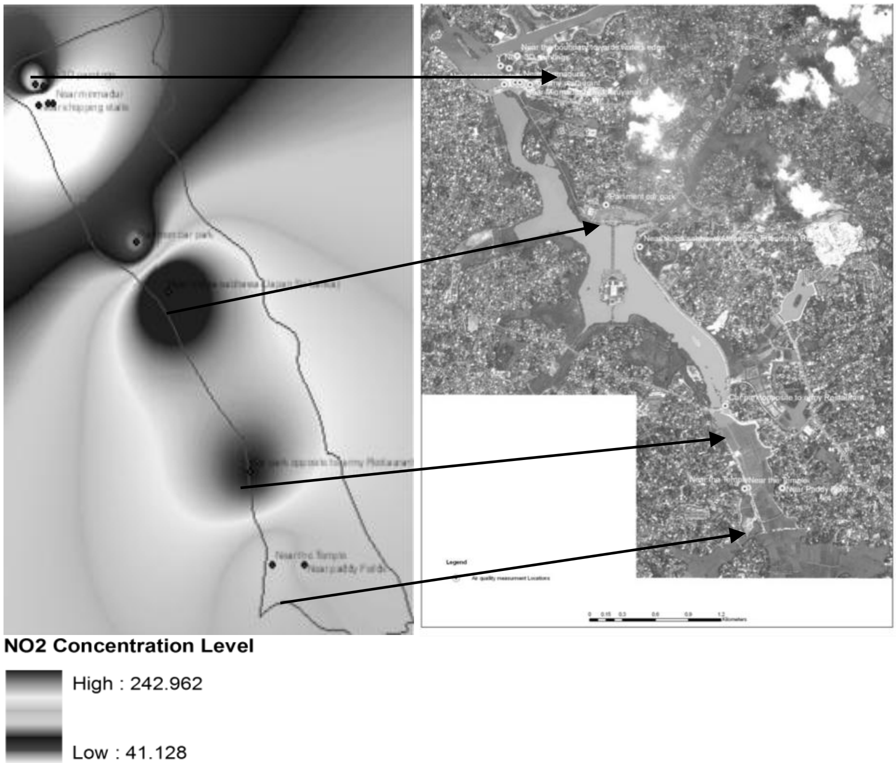


Figure 3: Weekly average NO_2 levels ($\mu gm/m^3$) recorded at the 10 sample locations.

A value greater than 100 $\mu gm/m^3$ will provide a SLAQI (Sri Lanka Air Quality Index) value greater than 100 and therefore will be considered unhealthy. Sampling locations: L1 - Diyatha Uyana shopping area; L2 - Diyatha Uyana boundary with Waters edge; L3 - Diyatha Uyana 3D painted area; L4 - Diyatha Uyana children’s play area; L5 - Diyatha Uyana Min Medura; L6 - Parliament car park; L7 - Japanese Friendship Road; L8 - Car Park at the Kimbulawala Junction; L9 - Near the temple along Kimbulawala-Pamunuwa Road; L10 - Kimbulawala Paddy Field.



Map 9 : Air Quality testing locations in four parks and neighbourhoods

Other than the site L6 and L8 the weekly average SO_2 levels were below the permissible air quality standard throughout the study period (Figure 4). As in the case of NO_2, average SO_2 levels showed temporal fluctuations during the study period with some weeks yielding high values. At site L6 the standard value was exceeded only during one out of the six weeks during which measurements were taken. However the average SO_2 levels at site 8 exceeded the permissible value 50% of the time. Both sites showing high values are parking areas, which are also located in close proximity to the road.

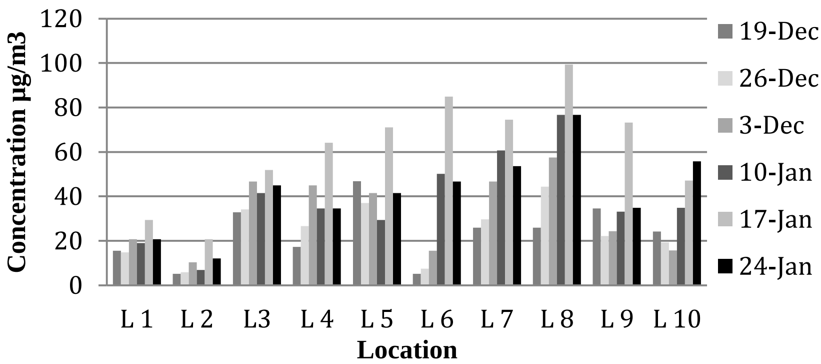


Figure 4: Weekly average SO_2 levels (µgm/m^3) recorded in the 10 sample locations. A value greater than 80 µgm/m^3 will provide a SLAQI (Sri Lanka Air Quality Index) value greater than 100 and therefore will be considered unhealthy. Sampling locations: L1 - Diyatha Uyana shopping area; L2 - Diyatha Uyana boundary with Waters edge; L3 - Diyatha Uyana 3D painted area; L4 - Diyatha Uyana children's play area; L5 - Diyatha Uyana Min Medura; L6 - Parliament car park; L7 - Japanese Friendship Road; L8 - Car Park at the Kimbulawala Junction; L9 - Near the temple along Kimbulawala-Pamunuwa Road; L10 - Kimbulawala Paddy Field.

The SO_2 and NO_2 concentrations at locations which are used heavily are well within the standard concentrations stipulated by the CEA which ensures good air quality for the users. The NO_2 concentration was also mapped graphically to highlight the range of weekly concentrations that persist at the four study sites (Figure 5), which once again shows that Kimbulawala Junction and Japanese Friendship Road park has the lowest air quality with respect to NO_2 concentration.

3.2 Visitation Patterns

This visitor survey indicated that more than 66% of the park users are between 29 and 49 yrs of age (Figure 6). The younger age groups (20 to 29) showed a higher preference towards Diyatha Uyana while the older age groups (40-49) showed a higher preference to the Model Paddy field walk path (Figure 7). This preference was related to the activities they perform during their visitation to these sites. The younger age groups use the urban parks mainly as a meeting place and hence prefers Diyatha Uyana which provides conditions conducive for social gathering while the middle aged group use the urban parks mainly for physical exercise and hence shows a higher preference towards the model paddy field walk path which is ideally suited for this purpose. The Parliament Green is more popular with the adult age groups of 30-39, 40-49 and above 50 (57%). The senior citizens sowed a higher preference to this site as the design of parliament green creates an environment with quiet privacy where they feel safe and content. They also have the ability to interact with their piers while walking slowly along the path or sitting on the stepped tiers when tired. The 50+ group least preferred the Japanese friendship road pathway as it was bordering a road with heavy traffic and a lake on the other side. The visitor survey also indicated that usage of these urban parks by children is very low which may indicate that their participation in physical activity is declining as they are spending their leisure time more on sedentary activities such as watching television or playing computer games.

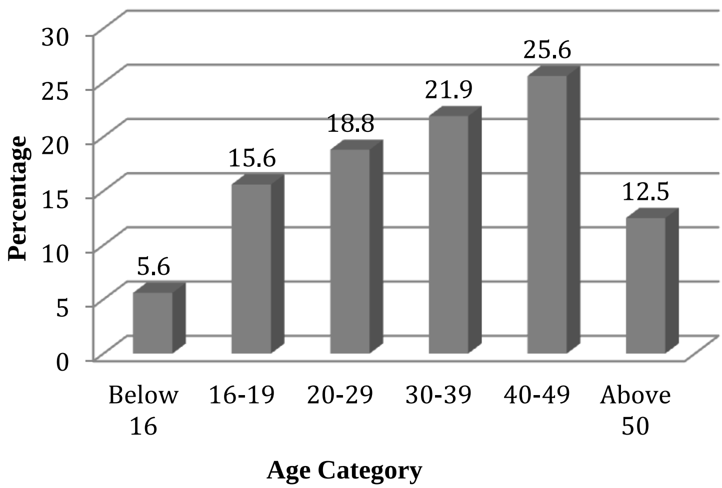


Figure 6: Usage of parks and open spaces by different age groups

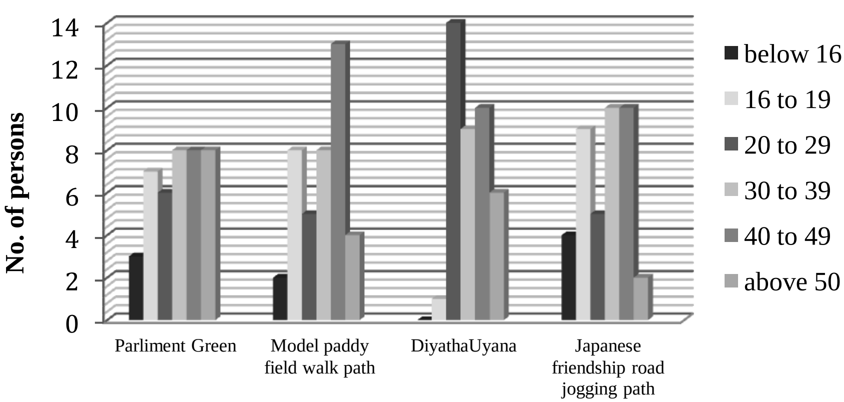


Figure 7: Usage of the four selected parks by different age groups

The visitor survey also indicated that majority of the persons (97%) visiting these urban parks showed a preference towards a specific site while a 3% of the visitors indicated that they use more than one park. The Parliament Green, Diyatha Uyana and Model farm jogging path were equal in preference. Japanese friendship Road park received a lower preference. Japanese friendship park had fewer facilities compared to the other three parks that have food courts, seating etc., facilitating a range of choices which may have contributed to the lower preference shown by visitors towards Japanese friendship road park (Figure 8).

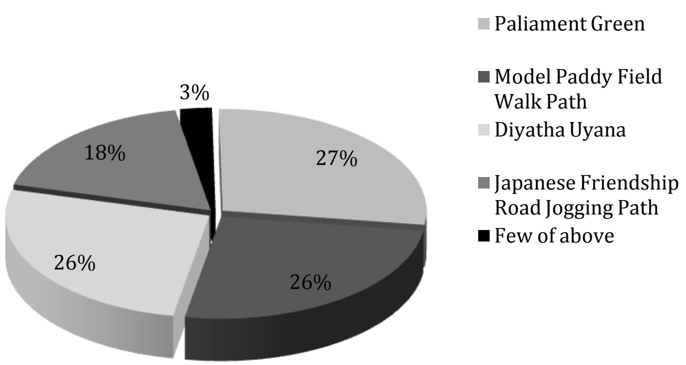


Figure 8: Visitation to parks

Majority of the users choose to visit these parks with friends, followed by children or the spouse. They highlight the fact that the parks have created an environment conducive for people to gather and spend their leisure time (Figure 9).

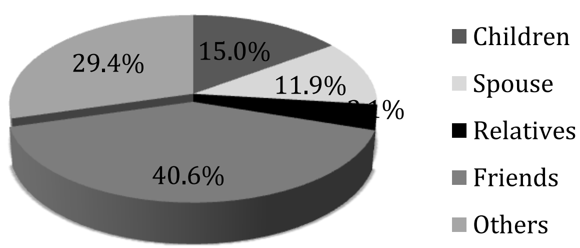


Figure 9: Relationships between park users

4. CONCLUSION

Although the urban open spaces in and around the city of Colombo have been transformed to provide more opportunities for recreation for the urban dwellers, there has not been any concerted effort to evaluate the merits and demerits of this transformation. This study was undertaken to address this knowledge gap and to act as a precedent study to promote similar initiatives in future. Furthermore, it was understood that because of the multifaceted character in these improvements they should be revisited in a multidisciplinary manner to ascertain its success or drawbacks. Although it is needed to investigate on different environmental conditions such as air quality, thermal comfort in the parks to obtain a thorough knowledge on the aspect, the limitations such as the period of study and security constrains the parameter was limited to air quality. Furthermore when considering the type of usage of the open spaces and the segment of population, it was decided that ascertaining the quality of air is the most important parameter when obtaining an idea on the quality of environment.

The air quality data generated from this study indicates that the parks design has taken into consideration the health aspects by constructing car parks adjacent to the roadways and locating the public use areas away from the busy roadways ensuring better quality environment to the user. The urban regeneration efforts commenced recently, focusing on this aspect of maximizing the open spaces and strengthening the green blue integration, has created a sustainable and healthy environment within cities. In these endeavors cities which are blessed with natural environments, rich in biodiversity has an advantage over those who do not. The discussed study area could be considered as a catalyst in such initiatives. The spectacular environment created within the city has not only preserved the pristine habitats, generated more recreational opportunities, but most importantly, has provided a healthier environment for the user community.

The analysis of the results revealed that the senior citizen group of 50+ preferred parliament green mostly, followed by Diyatha Uyana and Model farm walk path while the younger age groups preferred Diyatha Uyana that provides conducive for gathering. This indicates that park design should also take into consider many uses of an urban open space and provide many use opportunities to meet different needs of the user community. All in all the hypothesis tested that the parks have improved the environment and there by uplifted the social well being is supported by the findings of this study. It can be stated that the urban regeneration efforts have been successful in achieving their objectives. The efforts have created a healthy environment and attracted a user population for active and passive use and the user's have given a validity to the regeneration initiatives.

Overall the results of this study will assist in identifying important parameters that needs to be considered at the design stage of open spaces. The findings will also assist the design of open arenas responsive to urban issues such as health and social wellbeing. Therefore, this knowledge can contribute to the sustainable development of cities of the future.

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ADDRESSING HUMAN THERMAL ADAPTATION IN OUTDOOR COMFORT RESEARCH

A Literature Review

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Abstract

Thermal comfort of persons staying outdoors is one of the vital aspects that influence outdoor activities in streets, playgrounds, urban parks, etc. The use of the space is highly affected by the microclimate and for over 60 years many methods have been developed to assess the influence of these climatic parameters on thermal comfort. The influence of thermal comfort on outdoor activities is a phenomena that comprises of both climatic and behavioural aspects. After discovering drawbacks in theoretical thermal comfort assessment models, thermal adaptation aspects have received a great attention in thermal comfort research. This paper presents a review of research over the past years, focusing on the perception of outdoor thermal comfort and the use of outdoor spaces with relevance to thermal adaptation. It is intended to highlight the limitations of current adaptation assessment methods and discuss a possible framework to evaluate thermal environment based on physical adaptation

Keywords: *Outdoor comfort, Thermal adaptation, Behavioral adaptation Outdoor activities*

1. Introduction

Outdoor spaces are important to a sustainable city as they are the spaces that link the public with the urban built context while accommodating daily pedestrian traffic and various outdoor activities. Active and quality outdoor spaces contribute greatly to the livability and vitality of the urban environment and encouraging more people to utilize outdoor spaces would greater benefits to cities in various forms including in the physical, environmental, economic and social spheres. (Hakim et al., 1998; Jacobs, 1972; Santamouris, 2001). With rapid urbanization, cities are increasingly expanding their boundaries to accommodate the extensive number of buildings that have sprung up to cater to the high growth in population; this urban situation can be observed to have adverse impacts on the urban climate. One such identifiable negative outcome is the phenomenon known as the urban heat island (Todhunter, 1990; Oke, 1991) where temperatures in densely built urban areas are higher than the temperatures in the vicinity due to changes in heat balance. According to Population Reference Bureau (2008), half of the worlds' population now live in the cities and therefore are vulnerable to extreme weather conditions in the global context of climate change.

Improved microclimatic conditions benefit the city in various dimensions. People are more inclined to use outdoor spaces when sources of discomfort are controlled. Attracting the public to engage in sedentary activities and to use outdoor open spaces and public walkways by having favourable microclimatic conditions would in turn result in the promotion of such spaces. This would contribute towards the development of a city and the local economy. Clean outdoor environments reflect on indoor environments reducing energy demand and pollutant concentrations inside buildings.

Outdoor thermal comfort in an urban environment is a complex issue with multiple layers of concern, which cannot be limited to certain factors. However, it is one of the factors that influence outdoor activities in streets, plazas, playgrounds, urban parks, etc. The amount and the intensity of such activities are affected by the level of the discomfort experienced by the inhabitants when they are exposed to the climatic conditions in these outdoor spaces (Givoni et al, 2003). The quality of an outdoor space is highly dependent on the thermal comfort of the users of the space. Peoples' sensation of thermal comfort is greatly affected by the local microclimate and becomes a decisive factor when choosing to use the space. As an example, Gehl (1971) in his work, "Life between Buildings: Using public space" studied the influence of microclimate on outdoor activities by counting people sitting on sunny and shady benches. He showed that local sunny or shady conditions significantly affect the desire of people to either stay or leave.

On a hot summer day people staying outdoors exposed to the sun may feel thermal discomfort depending on the combination of the air temperature, surface temperature of the surrounding areas, the wind speed and the humidity level. The discomfort caused may discourage them from utilizing urban parks or outdoor urban areas, whereas the availability of shade may encourage their usage. Similarly, in cold regions, the prevalent wind speed and air temperature, if coupled with extensive shading might discourage people from utilizing open outdoor spaces whereas the provision of sunny areas without wind may encourage public activities.

It is understood that in addition to the climatic aspects of thermal comfort, a wide range of social and physical aspects come into play when people are using outdoor spaces. For example, people often engage in activities outdoors, either alone or with other people, and these activities may have a purpose that becomes the reason to be outdoors. Therefore, the use of outdoor space is not only determined by the state of body, but also by the state of mind. In this situation, assessment of outdoor comfort or the use of space related directly to comfort becomes a complex issue comprising both dynamic and subjective aspects. Dynamic in the sense that adaptation to an ambient thermal condition is progressive, and subjective in the sense that the evaluation of thermal comfort in not always consistent with the measurable climate or the biometeorological condition. Therefore as Chen (2012) has suggested, the ideal framework for thermal comfort assessment should work on at least four levels: physical, psychological, physiological and social/behavioural.

According to Nicol (1990), people take action to improve their comfort conditions by modifying their clothing and metabolic rate and such behaviour are known as adaptive actions. He further described that 'adaptive opportunity', defined as the degree to which people can adapt to their environment, is important for their satisfaction with a space. As Baker and Standaven (1996) explained, when adaptive opportunity is limited, the departure from neutrality causes stress and dissatisfaction.

2. Physical adaptation / behavioural responses in comfort assessment

As stated by Nikolopoulou and Steemers (2003), the term 'adaptation' can be broadly defined as the gradual decrease of the organism's response to repeated exposure to a stimulus, involving all the actions that make them better suited to survive in such an environment. In the context of thermal comfort, this may involve all the processes that people go through to improve the fit between the environment and their requirements. Brager and de Dear (1998) separated the adaptive opportunity into three different processes – behavioural adjustment (physical adaptation), physiological acclimatization and psychological habituation or expectation. Thermal stressors are the impulses that trigger sensations (impacting homeostasis) to prioritize behavioural responses. On this lead, Cabanac (1992) stated that priority is given to any behavioural response that maximises pleasure or minimizes displeasure with minimal regulatory strain. Subsequently, thermal pleasure or comfort is acquired after a successful behavioural response, and will continue until a new equilibrium is reached.

In this paper, behavioural responses or the physical adaptation of people is the main focus as it is a significant factor in adapting to outdoor thermal environment. With the psychological expectations and perceived control over a thermal environment and with the triggered sensations from heat imbalance in the body, people incline to take reactive (change the environmental conditions) or interactive (adjust themselves according to thermal environment) measures to maintain the thermal balance in the body to reduce distress. Since reactive methods are limited in the outdoors due to the larger variation of the thermal environment, people use interactive methods to adapt behaviourally to the prevailing conditions (Wohwill, 1975; Nikolopoulou and Steemers, 2003; Stathopoulos et al., 2004; Walton et al., 2007).

2.1. BEHAVIOURAL/PHYSICAL ADJUSTMENT

Behavioural adjustment includes all modifications a person might consciously, or unconsciously make, which in turn will modify heat and mass fluxes governing the body's thermal balance (Wohlwill, 1975). Brager and de Dear (1998) defined adjustment in terms of three categories: (1) personal adjustment: adjusting to the surroundings by changing personal variables, such as adjusting clothing, activity, posture, eating/drinking hot/cold food or beverages, or moving to a different location. Nikolopoulou and Steemers (2003) identified this adjustment type as "interactive adaptation". (2) Technological or environmental adjustment: modifying the surrounding themselves, when control is available, such as opening/closing windows or shades, turning on fans or heating, blocking air diffusers, or operating other HVAC control, etc. According to Nikolopoulou and Steemers (2003), this method is known as "interactive adaptation", which is more common in indoors. Finally (3) cultural adjustments, including scheduling activities, siestas, adapting dress codes, etc.

Behavioural adjustment of the body's heat-balance probably offers the greatest opportunity for people to play an active role in maintaining their own comfort (Brager and de Dear, 1998). As stated by Chatonnet and Cabanac (1965), behavioural thermoregulation is well developed in man, becomes preponderant, and tends to supplant other forms of thermoregulation. Behavioural adjustment represents an immediate and conscious feedback link, where the sense of discomfort or dissatisfaction initiate the adaptive responses swiftly, and this becomes significantly important in unpredictable outdoor environments.

3. Thermal adaptation in comfort assessment – evidence from field experiments

Studies done by Webb (1959), Nicol (1973) and Humphreys (1975) were the first experiments that identified differences between the results obtained by subjects and theoretical models in indoor environments. Subsequently, many surveys have been conducted using subjects in real environments to relate the thermal sensations on ASHRAE scale to the physical environment (Sharma & Ali, 1983; Busch, 1992; Matthews & Nicol, 1995; Taki, 1999, Nicol, 1999; Bouden, 2001; de Dear & Brager, 1998).

Nicol (2004) reported that the conditions that the subjects found to be comfortable or voted “0” in the ASHRAE scale were different from the predictions of the PMV model, particularly when buildings were not mechanically heated or cooled. Temperatures that were predicted to bring discomfort by the PMV model were found to be comfortable by subjects during in field surveys. Thus, it was concluded that PMV (ISO 7730) overestimates the occupant response on the ASHRAE scale at high temperatures and underestimates it at low temperatures in tropical climates.

The following data of field studies done by Nicol and Humphreys (1973) in indoor environments in UK, India, Iraq and Singapore shows that comfort votes change with the mean temperature that is experienced. From these results, it can be observed that temperatures above 30°C are considered comfortable in some cases.

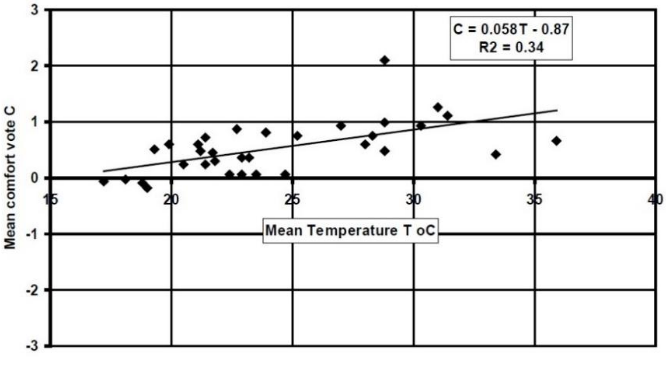

Figure. 01: Mean comfort vote on the ASHRAE comfort scale as a function of mean temperature experienced. Each point is the mean over a whole field survey (Nicol and Humphreys, 1973).

Similar to the differences discovered in indoor studies, discrepancies can also be observed between predicted comfort levels and the subjective votes in outdoor field studies (Nikolopoulou, 2001; Thorsson, 2004; Feriadi and Wong, 2004; Zhang et al., 2007; Lin et al., 2011; Ng and Cheng, 2012; Yahia and Johansson, 2013). It should be noted that early outdoor thermal comfort field studies employed indoor thermal indices such as PMV for comfort assessment (Mayer and Hoppe, 1987; Hoppe and Seidl, 1991).

Work by Nikolopoulou et al. (2001) is one of the first outdoor thermal comfort studies to address peoples' behaviour. In this study done in UK, subjective votes reported that the majority (>80%) of the people were in the comfort range, whereas PMV predicted that only 35% of the subjects were within the comfort levels. Subsequently the study done in 14 different locations in Europe by Nikolopoulou and Lykoudis in 2006 reported a variation of 10°C of neutral temperatures, which they accounted for by recent thermal experience and expectations.

Thorsson et al. (2004) used PMV to investigate the thermal bioclimatic conditions and patterns of behaviour in an urban park in Göteborg, Sweden. Similar to the results obtained by Nikolopoulou in 2001, PMV overestimated the levels of discomfort. It was also concluded that steady-state models such as the PMV index might not be appropriate for the assessment of short-term outdoor thermal comfort.

Physiological Equivalent Temperature (PET) is one of the most widely used indexes in outdoor thermal comfort research. According to the results of a high number of outdoor field studies carried out in hot climates, it is evidenced that subjects have a higher neutral or comfortable temperature range compared to European PET range.

Mahmoud (2011) analysed the microclimatic and human comfort conditions in an urban park in Cairo, Egypt and demonstrated that most landscape zones were thermally comfortable within a range of 22-30°C PET in the hot month and within a range of 21-29°C PET in the cold month.

According to a subjective survey conducted by Lin et al., (2009) people in Taiwan have accepted the PET range of 21°C – 28.5°C as comfortable throughout the year. These ranges are different from the ranges in European countries as stated by Jendritzky et al. (1990), Matzarakis and Mayer (1997). Table 01 shows the difference of the PET ranges for Taiwan and Europe in relation to PMV scale.

The results of the study done by Nasir and Ahmed (2013) proved that the respondents adapted to a higher range of thermal conditions (21.1 - 39.4°C of PET) compared to the comfortable range of PET (18 - 23 °C) in Europe. Almost 70% of the subjects confirmed that they psychologically perceived outdoor conditions more favourably and adapted better to such conditions.

Thus, it is clear that comfortable PET ranges differ from region to region as well as from season to season depending on the climatic condition. Therefore, a constant PET range cannot be directly used in thermal comfort assessment to derive comfort conditions without the human perception of comfortable conditions. All the above studies done in indoors and outdoors reported contradictions between the predicted comfort levels by the theoretical models and actual subjective votes for comfort levels. Thus, it is apparent that none of these short term changes are adequately accounted for in heat balance models (Nicol, 2004). And most importantly thermal steady state between the subject and the microclimate is a rare occurrence in the outdoors.

This lead to emphasise the inadequacy of a purely physiological approach in characterizing comfort conditions outdoors. Besides, these thermal indices are based on thermo-physiology and heat exchange theories which do not take human thermal adaptation into account, which can be identified as a major limitation.

PMV	PET range for Taiwan (°C)	PET range for Western/Middle European (°C)	Thermal perception	Grade of physiological stress
			Very cold	Extreme cold stress
−3.5	14	4		
			Cold	Strong cold stress
−2.5	18	8		
			Cool	Moderate cold stress
−1.5	22	13		
			Slightly cool	Slight cold stress
−0.5	26	18		
			Comfortable(Neutral)	No thermal stress
0.5	30	23		
			Slightly warm	Slight heat stress
1.5	34	29		
			Warm	Moderate heat stress
2.5	38	35		
			Hot	Strong heat stress
3.5	42	41		
			Very hot	Extreme heat stress

Table 01; Physiological Equivalent Temperature (PET) ranges for Europe and Taiwan (Lin and Matzarakis, 2008)

4. Addressing the need of an adaptive approach to assess human thermal comfort – current methods of assessing behavioural adaptation

Recognising the inability of steady state models in accounting human thermal adaptation in comfort research, a large number of studies have been done to incorporate human dimensions into comfort assessment. Primarily these assessments are based on human responses in different thermal environments and were done in both climate controlled chambers and real outdoor environments. Some studies have focused on modeling and assessment methods in a thermo-physiological perspective (e.g.; Gulyas 2006, Lin and Matzarakis, 2008, 2010; Hoppe, 2002, Hwang and Lin, 2010). Other have focused on detailed investigations of the climatic parameters that determine the thermal comfort levels of humans (e.g.; Nikolopoulou & Steemers, 2003; Cheng and Ng, 2006; Spagnolo & De dear, 2003, Walton et al., 2007).

Experiments done in climate controlled environments have shed some light on the physiological and psychological aspects and the results have provided useful information. In most of these studies, links between human thermo-regulation and thermal environment were established to evaluate or rate comfort conditions. (Chung, 2005; Zhang, 2009; Ghaddar, 2011; Parkinson and de Dear, 2015). The issue in these studies is that, whether the results can be used in real outdoor environments with real people who are taking different measures to keep themselves comfortable with the prevailing conditions.

Unlike in climate-controlled environments, capturing all adaptation aspects in real outdoor environments is highly unfeasible due to various reasons. These reasons include factors such as providing wide temperature ranges, controlling human physical/behavioural changes (clothing, activities etc.), measuring skin and core temperatures of people to evaluate thermoregulation, etc.

In this case, obtaining human sensation and preference votes in relation to the thermal environment is the most widely used method in outdoor field experiments. Thermal sensation votes are obtained on an ASHRAE five or seven point scale (-2 to +2 or -3 to +3 respectively) on their perception or the impression of the current climatic conditions. It questions the subject as; “To what extent are you comfortable in this location?” These votes are regressed with environmental variables to derive a comfort model, which is a representation of the climatic parameters (sun, wind, temperature and humidity). Figure 06 shows the basic process of integrating human adaptation aspects in developing adaptive models.

Based on this assessment method, many studies have reported temperature ranges in different regions where people accepted as neutral or comfortable. These neutral temperature ranges describes how well people are adapted to their thermal environment. Certain studies have calibrated steady state comfort models such as PET and UTCI, to derive neutral ranges for those theoretical indices (Lin and Matzarakis, 2008; Spagnolo and de Dear, 2003).

5. Questioning the use of TSV in developing “adaptive” thermal comfort models.

The main drawback identified in the thermal sensation votes is that it does not precisely count any adaptation aspect, but provides an overall picture of the comfort levels. This comfort level can be misleading since people would not be outdoors if the conditions caused intolerable thermal stress. As Hoppe (2002) and Walton et al. (2007) stated, people gain a greater choice of climatic conditions outdoors, and they select to expose to the weather conditions and if it were uncomfortable, they would not elect to do so. People do have a great consciousness about the thermal environment and the responses can be intentional or unintentional to maintain the comfort levels. This situation would not be the same for holidaymakers who would voluntarily expose themselves to extreme conditions, but it is relevant in the day today life, in urban parks or cafes in street corners.

With this issue, a question can be raised on the effectiveness of thermal sensation votes in taking thermal adaptation aspects (especially physical/behavioural adaptation) in to comfort assessment. In many of the field studies done with thermal sensation votes in the outdoors, majority of people have reported to be comfortable or have stated neutral. The following are some examples for the above statement.

Nikolopoulou et al. (2001) reported that, the curves from predicted mean vote (PMV) and actual sensation vote (ASV) showed a large variation. PMV predicted a very low percentage to be in the comfortable zone, whereas ASV reported a large percentage to be comfortable (Figure 02).

Stathopoulos et al. (2004), reported in their study that the overall comfort results were above zero from the subjective votes. It was further mentioned that one of the facts to receive that results is that the residents were capable of adjusting their clothing and activity levels according to the outdoor conditions in order to make themselves comfortable.

Walton et al. (2007) reported that more than 80% of the subjects stated as being comfortable within the central categories of the Bedford scale, in the study done in Wellington

The study done by Nasir and Ahmed (2013) in Malaysia with a total of 438 subjects revealed that 70% of the respondents were in the comfort conditions even if the PET range was higher (Figure 03). PET curve was skewed towards warm range, indicating that people are adapted to higher temperature ranges and that they are comfortable to be exposed to them.

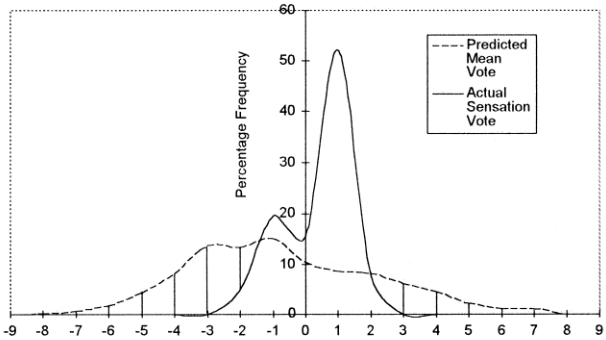

Figure 02: Percentage frequency distribution for Predicted Mean Vote and Actual Sensation Vote. Nikolopoulou eta al. (2001).

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Nicol (2004) stated that the sensation is the “trigger” for subjects to change their own preferences in order to suit the environment, or to change the environment in order to suit themselves. Therefore, with the thermal experience, expectations and perceived control on thermal environments people have acquired the knowledge to adapt themselves appropriately when the thermos-physiology imbalance alarms the sensations.

The method of comfort assessment with sensation votes does not adequately account for physical adaptation or behavioural responses of people. As discussed earlier and with the evidence from the literature, people seem to be more or less adapted to their thermal environment when outdoors. Thus, it is a question if the real influence of the environment on the degree of physical adaptation or the real influence of the thermal environment on human comfort can be derived from this approach.

There is a need of a framework that can account for behavioural changes of people outdoors with respect to the thermal environment in order to evaluate the influence of climatic variables.

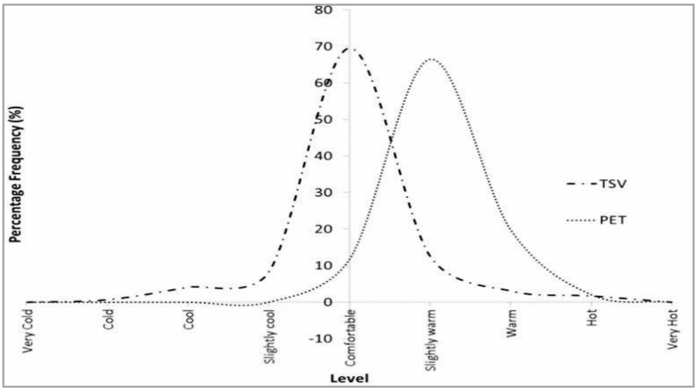

Figure 03: Percentage Frequency (%) on Thermal Sensation Vote (TSV) and Physiological Equivalent Temperature (PET) (Nasir and Ahmad, 2012)

6. Proposed general framework for physical adaptation - creating the adaptive thermal comfort index.

Chen (2012) suggests an assessment framework (Figure 04) to evaluate perceptions of outdoor thermal comfort in terms of human adaptation. This framework consists of four levels that are; Physical Physiological, Psychological and Social/behavioural.

This framework is conceptualized to connect the microclimate with human adaptation aspects or sensations as well as with the utilization of space in both temporal and spatial terms. This framework does not intend to merely capture the sensations but also aims to account for the behavioural changes that people adopt to remain comfortable in a certain location with the availability of changing preferences. Figure 04 shows the outline of the suggested framework. If divided into two sections, the first section consists of static and objective aspects (physical and physiological) that should be measured and modelled effectively to provide "climatic knowledge". The second section consists of dynamic and subjective aspects, which are the psychological and social/behavioural characteristics that require in-depth field interviews and observations to provide "human knowledge".

Following the framework suggested by Chen, the current study incorporates the methodology used by D. Walton, M. Donn and V. Dravitzky in 2007 to develop the comfort model for Wellington, New Zealand. In this methodology, social/behavioural adaptation aspects were accounted effectively to develop the base for thermal environment rating.

Subjective data includes not only peoples' comfort rating/level, but the measures people would take to adapt to the prevailing conditions such as, time of exposure, seating position, clothing levels, expected time of stay, exposure to sun/wind etc. These data is regressed with the statistical approach known as factor analysis to gauge the degree of each behavioural adjustment contributing the main scale score in comfort outdoors. To evaluate the importance of different behavioural adjustments and their influence on the comfort level is expected be revealed from this method. Subsequently, the prominent behavioural changes will be regressed with climatic components in order to derive a rating index of thermal environment based on physical adaptation. As most of the adaptive models, this index will be a representation of the climatic parameters. The major difference of this method is that it is not primarily based on human votes on thermal comfort, but it further questions and analyses peoples behavioural adaptation that lead them to provide the relevant vote on thermal comfort.

The expected outcomes will provide more knowledge on human behavioural adjustment with respect to the prevailing climatic conditions and further could be extended to estimate the seasonal changes as well. It will contribute to the understanding of thermal interactions and acceptance of occupants in dynamic outdoor conditions with respect to environmental stimulus and will supplement the knowledge of thermal comfort assessment. Thus, adding to the understanding of combinations of environmental stimulus that requires minimum adaptation, resulting comfort in outdoor environments will help the designers in planning outdoor environments.

As Givoni (2003) stated, ‘‘In order to evaluate the importance of modifying the outdoor climate in a particular direction by specific design details it would be helpful if the designer would have some means for ‘predicting’ the effect of a particular change in a climatic element on the comfort of persons staying outdoor.” The statement implies how urban design can influence the microclimate of an urban environment as well as peoples’ outdoor thermal comfort and, in turn, how peoples’ thermal comfort can be influenced by their use of outdoor urban spaces. The proposed framework will provide a prominent adaptive rating system of the thermal environment that could be used in spatial planning and design to evaluate the influence of the proposed developments.

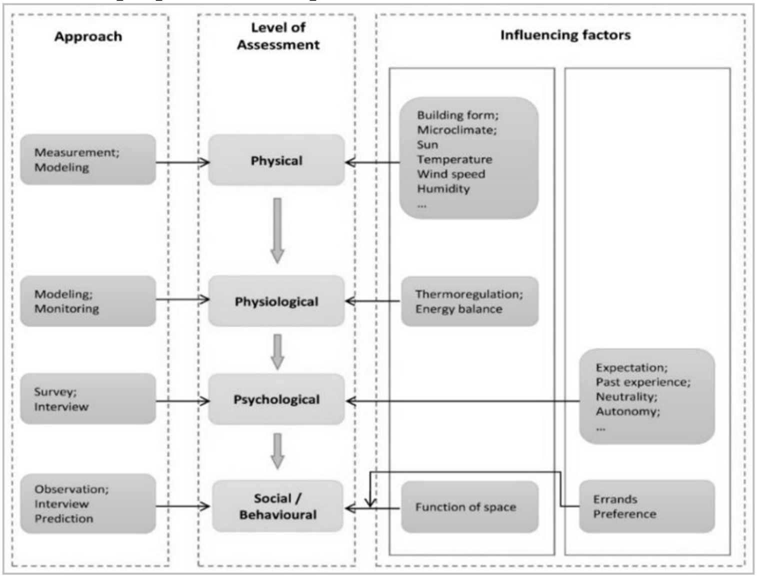

Figure 04: A general framework for outdoor thermal comfort assessment based on behavioural aspects. - Chen. L. (2012).

7. Conclusions and future work

The above review indicates that thermal comfort assessments are both dynamic and subjective. It can be considered dynamic because the adaptation to an ambient thermal condition is progressive and various adaptive aspects primarily affect thermal sensation. It is subjective in the sense that a purely physical or physiological method cannot precisely gauge comfort levels, as it is not consistent with the objective climatic or biometeorological condition.

The use of outdoor space depends on various physical and social factors that affect the perception of people. Thus, the use of outdoor space is not only determined by the state of the body, but also by the state of the mind which plays a major role in influencing peoples' perception on space and utilization (Chen, 2012). Behavioural adjustments play a major role in adapting people to outdoor spaces when the sensation triggers to change the preferences (Nicol, 2004).

The prime objective of the approach is to bridge physical adaptation and behavioural responses of people in the outdoors with thermal environment, in order to develop a rating system for comfort assessment. As future work, this framework can be tested in different regions to evaluate its applicability in a wider climate range. It will enrich the understanding of how people interact with the thermal environment in different regions and climates. Further, prominent outdoor steady state models, such as, PET and UTCI can be calibrated using this adaptive index for different clime.

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SEATING AS A CULTURAL EXPRESSION: A CRITICAL READING OF SEATING IN NON-SECULAR BUDDHIST CONTEXTS IN COLONIAL SRI LANKA

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Abstract
Objects used to assist posture were associated with socio-cultural values of social status and hierarchy as well as cultural values ever since man began to utilize objects for functional purpose. The colonial Sri Lanka is characterized by emergence of new social categories, culture and identity. The mingling of traditional caste with a new concept of class and role played by newly introduced Christianity was crucial in this regard. These social changes resulted in a change of perception towards material objects creating a seminal change from the earlier practices built upon Buddhist culture. Accordingly, this article examines how seating used for preaching in Buddhist context changed with this socio-cultural change. A literature based study on pre-colonial and colonial usage of furniture was carried out with special emphasis on non-secular contexts. Existing examples from the late 19th century when the changes became clearly apparent were studied in detail. Influence of pulpits and celebrant chairs used in Christian preaching is observed. New meaning was derived from integrated design elements borrowed from Buddhist culture and prevailing forms of Christianity. Additionally, colonial chairs of authority and the new role of the preaching monk as a 'leader' seemed to have been aligned in creating new meaning for seating.

Keywords: *Cultural Objects, Identity, Meaning, Seating Furniture, Social status*

1. Introduction

The material attachment of a society with an object or a group of objects is dependent on beliefs associated the ‘value’ assigned to that particular object or object group. In addition to material and utilitarian value, certain objects have aesthetic value, some possess spiritual value and some express attitudes towards other human beings or towards the world. As scholars observe in bygone societies, objects were used by a much larger population and were therefore potentially more sincere sources of information than words or written sources. Thus it remains true that objects can make accessible aspects of a culture that are not always present or detectable in other modes of cultural expression. Therefore material objects are potentially more truthful ‘expressers’ or indicators of a society’s cultural attributes.

Since the introduction of Buddhism in 3rd century BC, Sri Lankan society was inseparable from Buddhist culture. Buddhist culture can be identified with state, kingship and the people at the macro level. At the micro level of society was the Buddhist monastery; the center of education and culture (Seneviratne, 2000). As guided by Buddhist philosophy, possession and use of material objects was minimal especially in non-secular contexts. The typical village house would have a short raised platform on which a mat would be laid to sit or sleep on. Use of furnishing including seating for monks was dictated by the Book of Discipline or *Vinaya Pitaka*. They were especially discouraged from using ‘high and broad’ beds and only certain furnishings were allowed to be used with carvings on. In a symbolical sense, the practice of using an *ásana;* a plain stone seat; to signify and venerate the Lord Buddha before the use of human iconography is recorded.

From 1505 AD to 1948 AD, Sri Lankan society came in contact with the Portuguese, Dutch and British colonisers respectively. This period is considered to be the deciding factor for what was to become ‘modern’ Sri Lanka (De Silva, 2005). The era is marked by a gradual yet seminal change to methods of governance and justice, social structure, economy, education, religion and the inevitable transfer of cultural attributes of the colonizers. The greatest social change occurred due to the abolition of the *Rajakariya* system and the gradual change of social hierarchy from caste to class. Education, stemming from Christian missionary schools, facilitated upward mobility through the classes and resulted in the creation of the new Sri Lankan middle class. A new class of elites emerged too, earning great amounts through plantations. Imitation of western practices developed prolifically, especially that of British influence which penetrated taste, opinions, morals and intellect of the locals. As Jones (2013) observes, the adaptation of British taste by the Sri Lankan elite was greater than their counterparts in India. Edifices in European styles were built by the colonizers that were visual reminders of their dominance (Cannadine, 2002). Furnishing of the dwelling environment was at the time a measurement or a valuator for the worth of a particular family who owned the property.

Therefore it became vital for the elite's to maintain their high living standards in order to receive recognition and respect and portray their allegiance to the colonial government (Jayawardena, 2000). As Jayawardena (2000) further notes this was essential at the time to survive the social structure and to climb the social pyramid.

In another twist of fate the influence of Christian values and practices influenced society in the religious realm challenging the established Buddhist culture. In its various forms throughout the three periods of the colonial encounter, Christian advocates were committed to an agenda Buddhism had not faced before: proselytization. The colonizer's governments sponsored Christianity as a whole and only marginally supported Buddhist institutions, if not neglecting them altogether (De Silva, 2005). This resulted in the gradual disintegration of Buddhist culture from the Sri Lankan society. However as the work of Seneviratne, Daniel (2000) and De Silva (2005) supports, towards the end of the 19th century, construction of a religious identity that was in par with the Christian colonizers and converts, became important for the Buddhist who were still the majority. As Seneviratne (2000) elaborates most aptly, the crisis was addressed through Buddhist revival movements. Methods of teaching *dhamma* was intentionally adapted to reflect the Christian style of preaching while the role of the Buddhist monk changed to that of a community leader. Therefore a paradigm shift occurred in the expression of material objects used in monasteries, *dharmasaala, vihara* etc. Where seating is concerned, we observed that despite earlier teachings of minimal possessions, for example the *dharmásana,* from which a monk would teach *dhamma* from, become more throne-like and elaborate towards the latter half of the 19th century.

Though there exist records of colonial furniture collections (Brohier (1969) and Daswatte (2012)) a study regarding the symbolical and expressive capacity of seating is wholly lacking in the domain of historical and cultural design research. Thus it was the intention of this research to critically examine the change of expression in seating used in non- secular Buddhist contexts. We have mainly drawn upon studies of social change, religious transformation and material possession while critically examining historical records and existing examples of seating of like-wise context in the colonial period.

Methodologically, we engaged in a literature based study on 'seating' in the pre-colonial era with special emphasis on King's thrones, seating for the sangha and *ásana* and on the significant socio-economic and religious changes of the colonial period and developments of seating in general. Through this first study we gained background data on the concept and practice of seating in pre-colonial Sri Lanka. Further, we gathered literature based data on the introduction, import, manufacture and socio-cultural perception of seating during the colonial era. Surviving examples were examined in the prominent museums, churches and elite homes. The examples drawn throughout the text to validate our point are from this study.

2. Discussion

2.1 ASPECTS OF SEATING PRIOR TO THE COLONIAL ERA

Daswatte (2006) observes that seating in Sri Lankan commoner's homes of the era was provided by high plinths of the verandahs that were built to keep out jungle animals and flood water. At times, mats were laid down on platforms. The half walls that stood on the edge of the verandah also served as seating while no loose items of furniture – in European sense – were seen in these houses. As critically examined by Tenner (1997) it was in fact a common trait amongst most of the Southern and East Asian peoples to be seated on the ground or on slightly raised platforms. However, it seems that from an early period the concept of a special 'seat' was associated with power and social status. For example, pre- Columbian Mexican rulers were often called the 'He of the Mat'; a direct reference to the association of power with the ownership of the seat (Tenner, 1997). A category of seats known as '*píṯha'* used by Indian kings, are one of the first recorded types of movable seating devices of the South Asian region. These were similar to a small raised stage or platform with short legs. It is indispensable to note that these 'thrones' were made for cross-legged seating. This posture was the natural manner of sitting in these cultures and the specially made *píṯha* of the King succeeded in maintaining that posture while positioning him at a higher elevation.

It is plausible that with the arrival of Aryans from Northern India in circa 6th century BC these aspects of seating too influenced the locals and the later established monarchies. These are likely to have been further developed with the introduction of Buddhism in 3rd century. According to the Mahavamsa, King Kasyapa V assigned the *dharmasangini* to be written on gold leaf and stored upon a *píṯha* in a temple. The chronicle also states that the reason why Lord Buddha visited Sri Lanka for the second time was to solve a dispute among two *Naaga* kings regarding a *pallanka* made of gem stones.

2.2 *ÁSANA* AND THE SEAT OF THE BUDDHIST MONK

The term *Ásana* is derived from the Sanskrit word *ásati* meaning 'sitting' or 'sitting down'. It is commonly found in historical texts while it is at present being used to denote the invitation given to monks to sit; *ásana panaweema* and in formal gatherings where a host would invite the guests to sit; *asun ganna* etc. To denote different types of seats, the noun '*ásana'* is used in conjunction with an adjective; a solitary seat- *ékásana (éka+ ásana)*; without a seat- *anásana*; a seat on which *dhamma* would be taught from- *dharmásana*. A second denotation of the word is its linkage with not the object of the seat itself but rather of the posture in which one would be seated. Therefore we come across terms such as *lalithásana* (*lalitha + ásana;* the posture of the infamous *Avalokitheswara* statue, with one leg folded up on the seat, while the other hangs freely down) and postures in which statues of Lord Buddha are traditionally depicted; e.g.: *weerásana, wajrásana, pathmásana* etc

Paranavitana (cited in Perera, 1976: p.31) notes the interesting practice in which the *ásana* was an object of worship in ancient Sri Lanka. He notes shrines called *ásanaghara* (*ásana*; seat, *ghara*; house) where the only object of veneration was "a throne in the shape of a large rectangular slab of stone, smoothly chisselled, set up on a raised platform". Fernando (1978) argueed that it was common belief among the Buddhists that the existence of the relics of Buddha was akin to his own existence. Therefore the inclusion of relics when building an *ásana* or a 'vacant throne' is presented as proof that the object itself was venerated. In addition, after the course of Buddha's second visit to Sri Lanka, when the dispute over the gem-throne was settled, Buddha himself is said to have sat upon it which later would have made it an object of worship. The Mahavamsa also records the building of a priceless *ásana* built with the first construction of the Lovamahapaya (2nd century BC). This symbolical representation of the Buddha himself in the form of an *ásana* is also established by Coomaraswamy (1979).

It is interesting to note that the first representation of the human form of Buddha depicts Him teaching *dhamma* on a likewise *ásana* found in the older painings of Hindagala Vihara cave in the Kandy district. The paintings date back to the Anuradhapura period (7th century AD) and contains two images of Buddha, one which appears to be a depiction of a *dharmadesana (*teaching of *dhamma*). Scholars believe that this is this scene represents the visitation and teaching of dhamma to Sakka (Indra) while the Buddha was at the Indasala cave. The relative position of the *ásana* and the figures are crucial in the identification of this scene (Silva, 1990). Explanation suggests that the seating device, the postion of Buddha and relative postions of other subjects in relation to the seated Buddha represent heirarchy and power relations among them.

The Buddhist monks as the followers of Buddha’s teachings and preservers of the *dhamma* were considered symbols of Buddhist virtue and values throughout Sri Lankan history. As Ariyesako (1998, p. 166) comments, a Buddhist monk’s first and foremost duty was to be well versed in the *dhamma* (the Buddhist doctrine). The manner of which to teach *dhamma* was guided by the Pali canon: *Vinaya Pitaka.* In contrast to the Christian counterparts, a Buddhist monk would always wait for an invitation to teach *dhamma*, so there was no question of proselytizing or any reference to the act or ‘preaching’ in his conduct. He is also cautioned to be mindful of whether “the time is appropriate and the audience (is) properly receptive” (Ariyesako, 1998)

Reference to pre-colonial furniture in Buddhist religious places is minimal. This is most likely due to the fact that the *Vinaya Pitaka* has laid specific guidelines on the use of all material objects, including furniture. It elaborately dictates that high (*uchchasayana)* and great (*mahasayana)* furnishings were unsuitable for the monks (Horner, 1949). It also notes that a monk may not teach *dhamma,* to one who was seated on a seat while he was seated on the ground, who was seated on a high seat while he was seated on a low seat or who was seated while he was standing. (Sekhiya teaching 57-72; BMC 505- 508 cited in Ariyesako; 1998)

As the *Vinaya Pitaka* points out, furnishings were divided into two sorts: allowable and not. “Allowable; A square seat not large enough to lie down on *(ásandika)* is allowable even if its legs are tall, and the same holds true for a bench with a back and arms. The Commentary notes that this allowance applies only to non-square rectangular seats without a back and arms. Other allowable seats include a wicker bench, a bench plaited with cloth, a ram-legged bench (this the Commentary defines as a bench with legs fastened on top of wooden blocks), a bench with interlocking legs, a wooden bench, a stool/chair, and a straw bench.” Seating devices could be decorated. “Not allowable; the Canon forbids the use of high and great furnishings. Here the Commentary defines *high* as above the allowable height and *great* as covered with improper coverings and decorations. Examples listed include: a dais *(ásandi*—a tall square platform, large enough to lie on), a throne *(pallanka*—a seat with carvings of fierce animals on the feet), coverlets. However, it is also stated that if visiting a householder’s home, one is allowed to sit on hides or high or great furnishings arranged by them. These were considered the property of the house and therefore monks were required to accept it humbly. This was with three exceptions: a dais, a throne, or anything covered with cotton batting. However, they were not permitted to lie down on any of these items. If a dais was however included among these, it could be used after its legs were cut down to the proper length. A throne could also be after its fierce animal decorations have been cut off" (Thanissaro 2001, pp68-70).

2.3 COLONIAL CHANGES TO THE CONCEPT AND MANNER OF SEATING

Objects for use in the royal household and monastery were of the highest skill and craftsmanship since ancient times. Buddhism was the undoubted chief patron of arts. The colonial period however, resulted in the disintegration of Buddhism and the arts and crafts with the fall of Buddist institutions and lack of sponsorship (Coomaraswamy A. K., 1956). The Portuguese were the first to bring-together movable furniture such as benches, tables, chairs, screens, bedsteads and wardrobes. Significant additions to language to denote these new items of furniture further prove this fact. (Hussein, 2009, p. 277)

The Dutch period which coincided with the height of furniture development in Europe saw further expansion of variety, style and skill in furniture making. During this period traditional craft guilds were replaced by workshops or *winkels* set up by the Dutch. Each trade had a European master or superintendent (*baas*) and skilled European foremen trained in Europe (*meesterknechten*) of high rank and salary in the Dutch East India Company (VOC) service. Locals whose traditional occupation was carpentry found employment in these workshops and it was from the Dutch that the low-country Sinhalese especially of the south west, learnt to excel in such furniture making (Brohier, 1969, pp. xi- xiii). The quality, suitability of local wood and tradition of high craftsmanship resulted in high quality furniture, soon manufactured for export

The Portuguese who were said to have arrived with 'a sword in one hand and a cross in the other' were particularly determined in converting the local population to Roman Catholicism. Many local land owning aristocrats who had converted to Catholicism did acquire a great deal of wealth and improved their standard of living. A fine example of hierarchical seating can be observed in Wolvendaal Dutch Reformed church (built 1747 AD), where the servants were to be seated in plain benches with a front partition shadowing their view from the congregation. The use of a '*kerk* stool' or church stool; a chair or a simpler stool carried to church every Sunday for Dutch elite to mass by a servant (Brohier, 1969). This type of usage, where the seating device is given such importance and singularity must have been a totally new expression for the locals who were accustomed to sitting mainly on the floor for religious observances. Also, the cross legged and squatting seating postures seemed to have altogether disappeared.

2.4 STATELY SEATS AND THRONES OF THE COLONIAL ERA

In the making of a new cultural expression for seating in Buddhist religious contexts, the role played by iconic stately seats and thrones of the colonial era is indispensible. One of first indications of a stately gathering is recorded by the Portuguese historian Queyroz, about an audience with the king which took place in the Portuguese period. He further states that he met the king in a large and dim hall in a style or architecture common to Asia which was hung with Persian carpets, with the king dressed in a white kabaya. He further elaborates that the king was seated on a throne of ivory delicately wrought on a dais of six step covered with a cloth of gold. Knox (1958) observes that even in the later 17th century, only the king was allowed to sit on a stool with a back.

According to Brohier (1969) the throne used by the kings of Kandy provides a unique example of state-seats (Figure 1). He describes the basic style of the throne as being Baroque albite with eastern concepts of decorative motif. This throne and foot stool was presented to King Wimaladharmasuriya II by the Dutch Governor Thomas Van Rhee in 1693 AD. Quoting Pearson, Brohier claimed that the throne may have been imported by the Dutch or made in the coastal regions.

Figure 23: Royal Seat, Source: National Museum, SL

This throne holds a unique position in the history, not only because it is the finest example of a seat of power in the colonial period, but also because the elements that constitute the seat are used to express the historical lineage and claim to power that the owner holds. For example: the depiction of a *Soorya* or Sun at the center of the top rail to signify that the Sinhala kings descended from the Solar Dynasty (Brohier, 1969).

2.5 SEATS IN CHRISTIAN RELIGIOUS CONTEXTS

Another marked influence is found in the usage of seating and related devices in Christian religious contexts that hold a position of power or authority. Even though various forms of Christianity were introduced through the 450 year old encounter with the colonialists, the common trait was their agenda of proselytizing, albeit in varying degrees. The Christian sects considered in our study, the Roman Catholic Church, Dutch Reformed Church and the Church of England were each specifically guided by their doctrines as to how priests (and other missionaries) should engage in spreading the 'holy word'. Social institutions such as schools and hospitals help spread Christian values and beliefs. However, it was the church, built and sponsored by the colonial party in power served as the main context in which the Christian doctrine was preached. These edifices served as a visual expression to colonial hierarchy, built in styles that corresponded with those of Europe (e.g. Gothic) (Cannadine, 2002). Similarly, furniture in these places reflected their stylistic characteristics. Records on the origin of these furniture are minimum, and it is believed that some were imported directly from Europe while others were made in local workshops. However, two main pieces of furniture are observed as having a profound connection with preaching: the pulpit (Figure 2) and the celebrant's chair (Figure 3).

The word pulpit is derived from the Latin word *pulpitum*, meaning the stage or scaffold. In a church, it refers to the raised structure which was reached from a flight of steps (Anson, 1948, p. 154). This structure was from which the priest or minister preached and was essential in the days prior to methods of sound amplification. Their use has become obsolete over time. Examples of pulpits are observed in the churches of all three Christian sects. Nonetheless it was considered a crucial feature of the Dutch Reformed Church, where the protestant doctrine emphasized much more importance on the 'holy word' and its preaching.

Figure 2: Pulpit of Wolvendaal Church, Colombo

Figure 3: Celebrant's and minister's chairs of All Saint's Church, Hulftsdorp

The celebrant's chair was fundamentally associated with the sanctuary of the church and its altar. The chief priest who conducts the mass or worship is known here as the celebrant. It stood "as a symbol of his (the celebrant's) office of presiding over the assembly and of directing prayer" (McNamara, 2006). It was placed facing the congregation, preferably behind the altar table, but providing a straight view. Emminghaus (1997, p. 112) notes that it was "an expression of the hierarchical organization of the people of God: In the officiant, the Lord himself presides over the worship service. The chief celebrant is his representative." Therefore the celebrant's chair is wholly absent from the Dutch Reformed churches which lacks a separate sanctuary in its plan and calls for equal status of the preacher and the preached in its doctrine. Historically the celebrant's chair is an adaptation of the Episcopal chair (Bishop's throne or cathedra) and fulfills the same function for the community liturgy. The Bible refers to the use of the celebrant's chair; "in the synagogue, it was the right of the teacher to sit on a special stool or chair. The head of the synagogue, on the 'seat of Moses' (Matt: 23.2), sat facing the congregation" (Emminghaus, 1997, p. 112). Therefore the chair was not only a practical piece of seating but held position of theological value.

2.6 SEATS IN NON- SECULAR BUDDHIST CONTEXTS; A CHANGE OF OBJECT, AUTHORITY AND POSITION

Contrary to the limited and closely controlled use of seating dictated by *vinaya* law, towards the end of the 19th century and beyond, observation can be drawn to the usage of elaborate *dharmásana*, the presentation of them by the laity and the image of the monk's posture from one of meditation to one of preaching.

The *dharmásana* that developed in the late 19th century consisted of two elements; the 'enclosure' and the chair. They were usually a symmetrical structure made of timber, elaborately decorated with carvings. They created a 'space within a space' inside the *dharmasálá* and created a physical as well as a symbolic gap between the preaching monk and the listeners. The chair on which the preaching monk would sit was an upholstered high arm- chair. A cushioned ottoman was usually incorporated in sitting due to the greater height of the chair. Both the chair and the ottoman were skillfully embellished with carvings.

2.6.1 The change of the role of the Buddhist monk and manner of teaching dhamma

The early Buddhist-Christian dialog was a peaceful one, owning to the high level of tolerance characteristic of Buddhism. Wenzlhuemer (2008) records that resident Buddhist monks received missionaries who took engaged in long travels preaching, with great hospitality. Furthermore he notes that on several occasions Buddhist monks helped prepare places of Christian worship or allowed the *dharmashaala* of their temples to be used by the missionaries.

However, the Christian attitude in the majority of instances was not a likewise one. Strathern (1998) commenting on the 'Buddhist-Christian debate of 1543 AD' conducted by the Franciscan missionaries states that these disputes were specifically used to discredit the Buddhist doctrine and convince the indigenous ruler to embrace Christianity: what they considered to be absolute truth. Portuguese Franciscan missionaries considered the Sinhalese Buddhist monks as practitioners of superstitious believes and compared them with other pagan priests. He also notes that they remained ignorant of the Buddhist doctrine (Strathern, 1998).

While the more lenient approach of the Dutch and then the British towards Buddhism facilitated religious freedom, towards the later part of the 19th century the majority of Sri Lankans were faced with a crisis of identity. Seneviratne (2000) aptly argues that the new classes which emerged by embracing the politics, culture and economics of the colonial ruler had to now adapt their religion accordingly. Their approach was twofold. The minority adapted Christianity, the religion of the ruler while the majorities sort to reorganize and redefine the traditional religion to conform to modernity. While Christianity was rejected as a faith, the new Buddhism was modeled on it, consciously or unconsciously. The movement came to be known as the Buddhist revival and was highly influenced and led by Anagarika Dharmapala.

Dharmapala saw it as a renaissance of ‘traditional’ Buddhism, although scholars argue the movement is more of a reformation: aligning religion with the notion of ‘Sinhala’ ethnicity. In his agenda, the Buddhist monk was to play a new and crucial role. The model for that newly invented role was the Christian priest ministering to his flock. The monk of Dharmapala’s paradigm is a personality in whom a complex of traits-Methodism, punctuality, cleanliness, orderliness, time- consciousness, dedication, and “non-sensuousness.”(to use Dharmapala’s own term) – was rationally integrated” (Seneviratne, 2000, p. 27).

This Neo-Buddhism (as referred to by Seneviratne) was modeled on the organizational structure, social structure most importantly the idea of ministering to a flock as seen in Christian practice and culture. In the light of this new role, a new form of *dharmadesana* was vehemently promoted. The new *dharmadesana* was in sharp contrast from the traditional form. It was limited to about one hour, which was one twelfth of its original duration. Furthermore it was devoid of the elaborate ritualism that characterized the major part of the traditional form. Most importantly it gave prominence to a theme, which was included to the sermon in the form of a Pali verse chanted explicitly by the monk. It also lacked the dramatic performative quality that was essential to the ‘experience’ of a traditional *dharmadesana*. The new *dharmadesana* in its precise theme and format resembled more the sermon that was preached from “the Christian pulpit” than written references of *dharmadesana* of the medieval era (Daniel, 2000, p. 187).

The new identity and the new form of *dharmadesana* resulted in the essential construction of the *dharmasala* within the temple premises. Within it emerged the new form of *dharmásana*. The *dharmasala* was typically symmetrical and had four identical entrances. The *dharmásana* would be placed in the center and consisted of a distinctive, elaborately decorated high seat (Figure 4a&b) (Wickremeratne, 2012). This seat was customarily kept on a central platform or inside an enclosure (Basnayake, 1986).

2.6.2 Emergence of the new class of wealthy laity

The stately seats used by king and other officials, used similar seats of authority in their dwellings also. So they wanted to ‘present’ the monk in the new position of power with a likewise seat.

Figure 4: *Dharmasana* of Pothupitiya Sri Walukarama Maha Vihara, Wadduwa

The community abides to the temple becoming wealthy with a need to portray that wealth also. Prominently they wanted to gift the temple with various artifacts including ‘seats’. Name of donor and to whom the merit should be given is recorded to be well seen on these seats (or rather communicate somehow), to gain recognition within the community.

3. Conclusion

The colonial period of Sri Lankan history portrays a drastic change in the objects and devices used for seating, their methods of manufacture and social power relations associated with a ‘seat’. These changes in secular society are reflected in the usage of seating in religious contexts as well. Though the Buddhist monks guided by ‘monastic code’, cultural diffusion, interpretation and appropriation of another ‘cultures and alien practices’ had changed their identity, values and social life.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 506–518. ©

ADAPTATION OF *KINDURA* MYTHICAL CREATURE IN TRADITIONAL ARTS AND CRAFTS OF SRI LANKA: AN ANALYSIS OF GRAPHICAL ADAPTATION AND ITS IMPACT

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Abstract

The word "myth" comes from the Greek "mythos", meaning a word or a story. Humankind has made myths from the dawn of history. Many common themes run through world of myths and one such theme connects human beings with other animals. Therefore, from the early ages of storytelling, mythical creatures were prominent feature in each human culture. It is noticed that myths of diverse cultures are often linked by similar themes and concepts, but the difference is made with the process of adaptation which were done by each culture according to their own stories, beliefs and ideas. Many researches and studies have been carried to understand the origin and the background stories of these mythical arts, but yet few have been done to understand the graphical adaptations. This study intends to discuss the development of graphical adaptation of the mythical creatures from its original artefacts which is applied in Sri Lankan traditional art and craft. By understanding these graphical and visual adaptation of the local context, this research further places the initial foundation of updating the local mythical legends and creatures in a more effective manner in both art and design aspect, which has not been continued in recent past.

Keywords: *Mythological creatures, Graphical adaptation, Traditional art and craft*

1. Introduction

Human imagination had a tendency towards imaginative creatures from the early ages story telling. The stories themselves became myths filled with imaginary creatures as a prominent element of them. These creatures where mostly created by merging imaginary elements with real animals there by forming what is turned as a mythical creature.

Pattanaik (2003) states, “Myth can be defined in two ways. First, it is a sacred idea that is inherited over generations. Second, it is absurd, irrational, and fantastic concepts about the world that appeal to unsophisticated minds. The two meanings are two sides of the same coin.”

People believe in mythology regardless of their authenticity. Mythology evolves through the progression of human imagination and storytelling. Mythical creatures therefore can be identified as a communication which evolved alongside traditional storytelling. Therefore they evolved with the influence of different cultures. The origin of the myths were mostly common to several cultures therefore each culture adopted the mythical creatures into their own. The mythical creatures in arts and crafts of Sri Lanka, has also gone through this process of adaptation. It has become a great example of cultural creativeness producing uniqueness.

The intention of this paper is to examine these unique elements of Sri Lankan mythical creatures in order to study their graphical adaptations. Although there are seven interesting mythical creatures in arts and crafts of Sri Lanka we intend to consider *Kindura* as the focus of the study.

Research methodology will be to analysis written records, historical records, and folklore, research and scholar interviews focusing on the graphical adaptations in arts and crafts of Sri Lanka. Also a study on foreign mythologies and their cultural influence on Sri Lankan art will be done with respect to the scope of this paper.

2. Value of mythology and mythical creature in Asian traditions

The mythical creatures are interpreted as the animals of fantasy. If we take a glance in to the remnants of our ancient world we can find many mythical creatures, most of them created by adjoining two or more animals and creatively developing it in to a motif and a decorative design. It seems that we have inherited these iconographic and symbolic animals from the Hindus as we can see these animals in ancient Indian art. The Indian art history contains a huge number of mythical creatures, some are human bodies conjoined with animal heads and some are hybrid representations of number of animals.

These fantastic mythical creatures were once illustrated by people who have imagined them as they appeared in legends, folk stories and myths. And these stories were made out as explanations for the great powers and supernatural things early people saw and experienced, which they couldn’t explain: (e.g.: rain, thunder, flood, storm, etc.) These narratives existed in different cultures before they took part in the traditional literature.

Rosen (2009) states, “The legends, folktales, and spiritual stories of peoples around the world have always been filled with mythical creatures, from the earliest tales told around the fire to the books and movies that delight and terrify us today, the human imagination has populated the world with a marvellous variety of magical and menacing animals, monsters, spirits, and gods."

Rosen (2009) furthermore declares that "many of the mythical creatures explored here have supernatural or magical abilities. More powerful than mere humans, but less potent than the supreme deities worshipped in the world's faiths, these beings often bridge the gap between religion and folk beliefs. Some creatures are generally beneficent; others are mischievous or overtly malicious. All reveal something significant about the hearts and minds of the people who tell stories about them."

2.1. THE FUNCTIONS OF MYTH

A myth focuses on the worldview of a nation. Each culture has its own narratives, symbols and rituals to mould its people, and to build up the way they see the world. So each culture has its own unique identity. But overall, all cultures try to teach people what is good and what is bad with the help of myth.

3. Character of mythical creature in traditional arts and crafts of Sri Lanka

There are many mythologies, legends, chronicles and folklores fantasized with mythical beings in Sri Lanka. The main three types are the *yakshas*, *Nagas* and *Devas*. They are believed to be the former inhabitants of Sri Lanka even before the immigration of north Indians prior to historic era.

The historic chronicle, "Sinhabahu" is a great example from Sri Lanka, which describes the origin of the Sinhalese natives through animal hybridization. The story tries to empower the nation's supremacy and power by submitting that the Sinhalese inherit the blood of a lion, which lately helped to develop a symbol for the Sinhala nation. According to the story, the son of the lion and Princess Suppadevi was born with lion's paws/ legs with fur, which gave him the name Sinhabahu (*Sinha*-lion, *bahu*- hands). According to the *Mahavamsa*, Sinhabahu killed his own father and was rewarded as a hero. This is a fine example in Sri Lankan history where they used animal hybridization to signify and symbolize great power of an extraordinary chronicle.

Coomaraswamy, A.K. (1956) states, "the motifs in Sinhalese decorative art may be tabulated as followings, using, as far as possible, the names employed by the craftsman themselves:

1. **Divine -** Symbols of the sun (*ira*) and moon (*handa*).

2. **Animal - Mythical:** *Kindura, Serapendiya, Et-kanda-lihiniya, Makara, Bherunda-pakshaya, Nara-simha, Gaja-simha.*
Partly mythical, with a natural prototype: *hamsa, simha* (incl, *kibihi*"), *naga*.
Natural (real animals decoratively treated): fish (*matsya*, etc.); birds, especially parrot (*girava*), cock (*kukula*), peacock (*monara*), *sela-lihiniya*; beasts, especially deer (*mriga*), hare (*hava*), squirrel (*dandu-lena*), bull (*usamba*), elephant (*eta*), horse (*asvaya*); dog and crow; man (*manushya*).
3. **Vegetable - Mythical:** *nari-latha-vela* (semi-human*); kadu-pul, parasatu, palol, damba, imbqul, kap-ruka, mahari.*
Conventional: *kathuru mala* (scissors flower), *pica mala* (Jessamine), *sina-mala, nelum-mala* (lotus), *pala-peti* (lotus petal), *mala* (flower in general), *sapu-mala* (*sapu* flower), *vetakeyiya* (Pandanus), *mal-gaha* (flower tree), flower in pot, *Liya-vela* (branch or vine), *Liya-pata* (vine-leaf), *bo-kola* (bo-leaf), *bo-pat-kangul*, *suLiya, Malaya*; and traditional forms without special Sinhalese names, including pineapple, palmette, honeysuckle, knop and flower, cone, calyx-volute. No forms derived directly from fruits appear to occur.
4. **Inorganic -** Geometrical: dot (*binduwa*), line (*iri*); curve (*vaka*), circle, spiral, triangle, chevron (*diya-rela*), arch (*torana*), cross, *suvastika*; diaper, esp. *dela* (the net*), tundan-veda, kalas-dangaya, kundi-rakkan*; chequer; plait (*lanu-geta*); borders, *gal-binduva, arimbuva, panava, havadiya,* and fret. "

4. Identification of *Kindura* as a significant mythical creature

Kindura is a well-known creature in Hindu mythology and Buddhist mythology which is considered as an aerial or atmospheric mythical creature. Hindus had known them as the *Kinnara* and *Kinnaris*. The creatures who resemble the *Kinnaras* in Greek mythology are the harpies. But they were originally the goddesses of the sweeping storm, symbolic of the sudden and total disappearance of men.

4.1. MYTHOLOGIES RELATING TO *KINDURA* MYTHICAL CREATURE

According to the mythologies these species lived in the Himalayas, the Indian forest Broceliande and in Hindu mythology the *Vishnudharmottara* describes these creatures as half-human and half-horse, much similar to centaur in Greek mythologies. But *Kinnara* and *Kinnaris* which was illustrated as a half-human and half-bird types are represented at Barahat (third century B.C.) and at Ajantha (fifth century A.D.)

But in Sri Lanka the Kandyan artist enhanced the *Liya* or „woman-*Kindura*‟, like the mermaid is well spoken of than the merman. The form is found not only in purely decorative work, but of necessity also in pictures of the Chanda *Kinnara Jataka*, as at Kelaniya. The Chanda *Kinnara Jathaka* which was cited by Coomaraswamy (1956),

"The story of the *Jataka* is briefly thus: the Bodhisattva was incarnated as a *Kinnara* and lived with his wife Chanda in the Himalayas. The king of Benares committed his Government to his ministers and went alone to the Himalayas on a hunting expedition. The two *Kinnaras*, whose home was on the Mountains of the Moon, had come down from them and were playing and singing by a stream, Chanda dancing to the sound of her fellow flute. The king heard the sound, and creeping near, was smitten with love for Chanda. I will shoot the husband,' thought him, and kill him, and I will live here with his wife.' He shot and slew the *Kinnara*; his mate fled in fear and sorrow to the top of the mountain, and a dialogue ensued between her and the king, and she refused to live with him; his passion died away and he departed indifferent. Chanda embraced her fellow and brought him to the hill-top and cried aloud over him, taunting the gods to bring him to life again. Sakra's throne grew hot. (Sakra is the Chief of the Gods, and Lord of *Deva*-loka. In stories it is said that his throne grows hot whenever important event take place on earth, requiring immediate attention.) Pondering, he perceived the cause; in the form of a Brahman he approached, and from water pot took water and sprinkled the great being with it.' The dead *Kinnara* was restored to life, and Sakra departed, warning the *Kinnaras* never again to seek the haunts of men. The master thus identified the birth, at that time Anuruddha was the king, Rahula's mother was Chanda, and I myself was the *Kinnara*,'"

Ghosh, S., (2005) states "We are everlasting lover and beloved. We never separate. We are eternally husband and wife; never do we become mother and father. No offspring is seen in our lap. We are lover and beloved ever-embracing. In between us we do not permit any third creature demanding affection. Our life is a life of perpetual pleasure."

4.2. IDENTIFYING THE CHARACTERISTICS

Kindura is a mythological creature, which has a hybridization of a human upper body and a bird's lower body. The *Kinduras* can sing, play flute and dance with soft movements of the body. The *Kinduras* are tender hearted creatures as *Jataka* No.540 says a story of *Kinduras* who nurse a baby whose parents have gone to the woods. Referring the mythologies we can identify their habits as bathing in streams, swinging in creepers and sleeping on flower beds. They prepared their dresses with flowers, their feed was of dust specs of flowers and they used flower perfumes as their cosmetics. These kind hearted, harmless creatures which were described in Buddhist mythology is far more different from the half-horse, half-human creatures mentioned in the Hindu mythology. But the both literature mentioned the fondness of music and dance of them.

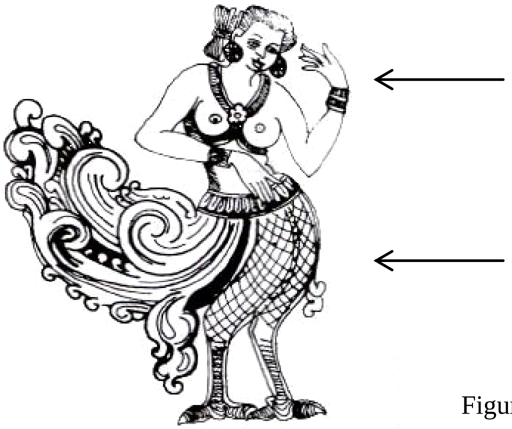

Figure 1, *Kindura*, modern
Source, De Silva, 2009

5. Significance of *Kindura* mythical creature in traditional art and craft

The earliest *Kindura* can be found in a museum near the Isurumuni Vihara. It is carved on a stone panel. Most of the decorative art of *Kindura* can be seen in the temple of tooth relic, Kandy. There are varieties of ways to interpret the *Kindura*, *Kinduras* whose wings were joined to the waist, and the *Kinduras* whose wings are joined to the back of the shoulder. The lower parts of the bodies were covered with feathers. The most beautiful *Kindura* image can be found in the Welihinda Sudarshararamaya paintings. *Kinduras* are holding flowers and *Liya*wela by their hands.

Figure 2, *Kinduras,* Sri Lanka (modern illustration)
Source, De Silva, 2009

5.1. CHARACTER SEMIOTICS

The Sri Lankan artists were inspires from the Bhuddist Jataka stories. Mostly the *Liya Kindura* was dressed her hair on top of her head and wearing flowers as a necklace. She has a pretty fair face and inherits a beautiful neck as the Brahma. The *Kindura* which is drawn in the Udunuwara flag was wearing a crown or a head cover. Mostly these creatures are holding a musical instrument and are dressed with different kind of accessories like earrings and bangles.

5.2. REPRESENTATION OF NATURAL PROTOTYPE

Since *Kindura* is a hybridization of a human and a bird, natural prototypes of the specific species are assimilated in to the graphical adaptation.

Human upper body - *Kinduras* are feminine creatures. To construe these characteristics, expressions were adapted into graphical form as very pleasant, peaceful with a slender smile on their faces and feminine gestures. The carving which can be found in the Embekka *Deva*le, is a carving which was done considering the feminine curves of a woman’s body. (Figure 3.1)

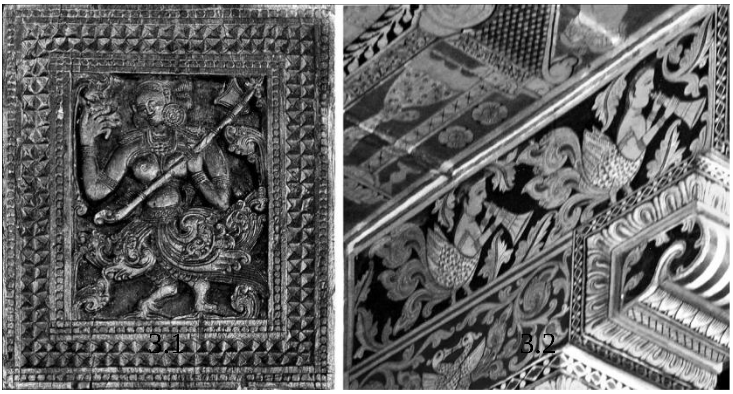

Figure 3, *Liya Kinduri* and *Kinduras*, Sri Lanka
3.1, *Liya Kinduri*, wood carving, Ambekke *Deva*le, Kandy,
3.2, *Kinduras* playing music, application of an architectural detailing, Temple of tooth relic, Kandy

Bird’s lower body- To illustrate the lower body of the *Kindura*, *Siththara* has used many conventional motif designs to differentiate different body parts of the bird. Different feather styles were used to exemplify feathers and textures of primary feathers, belly, thigh and wings, and sometimes *dela* (net) was used to illustrate the feathers on belly area.

Figure 4, parts of a bird
Source, Coomaraswamy (1956)

Figure 5, feathers of *Kindura*

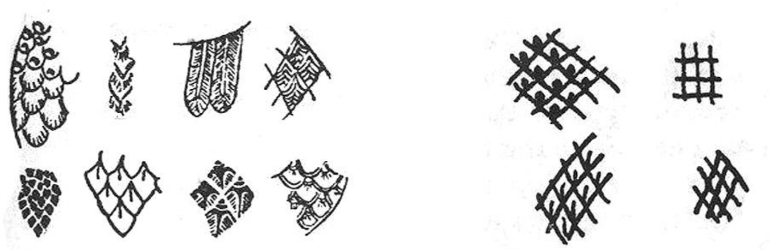

Figure 6, Methods of representing feathers, *dela* (net)
Source, Coomaraswamy 1956

Figure 7, tails of *Kindura*

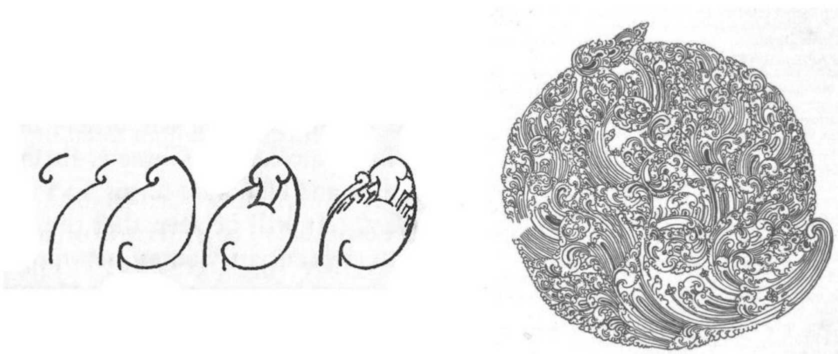

Figure 8, *Liya pata* ornament, showing manner of drawing, *Tiringi Tale*
Source: Coomaraswamy 1956

5.3. PERCEIVED CHARACTERISTICS THROUGH COLOR

Gibson (1950) points out that, “color, size, form, sequence, and still other qualities of perception may unquestionably be affected by the past experience and attitudes of the observer.”

In Sri Lankan culture people use different colors in their cultural occasions and events to resemble or symbolize a message. Examining the thoughts of scholars it can be said that the Sinhala *Siththara* have used specific colors to enhance the relevant characteristics of *Kindura* considering the colors which were used in Sri Lankan tradition. Rev. Unuwathurabubule (2007) states that yellow is a “dispassionate” and “pleasant” color when he was doing the amplification of the coloring techniques and representation of Buddha, *Rahath* and *Deva* images. Furthermore Prof. Sirisena (2007) suggests that the color yellow represents wisdom, power, goodwill and purity. When exemplifying the *Kindura*, in most of the paintings the Sinhala *Siththara* have used the color yellow. Considering the representations of the colors which are mostly used by the Sri Lankan *Siththara*, the colors which were used to illustrate *Kindura* was to convey the qualities of wisdom and goodwill.

5.4. INFLUENCES OF CULTURES IN THEIR RESPECTIVE TIME

Natives whom belong to two different cultural groups don’t see the world in the same way. Way of seeing things depends on a person’s past experiences and his cultural background. So though there were many incidents in Sri Lanka cross-cultural influences effected Sri Lankan art and architecture. Hindu and Tamil influences even alternated Sinhalese social lifestyles. Hinduism was adopted by Sinhalese since the Polonnaruwa period.

According to the thoughts of Wikramasinghe (1947), he has pointed out "though Sri Lankan tradition is not a deep and multifaceted one, it is an entity of a natural, relaxed, simple and subtle tradition. The main evidence to prove the creativity of the Sinhalese artist is the remnants of *Sandakadapahanas* and the *stupas*. This evidence proves the characteristics of simplicity, shallowness and the absence of the hidden significances of the Sri Lankan tradition."

9.1

9.2

Figure 9, Cultural influence on *Kindura*
Figure 9.1, Earliest *Kindura*: stone carving, Isurumuni Vihara museum Figure 9.2, Udunuwara *Kindura* flag,
Source: Author, Coomaraswamy 1956

Those influences were consciously visible in the graphical evolution of *Kindura* mythical creature. The simple, natural and subtle interpretation of *Kindura* is observable in Anuradhapura and Polonnaruwa period (Figure 9.1), while a more elaborated and detailed *Kindura* is exemplified in British colonial period. Even the accessories and adornments are influenced by the cultural background of the respective time. (Figure 9.2)

5.5 GRAPHICAL ADAPTATION THROUGH SUPPLEMENTS

5.5.1 Adornments

According to the mythologies and *jathaka* stories *Kinduras* are not ordinary animal species. Though they live in forests and live a primitive life, they are embedded with a spiritual value which positions them beyond a human or an animal. To add a value to this significant mythical creature Sinhala *Siththara* had used adornments such as necklaces, earrings, headdresses/crowns, bangles, waist chains/belts and even different attires.

In Uda Nuwara flag (Figure 9.2) the *Kindura* is illustrated in a majestic manner, wearing royal attire and a valued crown. According to the information Rev. Dheerananda (2013), the Uda Nuwara and Yata Nuwara were famous for Jewel makers in the Kandyan era. It was named as the Siruwana banda pradeshaya. The ones whom were mastered of the arts and craft were named as *Ran pattal shilpeen, Otunu pattal Shilpeen, Kadu pattal shilpeen* and *Sinhaasana pattal shilpeen*. As these communities of craftsman were experts of their talent they were devoted to supply their services for the king. By examining the Uda Nuwara flag it is evident that they have tried to communicate their region‟s unique talent by interpreting the finer details of the *Kindura*, its formal attire including the crown and the smoothly detailed frame of floral design.

When graphically presenting these adornments *Siththara* has used Inorganic, geometrical and conventional motif designs to demonstrate them.

Inorganic - Geometrical: dot *(binduwa)*, line *(iri);* curve *(vaka)*, circle, spiral, cross, esp. *dela* (the net), borders, *arimbuva,*

Conventional - *Pala-peti* (lotus petals)

Figure 10, Adornments- Royal attire, crown, jewellery

5.5.1 Accessories

In most of the paintings, carvings and sculptures these creatures are drawn as fun loving and a species which are fond of music. To augment the entertaining lifestyle of the *Kinduras* they are mostly portrayed with a horn like music instrument. And to enhance their naïve and fondness towards nature in some places *Liya Kinduri* is illustrated with flowers in their hands, and in some they appear to be holding a stick.

Figure 11, *Liya Kindura* and *Liya Kinduri* with accesorries: horn, flowers, and sticks
Source: Author, Coomaraswamy (1956)

As mentioned above, *Kindura* is a species with a spiritual value beyond human or animal. However the Sinhala *Siththara* used adornments and accessories of that time period which he could experience commonly in day to day lifestyle. Even the specific graphical detail which elaborates the character of *Kindura* was influenced by the motif design of the relevant time period. Therefore could it be that the graphical adaptation through supplement made a heavy impact on the character semiotics of *Kindura* thus reducing the divine and spiritual value of it.

6. Conclusion and further studies

All around the world in different cultures, fantastic mythical creatures appeared in different forms. We have a number of our own mythical creatures in our culture. The research of this paper discusses the scope of imagination of the Sinhalese *Siththara* with respect to different time periods and how they gradually established through diverse cultural influences, and how those cultures identify the mythical/divine *Kindura* using their visual semiotics. And furthermore the paper edify how *Siththara* has transfigure imagination into a grass root level through art and craft, where the common man can experience them rather than appreciating them as superior species.

When considering the foreign mythical creature, their applications in modern society and how they interact with people with different modes, it is evident that the Sri Lankan mythical creatures have become obsolete and are under-utilized compared to the other cultures. The evolution of this visual character has been discontinued since Kandyan period, and they are no longer a part of our society, as per they are merely appreciated as a historical decorative art up till now. Without knowing their origin and how they have graphically adopted into a specific culture or a tradition, it cannot be endure into the new generation as a different graphical character, rather than an application in traditional art and craft.

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Rajapaksha.U, et al (eds), 2015, "Making built environments responsive"*: Proceedings of the 8th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka,* pp. 519–531. ©

CAPACITY BUILDING IN CONSTRUCTION SMES: A PROPOSAL THROUGH ENABLING LEAN

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Abstract

Construction Small and Medium Enterprises (SMEs) makes a noteworthy contribution to GDP in national economy despite the challenges faced by them. One of their major problems is increase of non-value adding activities. Hence, construction SMEs need to be responsive to the challenges in implementing lean. Lean is a relatively new approach in the construction industry which minimizes waste, time and creates value. However, implementing lean may encounter challenges. Lack of capacities is the prevalent issue and hence, need to identify necessary capacities to achieve full benefit of lean implementation. Focusing on capacity building to enable lean construction will allow construction SMEs to better perform in the industry. Therefore, this paper attempts to investigate the importance of lean enabling capacity building in construction SMEs. Hence a comprehensive literature review was carried out to discuss the challenges faced by construction SMEs, lean philosophy, lean construction benefits, barriers and capacity building. Although, lean and capacity building related literature exists , there is a lack of research in capacity building strategies that enable lean in construction SMEs. Hence, the paper proposes a conceptual model for lean enabling capacity building for construction SMEs. The developed conceptual model will further guide this research study to identify lean enabling capacity building strategies for construction SMEs.

Keywords; *Capacity building, lean construction, construction SMEs, Sri Lanka*

1. Introduction

Construction industry is one of the competitive industries in most of the countries with a dispersed industrial structure and few barriers to entry (OECD, 2008). Therefore, large numbers of firms enter in to the industry and competition in the industry is increasing. Due to high competition, construction industry in many parts of the world suffers from problems such as workmanship defects, time, and cost overrun to name few (Harrington, Voehl & Wiggin, 2012). As globalization proceeds, developing countries and their enterprises face major challenges in strengthening their human and institutional capacities to take advantage of trade and investment opportunities (OECD, 2004). Although an extensive body of literature exists in the area of challenges face by large construction organizations, the issues encountered by SMEs is largely unreported (Hardie & Newell, 2011). According to Harvie (2004), a common characteristic of most of the economies is the significance of a sizeable and rapidly expanding SME sector. Hence, the importance of SMEs cannot be downgraded as they play a great role in the construction industry and making them responsive to solve their problems is paramount. Hence, Lean and capacity building are relatively new approaches in the construction industry which can be implemented by construction SMEs to better perform in the industry. Thus, the aim of this study is to develop a conceptual model for lean enabling capacity building to foster construction SMEs. Moreover, this paper is an early stage output of a postgraduate research.

2. Small and Medium Enterprises (SMEs)

SMEs are one of the backbones of economic growth in all countries which employ the prevalent percentage of the workforce (Agwu, & Emeti, 2014). There is no universally accepted definition for SME, as it seems to vary from country to country and also from industry to industry. Ayanda and Laraba (2011) identified three parameters generally applied by most countries to define SMEs, individually or in combination as; capital investment on plant and machinery, number of workers employed and volume of production or turnover of business.

Harvie (2004) and Harvie and Lee (2003) stated that the majority of SMEs are relatively small and over 95 percent of SMEs in the East-Asian region employ less than 100 people. In the developed and newly developing countries, SMEs generally employ a large percentage of the workforce and are responsible for income generation opportunities. These enterprises can also be described as one of the main drivers for poverty alleviation (Singh, Garg & Deshmukh, 2010; Agwu & Emeti, 2014).

According to Kadiri (2012), United State of America (USA) employs about 87% of its workforce in the SME sector, where as in German, it is 72.6%. The contribution of Sri Lankan SMEs is vital in many ways as they

provide over 60% of the private sector jobs, and generate 50-80% of total employment (Ministry of Finance and Planning, 2010). Hence, rapid growth of SME sector has largely influenced to construction industry as well.

2.1. CONSTRUCTION SMES

Construction SMEs can be recognized as one of the pillars of SMEs. According to Harvie (2004), construction SMEs play a greater role in Taiwan, China, Japan, Thailand and Vietnam where they contribute over 70% of employment, than they do in Indonesia or Malaysia, where they contribute only around 40%. According to Saleem (2010), construction SMEs typically account for 10 to 40 percent of all employment in the Middle East and North Africa region. The study of Emine (2012) found that construction SMEs are of high importance to developing countries especially in Arab region as they account for more than 90% of all firms. Moreover, research findings of Opafunso and Adepoju (2014) revealed that there was a 57% increase in the number of construction SMEs in Nigeria between the years 2009-2013.

Hence, the importance of construction SMEs to the economy should not be underestimated. The major advantage of construction SMEs is its employment potential at low capital cost (Agwu, & Emeti, 2014; OECD, 2008). Hence, the relative importance of construction SMEs in advanced and developing countries would continue to reconsideration of the role of construction SMEs in the economy (Ayanda & Laraba, 2011). However, construction SMEs are under pressure to compete in the industry and to maintain their market position due to the monopoly created by the large firms (Pulaj & Kume, 2014; Opafunso & Adepoju, 2014). Therefore, construction SMEs today faces number of challenges to foster in the competitive market place.

2.1.1 Challenges faced by Construction SMEs

Ofori and Toor (2012) contended the risks faced by construction SMEs in developing countries as lack of job continuity, the deficiencies in construction industry, difficulties in operating environment of the industries and access to finance, newly introduced regulations, greater competition from the larger number of enterprises in the industry offering the same services,. Construction researchers identified low level of technology, lack of skilled workers and management expertise, lack of access to international markets, unsupportive legislations, ineffective incentive policies and lack of financing as constant issues faced by managers in construction SMEs (Rymaszewska, 2014; Agwu & Emeti, 2014).

The continuous changes that affect the business environment due to the globalization process and the technology innovations, force SMEs to persistently look for new direction to preserve and advance their market position (Aremu 2004 as cited in Ayanda & Laraba, 2011). In order to remain competitive in global context and to be able to meet unprecedented market changes, organizations must not only design and offer better products and services; but need to improve their operations and processes (Rahman, Sharif & Esa, 2013). The concept of value has been commonly related to parameters such as cost, function and quality (Garrido & Pasquire, 2011). Hence, there is a need for construction SMEs to develop and implement new construction processes yielding higher value at lower costs (Bertelsen & Koskela, 2004).

The conventional systems used in the industry pursue the 'task' of project completion, however, neglect minimization of non-value addition and maximization of value (Koskela, Howell, Ballard & Tommelein, 2014). Therefore, a big challenge is in front of construction SMEs to look for new techniques, concepts & strategies to continue moving up the ladder, while increasing the value addition (Bhamu & Sangwan, 2014). As a response, many organizations are seeking to maximize value addition through embedding lean; as one of the most prominent improvement approaches within the construction industry (Nesensohn, Bryde, Ochieng, Fearon & Hackett, 2014). Further, Aziz and Hafez (2013) suggested lean as one of the best approach for improving the value in construction industry. SMEs can also be benefited by converting to lean, providing the process is adjusted accordingly (Rymaszewska, 2014). Hence, enabling lean in construction SMEs will minimize the non value addition and optimize performance in the construction industry.

3. Lean Philosophy

Rahman et al. (2013) defined lean as a set of tools that assist in the identification and elimination of waste that might improve quality as well as production time and cost. Laureani and Antony (2012) defined Lean as a process improvement methodology used to deliver products and services better, faster, and at a lower cost. Dual focus of lean on increasing business value and eliminating the waste made it one of the most popular business performance improvement approaches of the last decade (Jadhav, Mantha & Rane, 2014). Lean will allow companies to face continuous changes and disturbances, by giving them agility, the ability to quickly react to technical or environmental unpredictable problems or difficulties, to cope with such environments, companies need proactive workforces, and able, ready and motivated to think and suggest improvements (Alves, Carvalho & Sousa, 2012). Koskela (2004) stated that lean thinking is admirable for construction industry and Jadhav et al. (2014) highlighted that many organizations are implementing or willing to adopt lean principles since the past two decades.

Womack and Jones (1996) codified the essence of Lean Production (LP) into five well known basic principles as specify value, identify the value stream, avoid interruptions in value flow, let customers pull value, start pursuing perfection again. The core concept behind LP is to enable the flow of value creating work steps, while eliminating non-value steps (Marhani, Jaapar & Bari, 2012). This has encouraged many industries to adopt LP as their process improvement and problem solving approach or for improving speed to respond to customer needs and overall cost as part of management strategy to increase the market share and maximize profit (Kumar, Antony, Singh, Tiwari, & Perry, 2006). Hence, there is an increasingly positive trend in the construction industry to implement lean and seek the required improvement targets (Nesensohn et al., 2014).

4. Lean Construction

Koskela et al. (2014) introduced two slightly differing interpretations of Lean Construction (LC) as shown in the Figure 1.

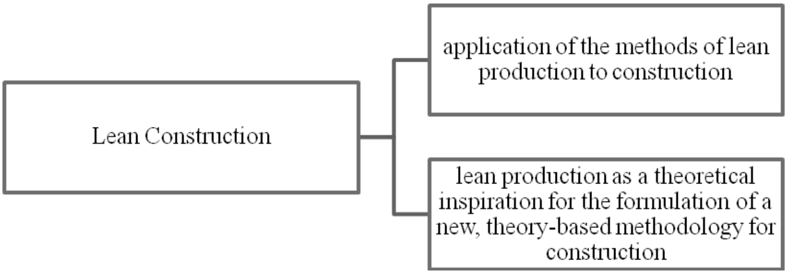

Figure 1: Lean Construction Interpretations (Koskela et al., 2014)

According to Figure 1, one interpretation holds about the application of lean production concepts to construction and the other interpretation views lean production as a theoretical inspiration for the formulation of a new, theory-based methodology for construction, called LC (Koskela et al., 2014). However, Aziz and Hafez (2013) specified that LC is using the same principles as lean production to reduce waste and increase the productivity and effectiveness in construction work. Moreover, Marhani et al. (2012) defined LC as a concurrent and continuous improvement to the construction project by reducing waste of resources and at the same time able to increase productivity of construction projects.

4.1. BENEFITS OF LEAN CONSTRUCTION

Egan Report (1998), recommending the UK construction industry to adopt lean thinking as a means of sustaining performance improvement in construction projects. However, embedding lean construction in an organization typically requires many changes and is a challenging endeavour (Nesensohn at al., 2014). The concept of lean is still relatively new to SMEs (Pingyu & Yu, 2010). However, many researchers such as Rymaszewska (2014); Laureani and Antony (2012) and Kumar et al. (2006) highlighted the importance of implementing lean concepts in SMEs. Table 1 shows the benefits of lean concepts to construction industry.

Table 1: Benefits of Lean Concepts to Construction Industry

Benefits of Lean Construction	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Higher quality construction	x		x	x			x
Greater customer satisfaction	x		x				x
Greater productivity	x			x	X	x	
Sustaining Performances				x			
Improved safety	x		x		X	x	
Better risk management	x						
Reduce cost	x		x				
Reduce construction time		x	x				
Reduce waste		x			X	x	x
Reduce rework		x					
(1) Bernstein & Jones (2013); (2) Antony (2011); (3) Aziz & Hafez (2013); (4) Egan Report (1998); (5) Marhani et al. (2012); (6) Umstot, Fauchier & Alves (2014); (7)Kumar et al. (2006)							

Despite the benefits that could be gained from lean implementation, Rymaszewska (2014) highlighted the importance of lean concept to be tailored to the specific needs of SMEs. Hence, it is important to identify benefits in order to promote the concept in construction SMEs.

4.2. BARRIERS FOR LEAN IMPLEMENTATION IN CONSTRUCTION INDUSTRY

A survey conducted by the practitioners of lean implementation revealed that changes to the production environment due to lean have only a 30% success rate and 70% of lean implementations experience decay and return to the original way of doing business (Schipper & Swets, 2010). Implementation of lean systems is not free from barriers (Jadhav et al., 2014).

Table 2 summarized the literature on barriers for lean implementation in construction industry.

Table 2: Barriers for Lean Implementation in Construction Industry

Barriers for Lean Implementation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Top management resistance	x	x	x							x	x	
Lack of top management involvement	x	x	x						x			
Lack of communication between management and workers		x										x
Workers' resistance to change	x	x	x	x	x	x	x					
Lack of empowerment of employees		x										
Knowledge-level constraints					x							
Lack of consultants and trainers in the field		x										x
Lack of formal training for employees		x										
Cultural difference		x	x	x								
Incompatibility with incentive schemes		x										
lack of resources to invest		x	x					x				
Lack of cooperation from suppliers		x										
Quality problems with supplied material	x	x										
Government policies		x	x									
(1) Rahman et al. (2013); (2) Jadhav et al. (2014); (3) Shang and Pheng (2014);.(4) Green, Harty, Elmualim, Larsen, & Kao (2008); (5) Pingyu & Yu (2010); (6) Sawhney & Chason (2005); (7) Larsen, & Kao (2008); (8) Pedersen and Huniche (2011); (09) Hines, Holweg and Rich (2004); (10) Veiga et al. (2011); (11) Hagstrom and Wollner (2011); (12) Cudney and Elrod (2010)												

Further, Jadhav et al. (2014) specified that the lack of a long-term philosophy is the most crucial obstacles to lean practice. The transformation towards LC will lead to changes in the culture and in its people (Green et al., 2008). Therefore, lean relies heavily on the skills of the people and how they respond to changes (Sawhney & Chason, 2005).

According to Jadhav et al. (2014), resources are primarily concerned about the human resources (soft resources) such as attitude, capability, knowledge, experience and skill to direct or lead the change and improvements. Physical (hard) resources include dedicated employees' time, allocation of fund, means of communication, information, material, machineries, latest technologies/methodologies, facilities and infrastructure (Jadhav et al., 2014). Lean-based construction requires changes in individual behaviour as well as the resources of the organization (Koskela et al., 2014).

Hence, it is important to identify necessary capacities to be built in order to obtain full benefits of lean implementation in construction industry.

5. Capacity Building

Wal and Marks (2007) defined capacity building as the development of an organization's capabilities, through a coherent set of activities aimed at embedding core skills and functions in order to build the organization's effectiveness and sustainability. Merino and Carmenado (2012) identified capacity building as an abstract and multidimensional concept. Enemark and Ahene (2002) and Groot and Molen (2001) defined capacity building as the development of human resources in terms of knowledge, skills, individual and group attitudes for the purpose of developing and managing certain areas in the community or an organization, which ensure long- term sustainability. Moreover, Boyd and Juhola (2009) reinforced the definition by specifying that capacity building provides an opportunity to understand strengths, weaknesses, threats and opportunities towards a resilient future through identification of broader issues around sustainable development of a particular program, project or process, including their unique cultural, social and ecological characteristics. Having considered the above definitions, capacity building can be defined as enrichment of hard and soft resources of an organization while minimizing the non challenges.

However, majority of local construction organizations in developing countries lack capacity and cannot meet the demand of construction work (Didibhuku & Mvubu, 2008 as cited in Kululanga, 2012: Enshassi, Al-Hallaq & Mohamed, 2006). SMEs in both developed and developing countries today face tough and challenging times in improving performance due to the challenges faced by them from the industry. At the same time, high global competition demands SMEs a higher level of capacity to maintain or increase steadily the performance of the business (Lagace & Bourgault, 2003; Guzman, Gutierrez, Cortes, & Ramire, 2012). To sustain a fair level of competitiveness in both the domestic and global markets, SMEs must strive to utilize tools and new concepts to reach the right markets in cost effective ways (Singh et al., 2010). Further, Harvie (2004) highlighted the significance of promoting more adaptable and flexible strategies by capacity building in construction SMEs.

6. Lean Enabling Capacity Building: A Conceptual Model

Lean is not just a set of tools and techniques, but at its heart is the people (Bhasin, 2012). It is the people whose knowledge, intelligence and desire to improve that steers organizations to new levels of continuous improvement (Bhasin, 2012). Therefore, lean relies heavily on the skills of the people and how they respond to changes (Sawhney & Chason, 2005). Further, implementing lean systems is not free from barriers (Jadhav et al., 2014). Therefore, applying LC for design and construction within the industry is becoming a highly pertinent issue (Nesensohn et al., 2014).

According to Groot and Molen (2000), capacity building is the development of knowledge, skills and attitudes in individuals and groups of people relevant in design, development, management and maintenance of institutional and operational infrastructures and processes that are locally meaningful. According to Koskela et al. (2014), lean-based construction requires changes in individual behaviour as well as the resources of the organization. Hence, necessary capacities need to identify in order to optimize the benefits of lean implementation. Figure 2 shows a conceptual model developed by combining lean and capacity building concepts in order to identify lean enabling capacity building strategies and hence to minimize challenges and optimise performance of construction SMEs through lean implementation.

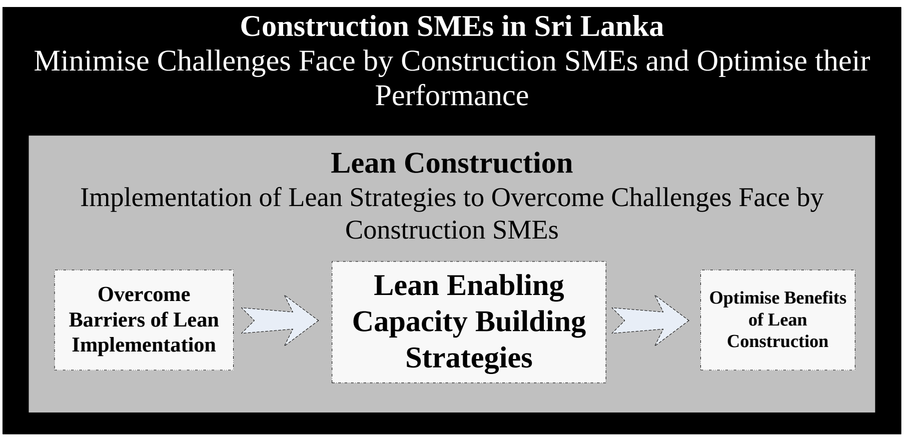

Figure 2: Conceptual model for lean enabling capacity building for construction SMEs

According to Figure 2, outer square of the conceptual model shows the nature of construction SMEs and challenges face by them. Literature review revealed that, construction industry can overcome most of the challenges by lean implementation and it shows in the inner second layer of the model. However, construction SMEs lack capacities to enable lean in the construction industry. Therefore, it is important to investigate lean enabling capacity building strategies. As per the conceptual model, it is expected to overcome barriers of lean implementation while optimizing the benefits of lean construction through lean enabling capacity building strategies. The strategies needed to be identified from further research.

7. Conclusion and Directions for Further Research

Lean construction and capacity building are relatively new approaches to the construction industry. However, there has been a remarkable increase in lean implementation in construction industry during last few decades. Hence, this paper critically reviewed the current state of construction SMEs to identify the challenges faced by them and how lean implementation can solve the aforementioned challenges. Many researchers highlighted the importance of implementing lean concepts and building capacities in construction SMEs. Hence, it is essential to identify capacities necessary to overcome the barriers of lean implementation in the construction industry.

Even though, lean and capacity building related literature is present worldwide, there is a lack of research in lean enabling capacity building strategies that enable lean in construction SMEs. Hence, a proper empirical study required to recognize the real situation. Subsequently, drivers, benefits and barriers for lean enabling capacity building strategies need to be exposed. As better lean practices can be achieved through capacity building, construction SMEs need to focus on lean enabling capacity building in order to be competitive in the construction industry. This paper is based on literature review in order to develop the conceptual model for the study. The developed conceptual model will guide further researches. Our future research will target the development of a lean enabling capacity building model with strategic guidelines for construction SMEs.

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