THE PRACTICE OF SUSTAINABLE CONCEPTS IN HIGH DENSITY RESIDENTIAL PROJECTS IN SRI LANKA

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Degree of Master of Science in Project Management

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DEDICATION

To my husband and sister

ACKNOWLEDGEMENT

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ABSTRACT

The Practice of Sustainable Concepts in High Density Residential Projects in Sri Lanka

There is a rapid interest in building sustainable green homes at present, but developers and contractors are reluctant to implement these practices, as the general perception is that the initial costs are high to use in smaller buildings such as residential builds. The study conducted was to determine the decision making process of developers and contractors on sustainable practices in large-scale residential projects.

A residential sustainability survey was conducted to ascertain certain factors that relate to sustainability. The participants were members of the ICTAD (Institute of Construction Training and Development), Grades C1 and C2 developers and contractors and also non ICTAD members selected through Sri Lanka Institute of Architects (SLIA) registered members and firms. The sustainability survey was categorized in to different levels by experience with sustainability, frequency of use, familiarity with sustainable practices, importance of implementing sustainability within the company or individuals, experience and opinions on the subject.

By conducting the survey the purpose was to compare and analyse and thereby identify the hesitations, cost conflicts, confusion with regard to residential sustainability and levels of integrations.

The study revealed that the respondents believed that the cost was most important but also indicated that they believed that it is important to build green to help the environment. They all agreed that sustainable builds were more complicated to design and build and cost more. Based on the survey there was an indication that developers and contractors had experience and was familiar with sustainability.

This study was also built upon existing research on rating systems that are applicable on sustainable practices and other sustainable practices present in the residential sector.

Key words: *Sustainable practices, rating systems applicable on sustainable practices*

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LIST OF ABBREVIATIONS

Abbreviation	Description
ICTAD	Institute of Construction Training and Developments
C1/ C2	Grading Scheme for Contractors, developed by the Institute of Construction Training and Developments (ICTAD)
SLIA	Sri Lanka Institute of Architects
GSHP	Ground Source Heat Pump
USGBC	United States Green Building Council
NZEH	Net-Zero Energy Home
LEED	Leadership in Energy and Environmental Design Green Building Rating System, developed by the U.S Green Building Council (USGBC), providing standards for environmentally sustainable construction
LEED-H	Leadership in Energy and Environmental Design Green Building Rating System that promotes the design and construction of high-performance homes
LEED-AP LEED	Professional Accreditation distinguishes building professionals with the knowledge and skills to successfully steward the LEED certification process.
ISO	the International Organization for Standardization
GBCSL	Green Building Council of Sri Lanka
GREEN-SL	Green Rating Systems, developed by the Green Building Council of Sri Lanka (USGBC)
LCA	Life-cycle Assessment
PV	Photovoltaic
Rating Avg.	Rating Average is a weighted average per column and row based on rated scale
BEES	Building for Environmental and Economic Sustainability
BMS	Building Management Systems
HVAC	Heating, Ventilation, and Air Conditioning Systems
IRC	International Residential Code
IECC	International Energy Conservation Code
GHG	Greenhouse gasses
EMSI	Environmental management information system

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CHAPTER 1

INTRODUCTION

1.1 Background

The global demand for building construction has increased rapidly over time with social and economic progress. The growing trend towards sustainable structures which meet the needs of the present without compromising the ability of future generations to meet their own needs has become important because of devastating climate change and scarce resources, leading societies around the world for sustainability. Even though sustainability does not impose a constraint to the construction industry, the building sector has a strong global potential to help protect the environment and by that increase the comfort and wellbeing of its occupants. Therefore in an environmentally unstable world, change in construction industry will be towards sustainability.

Sri Lanka has undergone rapid industrialization since the early 1980's, the per-capita income has almost doubled from 1985 to 1995 (Ileperuma, 2000). The liberation of the economy has increased the demand for domestic energy and the construction industry (Ileperuma, 2000). The population of the country meanwhile has increased from 14million in 1976 to the present 20.90million and is expected to peak at 21million in 2020. Sri Lanka already has one of the highest population densities in the world. Out of total greenhouse gas emissions, households produced 20% (Ileperuma, 2000). More and more houses will be built each year to accommodate the influx of new residents. If these developments are not built sustainably, they will become more and more expensive to build and also to maintain. Therefore the need for sustainable housing is critical in Sri Lanka (Kibert, 2008).

Sustainability is a term with a many definitions. Brandon points out there are existing definitions, but all are open to interpretation on key words or phrases (Brandon, 1999). How can sustainability verify effectiveness, there are different interpretations of what is sustainability? There is a balance between economic, social, and environmental factors, but the key is finding equilibrium (University of Michigan, 2002). Nature of the construction industry leads green buildings to be measured and quantified in order to prove that sustainability has enough foreseeable benefits for the developers, contractors and owners.

1.2 Problem Statement

Although there is a trend in “building green” the concept of sustainable development has evolved greatly since it was introduced and can be complex and challenging in many ways to implement. There is a debate over sustainability in designing and constructing of residential structures as they are smaller in scale and varies from site to site, and therefore difficult to make estimates in costs. Although there are sustainable rating systems such as the Leadership in Energy and Environmental Design for Homes (LEED-H) offering certification levels for residential buildings, most building professionals including building contractors and building designers find it challenging to meet all requirements needed. Extra expenses in initial cost being high to implement sustainability in a smaller scope of work is one of the main reasons why one would think that it would be difficult to do so in residential projects. However, that assumption could not be further from the truth. Embracing sustainable building has been shown to save money in the long run.

Building green could be complex and challenging to build in residential projects due to: difficulties in cost estimating (since residential projects are unique to one another), clients requirements (ex: restrictions on cost etc.), initial cost in sustainable practices, lack of knowledge on sustainable practices (ex: general public, contractor, developers, skilled labour etc.) and knowledge in green rating systems (developers and contractors).

1.3 Purpose of Study

The study was conducted to understand the decision making process from the contractors' point of view on residential sustainability by asking residential contractors and developers who are registered members of the Institute of Construction Training and Development (ICTAD) under grades C1 and C2 to assert various concepts and topics in sustainability (Institute of Construction Training and Development 2009). A number of non-members were also selected for the study.

The residential sustainability survey was categorized into different levels based on frequency, opinion, importance, experience and familiarity. Case study approach was elaborated in the research methodology. Data gathering was done by person to person semi-structured interviews and by telephone interviews.

This study will fulfil the need for clarification in green design and construction in housing projects with the outcome being useful for finding out the best practices that suit Sri Lanka. It aims to identify the reasons for not incorporating frequently sustainable design concepts by residential developers and contractors on residential projects in Sri Lanka.

This study is built around existing research on the applicability of rating systems and other sustainable practices withstanding in the residential sector.

1.4 Aim and Objectives of the Study

Aim of the study is to identify the reasons for not incorporating frequently sustainable design concepts by developers and contractors in high density residential projects in Sri Lanka.

Objectives of the study are as below:

- To define what is sustainability in design and construction field.

- To determine the residential contractors' and developers' knowledge of sustainability in design and construction based on: occurrence, importance, opening, experience and frequency.
- To determine the level of knowledge of sustainable rating systems among contractors and developers.
- Determine the practice of sustainable concepts by developers and contractors in large scale residential projects in Sri Lanka.

1.5 Scope and Limitations

The scope of this research is specially focused on the contractors and developers perspective, in sustainable housing projects in Sri Lanka from 01.03.2013 to 01.03.2017(projects both completed and under construction). The data collection was focused on ICTAD registered (2017) graded C1 and C2 contractors and developers, as well as non-members of ICTAD were selected by contacting architectural firms and architects who are registered under Sri Lankan Institute of Architects (SLIA). The selections of non-members were due to the fact that some of the large scale residential project contractors and developers were not registered under ICTAD and their capacity were defined based on 40 or more dwellings constructed within the last 4 years (2013 to 2017). ICTAD graded C1 and C2 contractors and developers were selected mainly to concentrate the study on large scale residential developments and also due to their involvement from inception to completion, marketing phase of a project in most instances.

1.6 Research Methodology

Literature Review

As the first step through the literature review, the definition of sustainability, sustainability concepts and sustainable rating systems used in Sri Lanka were examined through books, journals, online publications, written thesis and by case studies.

Questionnaire survey

Firstly, telephone interviews were carried out to verify the literature findings and to understand the residential developers and contractors knowledge of sustainability in design and construction based on: importance, opinion, experience and frequency. Above information were gathered through a questionnaire. Analysis of questioners provides answers to “why residential developers and contractors do not use frequently sustainable design concepts in Sri Lanka”.

Secondly, semi-structured person to person interviews were done to understand the respondent’s knowledge of sustainable practices, methods and also conclusions to go towards green designs in residential construction. Semi-structured interviews were carried out after identifying telephone survey issues and as solutions were validated and expressed by professionals.

1.7 Chapter Breakdown

Chapter 1 – Introduction

The first chapter comprises of the background of the research, problem statement, purpose of study, aim and objectives, scope and limitations of the research, methodology and chapter breakdown.

Chapter 2 – Literature Review

The chapter provides a comprehensive review on the current status on sustainable practices on construction filed and the need for sustainability on residential projects. The chapter comprises of defining and designing sustainability, active and passive systems for sustainable residential design and construction, rating system for sustainable design and construction, refining sustainability and pricing sustainability.

Chapter 3 – Research Methodology

The chapter elaborates the method of finding relevant data to achieve research needs and objectives.

Chapter 4 – Research Findings and Analysis

The chapter discusses about the collected data and various interpretations and analysis with regards to collected data.

Chapter 5 – Conclusions and Recommendations

The final chapter concludes the research with conclusion, recommendations and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A brief introduction to the background of the research was delivered in the first chapter. This chapter signifies the background solely by elaborating existing literature defining construction developers and contractors, sustainability and the need for sustainability. This chapter also consists with findings of systems for sustainable residential design and construction and sustainable rating systems used in Sri Lanka.

2.2 Defining Construction Developer and Contractor

Construction Developer

Construction developer can be a project owner or both contractor and the owner of a development project. The developer pursues profits from development of the land or selling a development (homes, apartments, commercial buildings etc.) or holding the development to gain a return on investments. In this research we are concentrating on residential developers who are actively involved in the process of a construction project from inception to completion as well as the marketing phase (Collins Dictionary of law, 2006).

Construction Contractor

A contractor (main contractor or prime contractor) in the residential sector is responsible for the daily oversight of construction site, management of labour, managements of venders and sub-contractors, and communicating with relevant parties and providing necessary contributions throughout the course of a building project. In this research we have selected contractors who contribute from inception to completion of a construction project (Collins Dictionary of law, 2006).

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2.3 Defining and Designing Sustainability

Housing is one of the basic necessities that help towards the wellbeing of people and their quality of life. Where, how homes are located and built, and its relationship with its environment influence people in their daily lives. A home is a part of the relationship people have with their environment therefore the concept of housing needs to have a different understanding, so by pressing issues such as overcrowding, urban divide, and climate change and pollution could be addressed effectively.

Climate change has become a serious and urgent issue. A large percentage of carbon dioxide emissions are produced in our homes by energy we use for heating, lighting and other ways energy is used around the house. Therefore it is vital that new homes are built in a way that energy is used at a minimum that in term would reduce the emissions that are harmful to the environment. With integrating high sustainable building standards in the design of the build will improve the overall wellbeing of its inhabitants (Kibert, 2008).

Sustainability is a term that has many definitions. There are existing definitions, but all are open to interpretation. It is a developing concept that is constantly changing.

"Meeting the needs of the present without compromising the ability of future generations to meet their own needs" This definition was endorsed at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (United Nations Division for Sustainable Development, 1992).

Since natural resources are depleting fast, "building in a better way by buildings being less energy intensive with locally sourced materials together with taking care about the complete lifecycle of the materials and its transportation, by optimising the production in order to lower our environmental footprint"(Roaf, 2004), Would be another example of a definition of sustainability with regard to building and construction.

Buildings heavily contribute to the degradation of the natural environment. A large percentage of the total energy consumed is through buildings. People have been aware of this fact in the recent years and the interest in building high performance buildings have grown significantly. Many successful new building projects have been completed all over the world. Most home builders in different countries are encouraged by governing bodies as it is believed that it would be mandatory in the future to asses all home builds on its sustainability standards. A set of sustainability design principles on design categories such as pollution, carbon dioxide emissions, materials, water, waste, ecology, wellbeing and management can be introduced as a code to adhere to or a rating system that would communicate the overall sustainability of a home (Roaf, 2004).

It is a challenge for most countries to provide sustainable housing to its people but more so in developing countries such as Sri Lanka. Population growth together with people migrating from remote to urban areas drives rapid urbanisation. The informal housing such as in slum areas found in most urban areas such as Colombo, Sri Lanka inhabited by the disadvantaged pose environmental problems for present and future generations. Sanitation issues and pollution which includes air and water pollution from sewers and garbage, health risks and injuries due to poor construction, hazards such as flooding and landslides, further risks such as crime and anti-social behaviour due to overcrowding are some. Some problems highlighted above are not limited to slum or urban overcrowded areas. Some low income housed located in areas such as hilly areas can be exposed to landslides that occur killing unsuspecting residents. Homes located closer to rivers carries a risk in flooding (Goonetilleke, Thomas, Ginn, and Gilbert, 2004).

Many developing regions with increasing awareness have recognised that the housing policies need to be changed bridging sustainability and affordability. If planned and built within an integrated sustainability frame work, it will not only be affordable to low income families but will also have them, multiple positive outcomes (T. Sugathapala, 2014).

Sri Lanka being an island located towards the south of the Indian sub-continent. It is a country that receives year around sunshine, rain and wind. All the natural resources the country has ideally should be made use of to harness energy. As things are, Sri Lanka generates more than half of it energy requirements through renewable resources such as bio mass and hydro. The balance is generated through imported fossil fuels. This makes the country very vulnerable to the fact that it drains the country's foreign reserves, which is scarce. The price fluctuations of the fossil fuel imported greatly effects price of the energy generated. Biomass, hydropower, wind power and solar power should be the main areas the country should look at as high potential productive methods that should be used in Sri Lanka (T.Sugathapala, 2014).

It is indicated that wind power turbines had a large potential in Sri Lanka. The use of wind energy by the ancient Sinhalese has been discovered to exist as far back as 300 BC. There is evidence of that found in Anuradhapura and other cities. Although there had been numerous local and international investors interested in establishing wind farms in Sri Lanka, such developments faced many obstacles due to economic and infrastructure issues. Hydropower generation is been used extensively throughout Sri Lanka where it had been largely developed over the years. Both larger government owned plats and small private hydro facilities exist. Currently ten large governments own hydroelectric power stations are in operation with the largest being the Victoria Dam. Studies are also conducted presently to ascertain whether there are petroleum resources within the Sri Lankan territory waters. Thermal power sources consist of all Fuel oil including diesel and coal. The thermal power station in Sri Lanka closely matches the capacity of hydroelectric. The only coal plant in Sri Lanka is the Norocholai coal power station. It would be ideal if a balance between imported fossil fuels and naturally sourced energy resources could be managed strategically to generate energy through the growing economy of the country (Brandon, 1999).

Sri Lanka will have to face many challenges with regard to ensuring continues supply of electricity and petroleum products. Sri Lanka's power generation is heading for crisis with hydropower generation is at its all-time low in the recent years due to technical issues and costs being high. Adding to that the water levels of reservoirs dropping over the years have contributed to the fact that water levels of reservoirs are seasonal and depend on rainfall during monsoons. Although the cost of thermal power production is high the country has had to increase thermal power so as to ensure the country could manage even when water levels are low.

Sri Lanka's main energy source or the most common energy source is biomass. The majority of the usage is domestically for cooking. The exact usage of bio mass energy is not accounted for as a very small percentage of bio mass is sold or channelled through a market. Sri Lanka has an abundance of bio mass as it is mainly an agricultural country. The waste from agricultural crops such as paddy, rubber, tea and coconut can made use of as bio mass. Municipal solid waste could also hold potential to be used as bio mass as large quantities are accumulated in urban areas.

The population in Sri Lanka has been growing steadily over the years. The population growth was last measured at 0.76 in 2013 according to the World Bank. Keeping up with the energy requirements of the future may depend on focusing on sustainable renewable energy sources, which could implement residential projects as well (World Bank International Energy Agency, 2014).

2.4 Active Systems for Sustainable Residential Design and Construction

Active Systems for Sustainable practices are mainly mechanical controlled systems (heating and ventilation systems, Light controls, occupancy controls, demand management etc.) to sustain comfort zones in a building. There are many sustainable techniques available when building a high performance home. One of the first steps toward sustainable residential design and construction is to understand where a home needs to change. One of the first ways to save energy in a home is by looking at its heating and cooling of space and the water heating system. The next process would be to ensure that the major appliances, equipment and lighting are at an optimum efficiency (Brown & DeKay, 2001).

Ground Source Heat Pump (GSHP) is one possible source of heating that could be used in a home. Here the heat is extracted from the ground, which also runs in reverse during a warmer climate to provide air conditioning, depositing heat from the home in to the ground.

Solar photovoltaic technology in residential buildings is mainly used for lighting. It is a fairly new concept for the application of solar power. It requires installing the solar photovoltaic phalanx on the structure of the building to harvest electricity.

The main use for solar photovoltaic technology in a residential building would be for lighting by guiding natural light through a light guide tube which intern improves daylight issues in a building such as in an underground room. It is suitable to use in an environment where there is an abundance of natural light (Parker & Dunlop, 1994).

Wind energy harvesting is another sustainability technique that could be integrated to a home. Electricity can be harvested in a residential project by a small-scale wind turbine. It harnesses the power of the wind and uses the same to generate electricity. Wind energy can be harvested in an environment where there is a lot of wind energy. Domestic wind turbines are known as micro wind or small wind turbines. If one is in a typically appropriate site, it can easily generate more power than what is normally consumed in a domestic environment. Wind energy is green, renewable energy which does not release any carbon or other pollutants in to the environment (Edwards, 2003).

The Net –Zero Energy Home (NZEH) is a home that creates as much energy as it uses. These homes minimise energy usage through efficiency and through renewable energy systems (NZEH Coalition, 2009). It is important that all the energy requirements of its residents are met in such a home. Usually a net Zero energy home would be built up to LEEDS platinum standard, which is the highest standard for sustainable structures (USGBC, 2008). Furthermore the building would be well insulated to avoid heat losses from walls as well as the roof, sufficient number of solar panels and equipped with energy efficient appliances. The solar panels produce more energy on certain days than others therefore when the energy yield increases the house injects electric power to the grid. Solar energy is clean, non-polluting and easy to get especially in a country such as Sri Lanka. The tropical climate permits for large amounts of sunlight throughout the year, making this an option. Installing solar panels to a roof of a residential building requires it to be integrated preferably in the construction process of the building. It can be also set on balconies or any other exterior walls where ample sunshine is available. Although the initial cost of installing solar energy equipment is high in a residential building, with the use of solar energy, the benefits that generate from its energy conservation and environmental protection will be increasingly apparent.

A net zero energy home would have a monitor where the residents could find out how much energy they are consuming, accordingly they can make simple changes to lower their energy consumption. As mentioned before another option would be to use GSHP for heating water. Both these options would not be viable if the water consumption is high.

Integrating energy efficient technologies by the installation of high efficiency air conditioning systems and where appropriate high efficiency hot water heating systems, installing energy saving kitchen appliances such as ovens and dish washers, low flow plumbing fixtures and dual flush toilets and installing light fixtures with daylight sensors with all exterior lighting, using compact fluorescent lights where appropriate are some of the energy efficient technologies that can be used in residential buildings.

2.5 Passive Design for Sustainable Residential Design and Construction

A passive design system for sustainable practices derives from finding solutions for four key building envelop issues; water, air, vapour and thermal. As an example sometimes the actual construction process of the house creates environmental issues such as noise pollution, dust and harmful contamination of water. Construction waste is sometimes dumped illegally in to rivers. Pre-fabricated housing construction could be an alternative, which could potentially be made environmentally sustainable and cost effective. The advantages would be off-site technology, reduced energy consumption with regards to the number of deliveries, less site disturbance and better control over the materials used. Passive designs are mainly built around four external envelop issues such as water, air, vapour and thermal conditions.

“Green Homes” or NZEH (Net-Zero Energy Homes) as mentioned before does not require to excessively use new techniques or systems to reduce energy consumption, but merely allows a look in to every possible opportunity to reduce the need for energy. Even though every home is different when it comes to location, site and climate, it has an opportunity to save energy and produce renewable energy. Exterior walls are a large component of a home that is exposed to the outdoor elements since the walls are penetrated with windows, piping, wiring but still need to maintain a good amount of insulation. High-energy efficient building envelope will permit for lower variations in temperature conditions in the interior spaces and reducing solar gain (Brown & DeKay, 2001). Placing windows in a specific way where negative and positive pressure zones would be created that will induce wind flow through the building. The floor plan for the building should also maximise solar gain (Chiras, 2003).

Another passive system option is having a green roof (USGBC, 2008). Green vegetative roof of a home would reduce the heat of the building during hot weather and also make the building more pleasing to the eye. A green roof would reduce the amount of water by acting as a sponge. The soil and the vegetation will absorb and filter water that would normally run down the gutter. A properly maintained roof garden can reduce energy costs by 10% and reduce storm water runoff by 90% (Kilbert, 2008).

Water in a residential building is used typically for cooking, cleaning, laundry, gardening, bath and shower, toilet and loss of water due to leaking. Sustainable practices such as reuse of water, installing water meters, minimising leaks, water saving installations in the house and rainwater harvesting would reduce water consumption (American Hydrotech Inc., 2008). Rainwater harvesting not only would save money with regard to water bills but would also help protect the environment. Rain Water from the roof down a drainpipe, through a sealed gully stored in to a tank below ground, so that there will be no light or temperature variants to change the quality of the water, would be an excellent method to harvest rainwater in a residential project.

2.6 Rating systems for Sustainable Design and Construction

In high density residential projects developers and contractors does not always have a fix clientele to buy houses. Therefore, the focuses on marketing aspects are high. Rating systems has become a world rewound marketing tool, which gives opportunities to build towards sustainability. Therefore, this chapter elaborates literature on few sustainable rating systems which are practice in Sri Lanka.

There are several rating systems as options for developers and contractors to regulate sustainable design and construction (Table 2.1). They cover similar assessment scales, topics and issues. One example is the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design for Homes (LEED-H) rating system. LEED-H is very efficient in identification and preparation stages of a project. The Leed's City Office Park, by Peter Foggo Associates, is an example of integration of sustainable design aspects to a building project. This project proves the cost of green buildings can offset by the operational cost savings during the first few years (Edward, 2003).

LEED-H- assessment evaluates the project and looks at the level of certification sought. The rating system presents an indicator of relative building performance by awarding a building a certificate according to how many required number of green building 'measures' are incorporated in to the build. As the rating level increases the design is expected to be more sustainable together with the design cost to be higher. It is understood that the build will offer more benefits and cost saving over time by incorporating higher levels of LEED. This point system covers performance in five areas of human and environmental health: energy efficiency, water saving, sustainable site development, materials selection and indoor environmental quality (Cassidy, 2008). An overview of the LEED-H can be found in Appendix A. The LEED levels of performance range from Certified, Silver, Gold and Platinum based on the points earned. Platinum is the highest (USGBC, 2008).

International organisation for standards (ISO) is an independent, non-government Organisation. It is the largest developer of international standards with a membership of 163 national standard bodies. More than 100 building standards have been developed by ISO. An ISO standard impacts everyone everywhere. It is there to safeguard consumers and any other end-users by giving international specifications for products, services and systems, to ensure quality, safety and efficiency. ISO standards make trade between countries easier. Their standards also aim to make transferring technology between two countries easier.

Sri Lanka Standards Institution (SLSI) represents Sri Lanka at the ISO as the member body. Sri Lanka Sustainable Energy Authority together with Sri Lanka Standards Institution provides technical expertise to promote ISO Standards in Sri Lanka.

ISO rating system is used in Sri Lanka to encourage developers and contractors with general principles and guidelines of sustainability in buildings and civil engineering works. It provides the government with a technical base for environmental legislation and health and safety. Implementing ISO standards in Sri Lanka not only provides technical advantages but also economic, social and environmental gains for consumers. Adhering to ISO certification is also a vital tool to strategically gain an advantage on securing a reputable cooperate image and a competitive long term advantage over others who does not follow ISO standards.

ISO 14001 is designed for any organisation who wants to show their Customers, insurers, financiers, public and also other regulators that they are committed to following standards of environmental management. The ISO 14001 standard is an environmental management system that encourages efficient use of resources and reduction of waste. An increase in Environmental performance and improvement in working conditions will uplift the image of the company which in turn would create market opportunities, reduce environmental complaints, have a better relationship with environmental regulators and reduce operational costs.

ISO/TC 163 looks at Thermal performance and the energy use in a built environment.

Energy performance comprises: Heating, lighting, ventilation, cooling, Domestic hot water and Appliances (International Organization for Standardization, 2007).

Some of the topics covered are; standards of thermal performance of materials, components, systems ,products of new and existing buildings, thermal insulation materials, calculation methods for heat and moisture transfer, calculation methods for energy use in buildings, methods for cooling and heating and calculation, ventilation and specifications for thermal insulation material. ISO / TC 205 deals with standards of building environment design. These standards help calculate and test building elements and address environmental concerns. It offers a comprehensive methodology for the design of high-performance indoor environments. ISO/ TC 205 collaborate closely with ISO/TC 163, especially in the adoption of new work items which are essential to improve the standards of the design process.

Much progress has been made in providing the right tools for the building industry to ensure sustainable buildings. ISO needs to be ready to respond to fast evolving technology, and other challenges to meet the needs of this day and of the future Appendix B (International Organization for Standardization, 2007).

Another example for sustainable rating systems is Environmental Management Information System (EMIS) is an information technology solution for tracing measurement of environmental pressures (El-Gayar & Firit, 2006), the state of the environment and the impacts on ecologies as part of their overall environmental management system. The main goal of this system is waste reduction to reduce hazard’s environmental impact and also to develop, implement, manage, coordinate and monitor environmental policies (El-Gayar & Firit, 2006). This system improves environmental performance and information on designing, pollution control and waste minimization, training, reporting to top management, and the setting of goals. Also in a project to organization's environmental affairs, overall management structure that addresses immediate and long-term impacts of its products, services and processes on the environment, assists with planning, controlling and monitoring policies. This system is becoming well known as a web-based response for Greenhouse gasses (GHG) reporting rule, which allows for reporting GHG emissions information. EMIS also encourages contractors and suppliers to establish their own EMIS.

Further option is GREEN-SL rating system, which is a green environmental rating system applicable to Sri Lanka. This rating system has been formulated by conducting research projects and workshops by an expert committee appointed by the Green Building Council of Sri Lanka (GBCSL).

It is for existing and new buildings where a set of performance standards is used to certify commercial, institutional and residential buildings of any size. GREEN-SL is a tool that helps to create a high-performance, more sustainable built environment by Providing a framework for design, construction, and evaluation. It is up to green building professionals to use this tool as part of an integrated planning and design process to achieve real results on the ground. Green building requires integrated approach, but in practice it depends on new strategies in the various aspects of design and construction. Accordingly, the heart of this rating is an introduction to the eight categories used in GREEN-SL namely, Management (MN), Sustainable sites(SS), Water efficiency(WE), Energy & atmosphere (EA), Material & Resources (MR), Indoor environment quality (EQ),Innovation & design process (ID) and Social & cultural awareness(SC). The intention is to encourage developers to implement sustainable practices that would reduce the negative environmental impact throughout the lifetime of the building. The rating system of the GBCSL consists four categories determining points (total points 100) that are obtained by the project.

Categories and required points to obtain a rating are platinum, gold, silver and certified Appendix C (GBCSL, 2015).

Above researched sustainable rating systems are generally used and practiced in Sri Lanka. As further analysis of discussed rating systems, similarities and overlaps of categories in residential sustainable rating systems are looked at in Table 2.1.

2.7 Refining Sustainability

Houses with energy-efficient design are a form of insurance against future high power prices. The key to the creation of such dwellings is usually a clever combination of both sustainable design (passive energy savers) and active systems working in unison. There are few indicators of sustainable practices such as:

- Reducing operational design cost - cost of green design will reduce with increase experience in building green in design and constructions.
- Minimizing operational cost - on average green buildings use 30% less energy than conventional buildings. More likely to generate renewable energy on site and also to generate grid power. The financial benefit of a 30% reduction in consumption is equal to or more than average additional cost associated with building green. (G.H. Kats, 2003).
- Reducing emissions - as a result of producing renewable energy on site (i.e. sola power) assists in minimizing emissions caused by using electricity generated by fossil fuel (G.H. Kats, 2003).
- Reducing water usage – Rain water harvesting, drip irrigation on garden areas and use of water saving fittings and accessories, waste water treatment systems are some areas to consider in the residential sector
- Reducing waste – waste segregation, use of bio-degradable materials on sites, reusable construction material and pre fabrication of materials to reduce site disturbances and pollution.

- Health Benefits – much lower source emissions from measures such as avoiding air intakes next to outlets, such as parking garages and avoiding re-circulations, improved thermal comfort and better ventilation (G.H. Kats, 2003).
- Better lighting quality – use of more day lighting, better daylight harvesting and better shading, greater occupancy controls over light levels and less glare (Kibert, 2008).

Many consider active sustainable systems in a house is a realm of prohibitively expensive photovoltaic panels, wind generators etc.. In fact, the easiest energy and water efficiency gains are made through carefully choosing the optimal existing design choice and then, in addition, making allowance for the integration of appropriate active systems. Truly sustainable houses integrate passive and active initiatives to create harmonized systems where energy use is reduced through as many methods as possible. In high density residential projects architects, developers and contractors are in a prime position firstly to encourage clients to choose sustainable options and secondly to ensure the strategic integration of environmental systems into their designs.

It is important to tackle early in the design phases the impacts of certain design decisions with respect to economic and the environment (Kibert, 2008). Systems such as the GREEN-SL rating system help apply life – cycle assessment (LCA) to measure the environmental performance of a building.

The economic benefits depend on initial cost, maintaining and operating costs and economic performance of the entire lifecycle of the building. High performance sustainable buildings improve the health and productivity of its occupants by improved lighting and ventilation systems. The occupant’s degree of satisfaction further increases with improved thermal comfort, acoustics and a number of other good indoor environmental benefits (Wu, Chan, and Shen, 2003). The building's design respects the local natural, economic, social and cultural surroundings such as protecting the natural scenery and working with the local climate, materials, technologies and terrain.

Safety, security, functionality and accessibility of a sustainable dwelling benefits its occupants providing physically and mentally a healthy place to live. Valuable information regarding the sustainability of their new home will give them a sense of satisfaction in choosing to live in a sustainable home.

Some of the other benefits of a sustainable project would be that the resale value of such a project would be high. The increasing attention of the concerned public and the Media has created an appetite among the consumers to buy sustainable homes as the overall quality of the homes are thought to be high, as they are expected to be built to a certain standard (GBCSL, 2015) .

Movements to reuse and recycle have encouraged designers and developers to think about what happens to the materials at the end of a building's life cycle. The land fields have been growing while the raw materials are depleted over time. Extending the life of raw materials can help with reducing emissions and energy required to make new materials (Ileperuma, 2000). The reuse of materials in construction is a necessity that needs to occur worldwide. A building that is designed with LCA in mind would focus primarily on the possibility of recycling of the materials used in the building. Sometimes the existing building materials of a demolished building can be utilised in the construction of the new building. Local resources such as timber from the surrounding areas could be used. Ideally it would be possible to dismantle the building in such a way where it can be recycled in the future. Glencoe Visitor's centre in Scotland is a good example for a building designed with LCA in mind. Primary concept of the designer is to use recycled materials and also to build as it could be dismantled easily to recycled later (Sassi, 2006).

The benefits of building green includes, cost savings from reduced energy, water and west. Lower operational cost, total financial benefits of green buildings over 10 times the average initial investment required to design and construct the sustainable building (G.H. Kats, 2003).

2.8 Pricing Sustainability

Sustainable concepts on residential sector often go hand in hand with cost. It has been evident in correspondence to find solutions to implements cost against sustainable concepts. Sustainable Construction requires a long-term view, considering initial capital cost, against running costs of the structure. It is perceived that the short term costs of a sustainable build are too high to justify their use in a competitive market, therefore there is a lag in the application of sustainable practices that improve building performance. This is also due to the lack of client demand and the belief that such methods are more expensive than the traditional construction methods. Sustainable developments are sometimes viewed as vague concepts; therefore people define it to suit their own interests. The idea of a "green building" is relatively new to architects and investors therefore building professionals maybe reluctant to pursue such a project.

Developers are sometimes reluctant in revealing information on costs. As a result, information on the costs of sustainable building has begun slowly. It is realized now that some requirements that were once assumed to increase costs are proving to be cost neutral. It is a fact that some energy efficient designs could be achieved at a lower cost than conventional design. In certain instances achieving higher green building ratings can be achieved at little extra cost.

Different sustainable practices in certain instances can benefit the pricing of constructions. It was confirmed by an analysis of green roofs by Nelms (2008) that the application of a green roof on a low-rise building such as a residential build, had a five times greater benefit than for a high rise building. Depending on the structure and the soil in a green roof it can sometimes capture between 50% and 90% of a rainfall. This waster can be collected and used in other ways to lesson costs (American Hydrotech, 2008). The application of high efficiency domestic appliances is another technique that would have a decrease in energy usage and low utility costs (Parker & Dunlop, 1994). Energy star rated appliance are the most technically advanced appliances available.

The perspective of the developing countries would be different in implementing sustainability in residential projects as priority is usually given to meeting basic needs of its citizens. Materials used in constructing sustainable equipment can be exotic materials, which are rare such as cadmium telluride used in solar panels. Although materials can be found easily in urban areas, the same cannot be said about the rural areas. A lot of the Eco friendly materials may not be available and transportation could be expensive. These factors can also affect the time frame of the actual build time to be longer.

Housing projects in developing countries such as in Sri Lanka most often provide accommodation of low standards in remote locations with limited consideration for its inhabitant's livelihood or wellbeing. In most housing programmes where many homes are built rapidly in close proximity to each other often creates a larger carbon foot print than a conventional build. Affordable housing is considered a social burden by most developing countries. It needs to be recognised that it is only through sustainable solutions that social development and improved economic prosperity can be unlocked.

2.9 Summary

This chapter elaborate the literature review as a comprehensive study on the current status on sustainable practices on construction filed and the need for sustainability on residential projects. Sustainability defined as "Meeting the needs of the present without compromising the ability of future generations to meet their own needs" refines the need to act fast on sustainable construction projects in Sri Lanka, giving examples of sustainable systems (passive and active systems) to implement on design and construction projects and also stating the importance of sustainable aspects as in long-term views of sustainability, considering initial capital cost against running costs of the building, energy saving techniques and appliances are some of the elaborated research areas in this chapter.

CHAPTER 03

RESEARCH METHODOLOGY

3.1 Introduction

The objective of this analysis is to find out how sustainable design is being applied to the residential construction industry. This chapter elaborates the method of finding relevant data to achieve research needs and objectives. Analysis will confirm facts based on the respondents (residential developers and contractors) whether the green design expected by the residential sector, whether it will be a profitable venture and whether is it practical enough to build green concepts in residential projects in Sri Lanka.

3.2 Research Design

Research Aim of the study is to identify the reasons for not incorporating frequently sustainable design concepts by developers and contractors in high density residential projects in Sri Lanka. The objective of this analysis, is to find out sustainable practice by developers and contractors in large scale residential projects as below:

1. To define what is sustainability in design and construction field.
2. To determine the residential contractors' and developers' knowledge of sustainability in design and construction based on: occurrence, importance, opening, experience and frequency.
3. To determine the level of knowledge of sustainable rating systems among contractors and developers.
4. Determine the practice of sustainable concepts by developers and contractors in large scale residential projects in Sri Lanka.

Research is a process that requires a plan to carry out the research successfully. Figure 3.1 describes the research process and the basis for this research. Comprehensive literature review was conducted based on books, journals, reports, case studies etc. related to the research topic to fulfilling some of the objectives. Next established the research design, research approach was selected and research technique to collect data was finalized. Later the collected data was analysed and achieved remaining objectives.

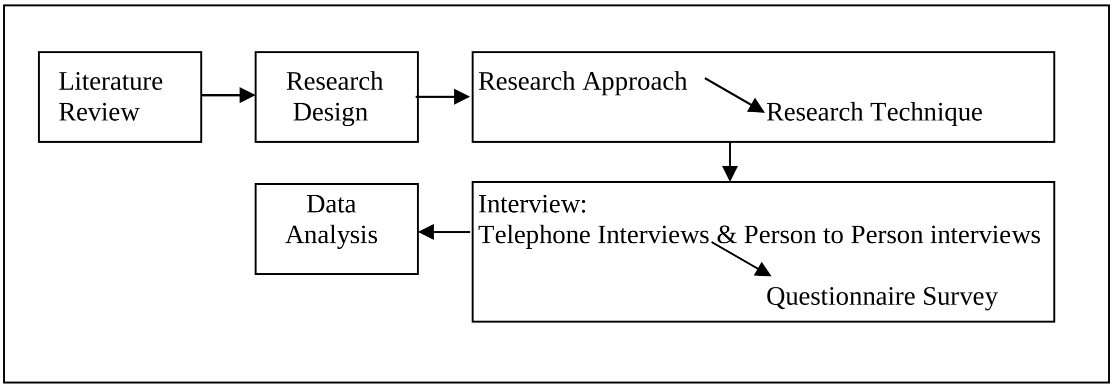

Figure 3.1: Research Process

3.2.1 Research approach

The survey found in Appendix D, is to determine residential developers and contractors views associated with green design and the actions taken to implement sustainable green design. The study measures the company's: experience, importance, opinions, familiarities and frequency of use of sustainability in order to understand the apprehensions, restraints, level of integration associated with residential sustainability in the current housing market. The data collected was entered into these categories. The methodology is as a result of grouping these factors. The procedures to achieve the aim of the study as follows:

A literature review was carried out to determine how sustainability is defined, practiced and how it is marketed. The literature also provided a base to the concept of the survey and the criteria for the study's parameters.

Data will be collected by a telephone-based survey and semi structured interviews, which will be compared against the aim of the study.

The end result of the study was based on the procedures mentioned earlier. The data obtained by the survey helped to identify the need for clarification in green designs in the residential sector. The information would be useful to the home builders industry to understand the best sustainable design aspects and practices, and also to resolve confusion in sustainable designs. In addition the study helped to identify the opinion of sustainability, frequency of the use of sustainability, experience with green buildings, familiarity with green concepts and the importance of sustainability within their company.

3.2.2 Selection of the participants and sample size

The targeted sample for this study is developers and contractors that are in the residential construction field that have or have not applied sustainable green designs in their build. The study concentrates only on high density residential complexes and schemes. Therefore, the selected participants are residential contractors and developers who are registered members (2017 registry) of the Institute of Construction Training and Development (ICTAD), under graded categories of C1 and C2 contractors (sample selection as stratified sampling technique). And also non-members of ICTAD were selected by contacting architectural firms who were registered under Sri Lankan Institute of Architects (SLIA); sample was selection as per Convenience sampling technique. Non-members of ICTAD were selected mainly due to the fact that known large scale residential projects were done by them. ICTAD graded C1 and C2 contractors and developers were selected mainly to concentrate the study on large scale residential developments and due to their involvement in projects from inception to completion.

Firstly, the selection of the sample respondents were carried through ICTAD registered C1 and C2 category (2017 ICTAD registry) contractors, out of 61 contractors and developers only 48 had experience with residential projects in the years of 01.03.2013 to 01.03.2017. All 48 responded to the survey.

Secondly, the selection of non-members of ICTAD was selected by contacting architectural firms were registered members of Sri Lankan Institute of Architects (SLIA). Selected sample for non-members of ICTAD was 10 developers, out of which 7 responded to the survey. Further, as a selection criteria (to define large scale residential contractors) the respondents needs to complete/under construction, 40 or more dwelling with in the years of 2013 to 2017. Therefore the total sample was 58 and out of which 3 did not complete the survey. Responded sample exists of 25 developers and 30 contractors. The survey response rate was 94.8%. Data was collected by person to person interviews: 11 respondents and 44 respondents through telephone interviews.

Research sample was selected through stratified sampling (ICTAD registered members) and convenience sampling (ICTAD registered non-members) method considering the nature and complexity of the construction industry, limitation of time and scope.

3.2.3 Research Techniques

Firstly, a comprehensive literature review was conducted based on books, journals, reports, case studies etc. related to the research topic to satisfy the objectives. Secondly, a research survey was done to establish literature findings and a further analysis to achieve research objectives, to understand residential developers and contractors knowledge of sustainability in design and construction based on: occurrence, opening, importance, experience and frequency and also to understand the level of knowledge of sustainable rating systems among developers and contractors. Further, to understand the views and suggestion from residential developers and contractors, why sustainability is not frequently practiced in residential projects in Sri Lanka.

The survey was carried out through person to person interviews and telephone interviews (refer Appendix D). The survey is directed to a competent, knowledgeable employee who knows the financial and clientele obligations of their company while maintaining a connection to the sustainable design decisions. This study focuses on the researched projects within the years of 01.03.2013 to 01.03.2017 (Projects both completed and under construction). The survey was voluntary with neither financial losses nor gain. There were no associated risks with participating in the survey. The respondent's information was collected anonymously with no obligation to supply all information and with the right to withdraw from the study at any time.

Questionnaire Survey

The person to person interviews and telephone interviews were conducted through questionnaires, mainly due to limitations of time and scope. A structured interview also gives flexibility to moderating during interviews (in comparison to unstructured interviews). The solutions identified to fulfil the objectives on the literature review were further analysed through questionnaire. For further analysis the structured interviews requires ranking. Therefore, questionnaire survey was carried out.

3.2.4 Explanation of survey

3.2.4.1 Demographics

The demographic survey included a number of fill-in-the blank types of questions that would help to gauge the respondent. This section included questions relating to the name of the company, type of company, their scope of work, area of the residence, typical price of residence and the delivery method used.

The respondent's name, and contact information was also requested. The demographic information was used to categorize different companies with regards to their size and volume of work versus their practice in sustainable green design in construction.

3.2.4.2 Likert scale questions for importance, opinion, experience, familiarity and frequency responses towards green design

The questions were to find out the respondent attitude and the action towards green design in their training programmes. The questions were for sustainable practices pertaining to experience were questions in tables 4.1. The performing to opinion were 4.6 tables. The Likert scale questions to find out the familiarity were questions under 4.7and 4.8. The frequency of use of sustainable practices were determined in table 4.9, also it determine the green techniques and how it should be sorted and the governments laws are helping or hindering the design process of green design in the residential construction sector. Questions were raised in table 4.2, 4.3 and 4.4 to find out the importance of green design in the company's mission and the degree of sustainability. Amount of effort put in to green design and find out why design cannot be implemented. This is also to understand why some clients shy away from green design and will help determine whether it will be necessary to include in their products. Knowledge of the respondents was examined through a check list of green building techniques and practices.

3.2.4.3 Close ended questions for familiarity responses towards sustainable design

The ranges of possible choices were extracted from LEED-H guide lines, Green Building Council of Sri Lanka (GBCSL), ISO, EMIS, GREEN-SL and literature review. The respondents could choose from a variety of green building terms.

Respondents were told to different items in numerical order of importance of design, marketing and construction phases. Questions were asked about the importance of sustainable practices under table

4.3, 4.4 and 4.9 by requesting them to prioritise the company's goals and to determine the commitment to green buildings.

3.2.4.4 Open-ended questions for free responses forward sustainable design

Questions were asked to find out the relevant issues and the views of the responder. The open-ended questions were 32, 33, 34, 35, 36 and 37. The questions asked about the systems and the rezones for sustainability and issues that will rise when achieving it. The ideas of the questions were to pursuit the respondent to come out with specific view of sustainability in the residential construction sector.

3.3 Data Analysis

Data collected through the interviews by questionnaires were analysed using rankings on Likert scale questions and chi-squared test was done for further analysis. Chi-squared test, where in the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true. Chi-squared test is a quantitative analysis method which is used for statistical information (rankings) from interviews to be analysed according to the chosen criteria.

3.4 Summary

The survey included a distinction of perception of green design, intention of green design and profitability of green design. The value of the green design is also quantified in terms of what the company finds to be most profitable in comparison to sustainability. The different parts of the survey area were grouped by different types of the questions.

CHAPTER 4

RESEARCH FINDING AND ANALYSIS

4.1 Introduction

The chapter elaborates in detail the research methodology of this research and discusses the research findings and analysis. The findings are elaborated under two main categories as interviews and questionnaire survey. The aim of the study is to identify the reasons for not incorporating frequently sustainable design concepts by developers and contractors in high density residential projects in Sri Lanka. In order to accomplish the aim, the objectives of the study need to be achieved. The first objective “To identify what is sustainability in design and construction field” was achieved by the literature review (chapter two: sub section topic ‘refining sustainability’). Further analysis of literature review and second, third and fourth objectives was achieved through structured interviews through questionnaires survey.

4.2 Demographic Profile of Respondents

The respondents were residential contractors (response level 100%) and developers (response level 89%). The research concentrates on residential developers and contractors because most high density residential projects are handled by these two groups in Sri Lanka. The developer is defined as a company, project owner or both the owner and contractor of a development project that invests in, develops and subdivides real estate for the purpose of building and selling dwellings. This survey have considered contractor as a company or an individuals that builds and supervises homes under a contract or for a speculation. As per typical responses the projects can be categorized as individual housing schemes and apartment housing complexes. The average size of residential projects per dwelling/unit was between 750 and 3000 square feet. Respondents’ annual contract work rangers from 100 to 1000 million (LKR) and the amount of work under construction/constructed annually rangers from 40 to 150 houses. Demographic information was given by 55 of respondents. Respondent’s positions were owners (31%), directors (13%), assistant directors

(20%), divisional Heads (29%) and none specified position or a tittle (7%) (Refer Figure 4-1).

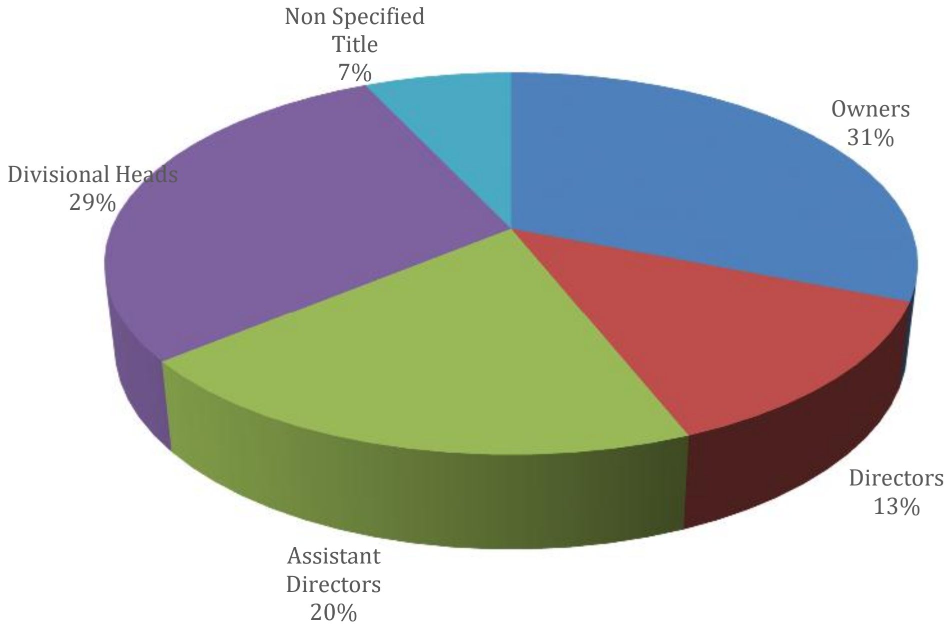

Figure 4.1: Respondent's positions held as a percentage of the total respondents

4.3 Analysis of Questioners – Statistical Analysis

The results of the survey were categorized and analysed based on the following parameters:

- Experience with sustainable practices and design concepts within residential developers and contractors
- Importance of sustainability within the company and further tier as importance of sustainability during design, construction and marketing phase.
- Opinion of sustainability in residential design phase within residential contractors and designers
- Familiarity with sustainable practices and concepts within residential developers and contractors

- Frequency of use of sustainable practices and concepts within the company and residential developers and contractors
- Familiarity of use of sustainable practices and concepts within the company and residential developers and contractors. Further analysed by categorising as following: Familiarity with sustainable techniques, existing rating systems and sustainable concepts and techniques

Survey results were shown with the highest response count on tables, along with the rating average. The rated average is the weighted response count divided by the total number of responses to highlight the highest, weighted response (Hilad, 2009).

4.3.1 Experience with sustainable practices between developer and contractors

Table 4.1 contains responses to 3 questions in relation to experience of sustainable designs or green building concepts. The responses will quantify the amount of practical application of green concepts by individual respondents. Questions were prepared in a 5 ranges with actual data in a Likert scale format (0= no experience, 1-10= barely experienced, 11-20= somewhat experienced, 21-30=experienced, 31-40 = very experienced). Question 1 gives an understanding of the company's experience with green buildings. The developer responded with a rating average of 3.48% and the contractor responded with a rating average of 2.7% both between barely experienced and experienced rating parameters.

Question 2 and 3 concentrates the experience of the designers and contractors in the company. 76% of developers stated that their primary designer was very experienced in sustainable green practices (ratings average of 4.68), whereas contractors had a ratings average of 3.3 (between somewhat experienced and experienced). With regards to the primary contractors experience with green practices, the developers and contractors had ratings averages of 3.6 and 3.47 (somewhat experienced and experienced) respectively (Refer Figure 4.1.1 and Figure 4.1.2).

4.3.2 Importance of sustainable practices between developer and contractors

Table 4.2 to 4.5 tables contains responses related to the importance of sustainable practices. Table 4.2 questions were prepared in a 5-point Likert rating scale format (1 = Not Important, 2 = Rarely Important, 3 = Somewhat Important, 4 = Important, 5 = Very Important). Considering both developers and contractors responses only 44% of developers and 10% of contractors agreed green design or sustainable practices were very important to their company and majority was between 3 = somewhat important and 5 = very important. Developers agreed on the importance of sustainability stronger, with a rating average of 3.76 than contactors (contractors rating average 2.9). There was a small percentage of contractors (6.67%) who believed that sustainability is not important to their company (Refer Figure 4.2).

Table 4.3 consist responses from developers and contractors with six questions based on importance of sustainable practices against other factors during the design phase. Questions were given in a 5-point ranking scale format (1 = Most Important, 2 = Important, 3 = Somewhat Important, 4 = Rarely Important, 5 = Least Important).

All Developers (100%) considered marketable design as the most important factor during the design phase. The next two important factors for developers were low initial cost (ratings average 1.08) and aesthetically pleasing designs (ratings average 1.20). With regards to low initial cost and aesthetically pleasing design 92% and 80% of developers considered it the most important factor respectively. All the other three factors (energy certified designer, energy ratings system approved and energy efficient designs) were considered as being between somewhat important and important.

Contractors believed that low initial cost and marketable designs were important factors (ratings average of 1.87 and 2.00 respectively). Aesthetically pleasing designs (ratings average 2.50) and energy efficient designs (ratings average 3.33) were considered as somewhat important. While energy certified designer and energy rating system approved were thought of as rarely important (ratings average of 4.00 and 4.20 respectively).

From the contractors perspective with regards to sustainable practices against other factors during the design phase, low initial cost was the most important factor with a rating average of 1.87 followed by marketable designs (2.00) and aesthetically pleasing designs (2.50). It is apparent from the results of table 4.3 that energy efficient designs, energy ratings system approved and energy sustainable certified designer were the least important with ratings of 3.33, 4.00 and 4.20 respectively (Refer Figure 4.3).

Table 4.4 shows responses from developers and contractors with questions relating to the importance of sustainable practices during the construction phase. The most important factor for developers is cost (1.00). Whilst for contractors it was constructability (1.00), very closely followed by cost with a ratings average of 1.07. Developers considered constructability, energy rating system approved and energy certified contractor as also very important all with ratings averages below 2.00. Energy efficient buildings was considered as somewhat important (2.52) by developers. Whilst developers viewed all five factors as being most important or somewhat important, contractors considered energy efficient building (3.40), energy certified contractor (3.93) and energy ratings system approved as the least important factors (Refer Figure 4.4).

The importance of sustainable practices during the marketing phase between the developer & contractor is examined in table 4.5. Developer’s considered energy rating approved the most essential factor for marketing with a ratings average of 2.08. However, contractors thought this was the least important factor giving it a rating of 4.40. The next factor considered as important by developers was energy efficiency of the building (2.32). Options and extras (3.00) were somewhat important and energy efficient appliances were given the least consideration with a rating of 3.76. Contractors did not give much importance to these four factors with energy efficiency of the building rated at 3.83. Both options & extras and energy efficient appliances were considered as rarely important by the contractors (Refer Figure 4.5).

4.3.3 Opinion regarding sustainable practices

Table 4.6 contains responses to questions 1 to 11 related to developers and contractors opinions regarding sustainable practices. Questions were posted in a 5-point Likert rating scale format (1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Disagree, 4 = Agree, 5 = Strongly Agree). The questions were opinions on overall company view (Q1 & Q11), perceived monetary value of sustainable practices (Q2, Q4 & Q8), constructability of sustainable residential projects (Q3 & Q7), and marketability of sustainable residential projects (Q5, Q6, Q9 & Q10).

The first questions asked the respondents whether they believed that the company actively incorporates sustainable designs. More than half the respondents for both developers (80%) and contractors (80%) were of the opinion that their companies actively incorporates sustainable design. Developers having a ratings average of 2.76 and contractors an average of 2.5. With regards to question 11 relating to sustainable design benefiting the environment all developers (100%) strongly agreed. Whilst 93.3% of contractors also strongly agreed.

When asked whether sustainable practices result in higher costs (Q2) both developers (ratings average 4.56) and contractors (ratings average 4.5) agreed. While 100% contractors were either agreeing or strongly agreeing 92% of developers fell within these two categories. Similarly question 4 also resulted in ratings averages close to that of question 2, 4.72 for developers and 4.33 for contractors. Both developers and contractors were of a similar opinion when it came to ratings systems and whether they were worth the cost (Q8). They had a ratings average of 2.88 and 2.53 respectively.

When asked whether sustainable designs are more complicated to build (Q3), 72% of developers agreed (ratings average of 3.72). While the contractors had a ratings average of 3.9 with all the respondents ranging from strongly agree to somewhat disagree. When asked about increased confusion over which standards to use (Q7), developers had a ratings average of 2.4 (somewhat disagree to agree). Contractors on the other hand thought that there was some confusion. They had a ratings average of 3.43.

Most developers (ratings average of 4.2) agreed that there is a growing demand for sustainable homes (Q5). In fact 88% either agreed or strongly agreed. Contractors (ratings average of 3.07) however somewhat disagreed with this opinion. Both parties somewhat disagreed that consumer demand for sustainable homes has affected design and construction of homes (Q6). Developers and contractors having a ratings average of 2.92 and 2.6 respectively. With regards to whether there is a consumer preference for green homes over traditional homes (Q9) and whether sustainable designs help to sell your homes faster (Q10), developers somewhat disagreed with a ratings average 2.92 and 3.32. Contractors were of a slightly different opinion with ratings average of 2.07 & 2.37 for questions 9 & 10 respectively (Refer Figure 4.6).

4.3.4 Familiarity with sustainable practices

Table 4.7 contains responses to questions relating to familiarity of both developers and contractors to sustainable practices. Question 1 asked the respondents to rate their familiarity with the green building council in Sri Lanka. Although the ratings average of 3.48 for developers suggest that they fall between somewhat familiar and familiar, 76% stated that they are somewhat familiar and all remaining 24% of developers stated that they are very familiar with the green building council. None of the contractors were unfamiliar with the council and they had a ratings average of 3.13. Developers were more familiar with national green building standards and energy star brands having a ratings average of 4.00 and 3.16 respectively compared to 2.93 and 2.67 for contractors (Refer Figure 4.7).

Table 4.8 presents the difference between developers and contractors relative to their familiarity with the green building concepts and techniques. All developers (100%) and all contractors (100%) were familiar with site selection, minimum disturbance to surrounding area, access to open space, drought tolerant plants & landscape design, erosion control, storm water treatment, solar water heating, rainwater collection systems, vegetated roof, pipe insulating, daylighting and solar orientation. All developers were also 100% familiar with value engineering. Developers and contractors were least (0%) familiar only with VOC's and green globes, while contracted also were not familiar (0%) with photovoltic energy, thermal bridges, framing efficiency, energy modelling and radon protection.

Developers and contractors both rarely use a rating system for assessing green or sustainable design. Developers having a rating average of 2.32 and contractors being 1.97. In relation how often a company actively trains its employees in green techniques, there was not much of a difference between developers and contractors. Both developers (ratings average 2.72) and contractors (ratings average 2.13) rarely seem to train their employees in green techniques and sustainable design

4.3.5 Frequency of use of sustainable practices

Table 4.9 contains responses to question 1 and question 2 that relate to the frequency of use of sustainable practices. The questions were posed in a 5-

point Likert rating scale format (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Frequently). Their responses were used to determine the developers and contractors frequency of using residential sustainable rating systems and sustainability training.

Question 1 measured how frequently developers and contractors actively used a rating system to assess sustainable designs. Contractors rarely used a ratings system for assessing green designs with a ratings average of 1.97. Developers however had a ratings average of 2.44 (between rarely and sometimes).

Both developers and contractors also had similar results with regards to whether they actively train their employees in green techniques. Contractors (ratings average of 2.13) are training employees rarely and developers (ratings average of 2.72) practicing employee training rarely to sometimes (Refer Figure 4.7).

4.4 Analysis of Results – Statistical Calculations

4.4.1 Data Analysis

The questioners were analysed by using Chi-Square test of Independence is used to determine if there is a significant relationship between two variables. The frequency of one variable is compared with different values of the second variable (Statistics Solutions, 2007).The two variables in this study is the ratings averages of developers and contractors.

4.4.1.1 Experience, Importance, Opinion and Frequency with Sustainable Practices of Developers and Contractors

In relation to experience with sustainable practices (Table 4-1) Developers had a ratings average greater than that of contractors for every question. Developers had a ratings average of 3.94 suggesting

that they were experienced with sustainable practices. Contractors on the other hand had a ratings average of 3.16 (somewhat experienced).
The comparison between developers and contractors using the chi squared test is shown in table 4-10. At the 95% confidence interval the chi square value is 7.81 with three degrees of freedom, while the actual tabulated value was 0.59. As 7.81 > 0.59 we can conclude that there is no significant difference between the developer response and the contractor response at the 95% confidence level.

Table 4-11 looks at the importance of sustainable practices between developers and contractors while the importance of sustainable practices during the design, construction and marketing phase is considered in table 4-12, 4-13 and 4-14 respectively. In all except the marketing phase both developer and contractor had similar ratings averages. In the marketing phase the developers (2.79) thought marketing was important to somewhat important, while contractors (4.16) considered it as rarely important. When looking at the chi squared values from table 4-11, at the 95% significant level with one degree of freedom it yielded a value of 3.84. The actual chi square value is 0.20.Therefore as expected there is no significant difference between the two responses (3.84 > 0.20).

The calculated chi squared value for table 4-12 is 5.05, chi squared at the 95% confidence interval with six degrees of freedom the is 12.59. As 12.59 > 5.05 there is no significant difference between the developers and contractor response with regards to the importance of sustainable practices during the design phase.

The importance of sustainable practices during the construction phase (Table 4-13) allowed a variation of 11.07 with 5 degrees of freedom at the 95% confidence interval. The actual value was much lower (5.66), the importance of sustainable practices during the marketing phase yielded similar results (Table 4-14) with a variation of 9.48 with four degrees of freedom at the 95% confidence interval and an actual value of 4.07. Therefore it is apparent that there is no significant difference in responses between developers and contractors on the importance of sustainable practices during design, construction and marketing phase.

All responses from developers and contractors regarding opinion of sustainable practices (Table 4-6) varied for the questions posed. Neither party strongly disagreed to any question. The developers had an overall ratings average of 3.58 (somewhat disagree to agree), while for contractors it was 2.94 (somewhat disagree). The variation between developers and contractors was 19.67 with 11 degrees of freedom at the 95% confidence interval. The actual value is 1.41 (Table 4-15). As 19.67 > 1.41 we can conclude that there is no significant difference in opinion of sustainable practices between the two groups.

Most developers were ranging between somewhat familiar and familiar with their responses (ratings average 3.55) for familiarity of sustainable practices. Contractors were closer to somewhat familiar as they had an overall ratings average of 2.91 (Table 4-7). The expected variation between developers and contractors (Table 4-16) was 7.81 with three degrees of freedom at the 95% confidence interval. The actual chi squared value was 0.40. As the results suggest (7.81 > 0.40), there is no significant difference between developer and contractor responses at the 95% confidence level.

With regards to frequency of use of sustainable practices (Table 4-9) on average developers used training and a ratings system rarely to sometimes (ratings average 2.58), the frequency for contractors (2.05) was less than that of developers, rarely using training and a rating system. The expected variation for the two groups were 5.99 with two degrees of freedom at the 95% confidence interval. The actual chi squared value was 0.22 (Table 4-17). Therefore there is no significant difference in responses for developers and contractors at the 95% confidence interval.

4.5 Summary

Developers and contractors varied in their opinion of importance of green designs during the design, construction and marketing phase, developers considering it more valuable. Both parties agreed that low cost and constructability was very important having similar ratings average. On the opinion of sustainable practices, familiarity with sustainable practices and frequency of use of sustainable practices the two respondents had comparable views except for their thought on growing demand for green homes and whether their companies are familiar with National Green Building Standards. Although there are a few differences when comparing ratings averages between the two groups, they did not differ significantly in these parameters (experience, importance, opinion, familiarity and frequency) of sustainable practices when using the chi squared test.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses on deriving at the conclusion of this research from research finding achieved in the proceeding chapter. Furthermore this chapter elaborates the summery of the research process, enabling towards the final outcome. Hence, conclusion includes revisiting the objectives were persisted through the research findings. The aim of this research is to understand “why developers and contractors do not frequently use sustainable concepts in residential projects in Sri Lanka?” to dive at the aim, certain objectives were established. The conclusion describes accomplishment of each objective together with research findings with further recommendations.

5.2 Revisiting the Objectives

<u>Objective 1 - To identify what is sustainability in design and construction field</u>

Objective 1of this research was accomplished through the literature review (Refer chapter two, subsection ‘Refine Sustainability’). The findings from literature review assisted to understand sustainable concepts in the construction field and out of which could be used in high density residential projects. This was further analysed by structured interviews through questionnaires survey (Refer chapter four).

<u>Objective 2 - To determine the level of knowledge of sustainable rating systems on residential developers and contractors</u>

Objective 2 was recognised as important during the initial interviews and later added to the questionnaire after the literature review (Refer Chapter 2). Responses from the developers and contractors indicated sustainable rating systems used in construction industry in Sri-Lanka, such as LEED-H, GREEN-SL, ISO ratings and EMIS standards. Developers and contractors were aware of the rating systems, but it is evident the importance of gaining rating points are negligible. As per the respondents, this situation has mainly accrued due to consumer demands of sustainable homes were minimum and also due to lack of recognition and benefits gained by building sustainable homes.

Objective 3 - To determine the residential contractors' and developers' knowledge of sustainability in design and construction based on: occurrence, importance, opening, experience and frequency

Objective 3 was attained by structured interviews by questionnaires survey (Refer Chapter 4). Research respondents were aware of sustainability and sustainable concepts, even though they had less or no experience in sustainable homes. It is also evident that company designers had thorough knowledge of green concepts. All respondents agreed the importance of sustainability, but it was contradictory in practice. Importance was more on aesthetics, cost savings, saleability and build-ability against sustainable practices and other factors. Developers and contractors suggested cost benefits on sustainable materials and integrate sustainability practices in residential projects as mandatory.

Objective 4 – Determine the practice of sustainable concepts by developers and contractors in large scale residential projects in Sri Lanka

Objective 4 was accomplished through the data received from the structured interviews by questionnaires survey (Refer Chapter 4). Respondents were well knowledge of sustainable aspects and the need for green homes. It was evident sustainability was not practice frequently in residential projects in Sri Lanka. Analysis of Likert scale question proves respondents focus mainly on financial and marketing benefits on residential projects against sustainability and other factors.

5.3 Conclusion and Recommendations

It is evident sustainable design and construction of residential projects will be critical in the future. There are many benefits by building green homes by environmental aspects and inhabitants, but also for developers and builders who build homes. Commitments and obligations towards sustainability need not only come from consumer, but also from residential building designers, contractors and developers. Even though both developers and contractors believe sustainability benefits the environmental foot print, it was rarely practiced. Analysis of responses proves respondents focus mainly on financial and marketing benefits on high density residential projects against sustainability concepts and other factors. Open ended questions responses gave hope towards sustainability in feature homes, but in order they required justifications on construction difficulties (i.e. lack of skilled labor), improve knowledge of general public in green concepts and solutions for cost overrun due to sustainability. Literature review resolves some issues for above said matters such as: The benefits of building green includes, cost savings from reduced energy, water and west. Also lower operational cost, total financial benefits of green buildings over 10 times the average initial investment required to design and construct the green building.

Further, recommendations were listed below, in order to achieve frequent use of sustainable practices in height density residential projects in Sri Lanka.

<u>Recommendations</u>

1. Auctioning the imposed sustainable practices as mandatory on residential building regulations for approvals, regulated by Urban Development Authority in Sri Lanka (i.e. Countries as Singapore and Australia have imposed listed sustainable aspects as mandatory on building regulations).
2. Impose pricing benefits on sustainable materials (ex: TAX benefits)
3. Organize and impose programs to enhance knowledge on sustainable practices (i.e. Training programs for skilled labor on sustainable design concepts, encouraging sustainable rating systems for better recognitions etc.).

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APPENDIX A

OVERVIEW OF LEED-H

LEED for Homes Version 2008

Innovation and Design Process (ID)

Credit 1 Integrated Project Planning

- 1.1 Preliminary Rating
- 1.2 Integrated Project Team
- 1.3 Professional Credentialed with Respect to LEED for Homes
- 1.4 Design Charrette
- 1.5 Building Orientation for Solar Design

Credit 2 Durability Management Process

- 2.1 Durability Planning
- 2.2 Durability Management
- 2.3 Third Party Durability Management Verification

Credit 3 Innovation of Regional Design

- 3.1 Innovation #1
- 3.2 Innovation #2
- 3.3 Innovation #3
- 3.4 Innovation #4

Location and Linkages (LL)

Credit 1 LEED ND

Credit 2 Site Selection

Credit 3 Preferred Locations

- 3.1 Edge Development
- 3.2 Infill
- 3.3 Previously Developed

Credit 4 Infrastructure

Credit 5 Community Resources

- 5.1 Basic Community Resources

5.2 Extensive Community Resources

5.3 Outstanding Community Resources

Credit 6 Access to Open Space

Sustainable Sites (SS)

Credit 1 Site Stewardship

1.1 Erosion

1.2 Minimize Disturbed Area of Site

Credit 2 Landscaping

2.1 No Invasive Plants

2.2 Basic Landscape Design

2.3 Limit Conventional Turf

2.4 Drought Tolerant Plants

` 2.5 Reduce Overall Irrigation Demand by at Least 20%

Credit 3 Local Heat Island Effects

Credit 4 Surface Water Management

4.1 Permeable Lot

4.2 Permanent Erosion Controls

4.3 Management of Run-off from Roof

Credit 5 Nontoxic Pest Control

Credit 6 Compact Development

6.1 Moderate Density

6.2 High Density

6.3 Very High Density

Water Efficiency (WE)

Credit 1 Water Reuse

1.1 Rainwater Harvesting System

1.2 Graywater Reuse System

1.3 Use of Municipal Recycled Water System

Credit 2 Irrigation System

2.1 High Efficiency Irrigation System

2.2 Third Party Inspection

2.3 Reduce Overall Irrigation Demand by at Least 45%

Credit 3 Indoor Water Use

3.1 High-Efficiency Fixtures and Fittings

3.2 Very High-Efficiency Fixtures and Fittings

Energy and Atmosphere (EA)

Credit 1 Optimize Energy Performance

1.1 Performance of ENERGY STAR for Homes

1.2 Exceptional Energy Performance

Credit 2 Insulation

2.1 Basic Insulation

2.2 Enhanced Insulation

Credit 3 Air Infiltration

3.1 Reduced Envelope Leakage

3.2 Greatly Reduced Envelope Leakage

3.3 Minimal Envelope Leakage

Credit 4 Windows

4.1 Good Windows

4.2 Exceptional Windows

Credit 5 Heating and Cooling Distribution System

5.1 Reduced Distribution Losses

5.2 Greatly Reduced Distribution Losses

5.3 Minimal Distribution Losses

Credit 6 Space Heating and Cooling Equipment

6.1 Good HVAC Design and Installation

6.2 High-Efficiency HVAC

6.3 Very High-Efficiency HVAC

Credit 7 Water Heating

7.1 Efficient Hot water Distribution

7.2 Pipe Insulation

Credit 8 Lighting

8.1 ENERGY STAR Lights

8.2 Improved Lighting

8.3 Advanced Lighting Package

Credit 9 Appliances

9.1 High-Efficiency Appliances

9.2 Water-Efficient Clothes Washer

Credit 10 Renewable Energy System

Credit 11 Residential Refrigerant Management

11.1 Refrigerant Charge Test

11.2 Appropriate HVAC Refrigerants

Materials and Resources (MR)

Credit 1Material-Efficient Framing

1.1 Framing Order Waste Factor Limit

1.2 Detailed Framing Documents

1.3 Detailed Cut List and Lumber Order

1.4 Framing Efficiencies

1.5 Off-Site Fabrication

Credit 2 Environmentally Preferable Products

2.1 FSC Certified Tropical Wood

2.2 Environmentally Preferable Products

Credit 3 Waste Management

3.1 Construction Waste Management Planning

3.2 Construction Waste Reduction

Indoor Environmental Quality (EQ)

Credit 1 ENERGY STAR with IAP (Indoor Air Package)

Credit 2 Combustion Venting

2.1 Basic Combustion Venting Measures

2.2 Enhanced Combustion Venting Measures

Credit 3 Moisture Load Control

Credit 4 Outdoor Air Ventilation

4.1 Basic Outdoor Air Ventilation

4.2 Enhanced Outdoor Air Ventilation

4.3 Third-Party Performance Testing

Credit 5 Local Exhaust

5.1 Basic Local Exhaust

5.2 Enhanced Local Exhaust

5.3 Third-Party Performance Testing

Credit 6 Distribution of Space

6.1 Room-by-Room Load Calculations

6.2 Return Air Flow/Room by Room Controls

6.3 Third-Party Performance Testing/Multiple Zones

Credit 7 Air Filtering

7.1 Good Filters

7.2 Better Filters

7.3 Best Filters

Credit 8 Contaminant Control

8.1 Indoor Contaminant Control during Construction

8.2 Indoor Contaminant Control

8.3 Preoccupancy Flush

Credit 9 Radon Protection

9.1 Radon-Resistant Construction in High-Risk Areas

9.2 Radon-Resistant Construction in Moderate-Risk Areas

Credit 10 Garage Pollutant Protection

10.1 No HVAC in Garage

10.2 Minimize Pollutants from Garage

10.3 Exhaust Fan in Garage

Awareness and Education (AE)

Credit 1 Education of the Homeowner or Tenant

1.1 Basic Operations Training

1.2 Enhanced Training

1.3 Public Awareness

APPENDIX B

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO standards for Homes and Sustainable Buildings

ISO 21542:2011 - Building construction -- Accessibility and usability

ISO 7730:2005 - Ergonomics of the thermal environment

ISO 16000-7:2007 - Indoor air -- Part 7: Sampling strategy

ISO 16032:2004 - Acoustics -- Measurement of sound pressure level

ISO 16000-1:2004 - Indoor air -- Part 1: General aspects of sampling

ISO 24521:2016 - Activities relating to drinking water

ISO 140-14:2004 - Acoustics -- Measurement of sound insulation in [Withdrawn]

ISO 16283-2:2015 - Acoustics -- Field measurement of sound

IEC 60601-1-11:2015 - Medical electrical equipment - Part 1-11

ISO 3055:1985 - Kitchen equipment - Coordinating sizes

ISO 4356:1977 - Bases for the design of structures - Deformations

ISO 21929-1:2011 - Sustainability in building construction [Under development]

ISO/NP 21678 Sustainability in buildings and civil engineering works

ISO/TS 21929-2:2015 - Sustainability in building construction

ISO 15392:2008 - Sustainability in building construction

ISO/TS 12720:2014 - Sustainability in buildings and civil

ISO/DIS 21931-2 - Sustainability in buildings and civil engineering [Under - development]

ISO 16813:2006 - Building environment design

ISO/TR 21932:2013 - Sustainability in buildings and civil engineering

ISO 21930:2007 - Sustainability in building construction

ISO 37120:2014 - Sustainable development of communities

IWA 9:2011 - Framework for managing sustainable developments

ISO 37101:2016 - Sustainable development in communities

ISO 17989-1:2015 - Tractors and machinery for agriculture and forestry

ISO 10987:2012 - Earth-moving machinery - Sustainability

ISO 50001:2011 - Energy management systems - Requirements

ISO 26000:2010 - Guidance on social responsibility

ISO 14040:2006 - Environmental management - Life cycle

ISO 14955-1:2014 - Machine tools -- Environmental evaluation

ISO/TS 14067:2013 - Greenhouse gases -- Carbon footprint

ISO 14044:2006 - Environmental management - Life cycle

ISO/TS 16095:2014 - Reclaimed rubber derived from products
ISO 14001:2015 - Environmental management systems
ISO 14046:2014 - Environmental management -- Water footprint
ISO 14025:2006 - Environmental labels and declarations - Type III
ISO 14001:2004 - Environmental management systems ... [Withdrawn]

APPENDIX C

GREEN-SL RATING SYSTEM

Green-SL® rating system for built environment

Credit 1 Management

- 1.1 Building Tuning
  - 1.1.1 Optimizing Occupants Comport and Energy Efficiency
- 1.2 Building User Guide
  - 1.2.1 Building User Guide
- 1.3 Environment Management
  - 1.3.1 Environment Management Plan
  - 1.3.2 Environment Management System (complying with ISO 14001)

Credit 2 Sustainable Sites

- 2.1 Site Selection
- 2.2 Development Density and Community Connectivity
- 2.3 Brownfield Redevelopment
- 2.4 Alternative Transportation
  - 2.4.1 Public Transportation Access
  - 2.4.2 Parking Capacity
- 2.5 Reduce Site Disturbance
  - 2.5.1 Protect or Restore Habitat
  - 2.5.2 Development Foot Print
- 2.6 Storm water Design, Quantity control - I
- 2.7 Storm water Design, Quantity control - II
- 2.8 Heat island Effect, Non-Roof
- 2.9 Heat island Effect, Roof
- 2.10 Light Pollution Reduction

Credit 3 Water Efficiency

- 3.1 Water Efficiency Landscaping
  - 3.1.1 Reduce Potable Water Consumption
  - 3.1.2 Eliminate Potable Water Consumption
- 3.2 Water Efficiency in Air-Conditioning System
- 3.3 Innovative West Water Technologies
  - 3.3.1 Reduce Potable Water Use or Treat West Water
  - 3.3.2 harvested Rainwater
- 3.4 Water Use Reduction

Credit 4 Energy and Atmosphere

- 4.1 Optimize Energy Performance
- 4.2 Renewable Energy
- 4.3 Additional Commissioning
- 4.4 Ozone Depletion
- 4.5 Measurements and Verifications
- 4.6 Green Power

Credit 5 Materials and Resources

- 5.1 Building resource
  - 5.1.1 Maintaining 50%of Existing Building Structure and Shell
  - 5.1.2 Maintaining 75%of Existing Building Structure and Non-Shell
- 5.2 Construction West Management
  - 5.2.1 For 50% Recycling
  - 5.2.2 For 75% Recycling
- 5.3 Resource Reuse
  - 5.3.1 For at least 5%of the Building
  - 5.3.2 For at least 10%of the Building
- 5.4 Recycled Content
  - 5.4.1 For At Least 10% of Total Value of Materials
  - 5.4.2 For At Least 20% of Total Value of Materials
- 5.5 Local/Regional/Materials
  - 5.5.1 For Minimum of 20% Usage
  - 5.5.2 For Minimum of 50% Usage
- 5.6 Rapidly Renewable Materials
- 5.7 Certified Wood

Credit 6 Indoor Environmental Quality

- 6.1 Outdoor Air Delivery Monitoring
- 6.2 Increased Ventilation
- 6.3 Construction IAQ Management Plan
  - 6.3.1 Construction IAQ Management Plan Before and After Construction
- 6.4 Law – Emitting Materials
  - 6.4.1 Paints and Coatings
  - 6.4.2 Carpet Systems
  - 6.4.3 Composite Wood and Agrifiber Products
- 6.5 Indoor Chemical and Pollution Source Control
- 6.6 Controllability of Systems
  - 6.6.1 Lighting Controls
  - 6.6.2 Contract Controls
- 6.7 Thermal Comfort, Design
- 6.8 Thermal Comfort, Verification
- 6.9 Daylight and Views
  - 6.9.1 Daylight
  - 6.9.2 Views

Credit 7 Innovation and Design Process

- 7.1 Innovation and Design
  - 7.1.1 Innovation and Design
  - 7.1.2 Exemplary Performance

Credit 8 Social and Cultural Awareness

- 8.1 Social Wellbeing, Public Health and Safety
- 8.1 Cultural Identity

APPENDIX D

QUESTIONNAIRE

SUSTAINABLE PRACTICES IN RESIDENTIAL PROJECTS IN SRI LANKA

Dear Sir/Madam,

Request for Filling Questionnaire

I am Nishadi Kulatilake currently a postgraduate student undertaking Degree of Master of Science/ Project Management at University of Moratuwa. In order to satisfy the requirement of the Master's Degree Certification, I am required to undertake a research and produce a Dissertation. My selected topic is “Sustainable Practices in Residential Projects in Sri Lanka”. My intention is to find solutions to practice sustainability in residential projects in Sri Lanka, by developers and contractors.

I would be very much great full if you can complete the attached questionnaire and also provide time allocation for an interview despite from your busy work schedule. The information disclosed here will only be used to complete my research and all information shall be treated as strictly confidential. Your early response will be highly appreciated.

Thank you.

Yours Faithfully,
Nishadi Kulatilake
Postgraduate student

Department of Building Economics
Facalty of Architecture
University of Moratuwa

Mobile No: 0779520515
Email: nishadi.kulatilake@gmail.com

QUESTIONNAIRE
Informed Consent Disclosure Agreement for Participants

A) Research Topic

Sustainable Practices in Residential Projects in Sri Lanka

B) Purpose of the study

The purpose of the study is to investigate the incentives, the motives, and the affordability of green buildings in residential applications for developers and contractors. The research study is to find the current consensus of home developers and contractors on "going green,"

C) Research Objectives

1. To define what is sustainability in design and construction field.
2. To analyse why contractors and developers do not use sustainable design concepts frequently in residential projects in Sri Lanka.
3. To understand the decision making process from the construction point of view on residential sustainability among residential contractors and developers.
4. To understand the residential contractors' and developers' knowledge of sustainability in design and construction based on: occurrence, importance, opening, experience and awareness.
5. To understand the level of knowledge of sustainable rating systems among contractors and developers.

D) Instructions to Respondents

You will undergo a short survey which consists of the series of questions related to their company's views and practices on sustainability design and green construction.

E) Time Required

15 to 20 minutes

F) Risks, benefits and Compensations

There are no personal risks or discomfort associated with participating in this study and also there are no direct benefits for participation in this study. Participating in this study will not receive any compensation.

G) Confidentiality

The information disclosed will be strictly confidential to the extent provided by law.

H) Contact personal if you have questions about the study:

The faculty supervisor, Master of Science/ Project Management, Department of Building Economics, Facalty of Architecture, University of Moratuwa, Sri Lanka

I) Agreement

I have read the procedure described above. I voluntarily agree to participate in the procedure and if requested can received a copy of this description.

Participant Signature:……………………………… Date:…………

Principal Investigator:………………………………Date: …………

J) Demographic Information

Name of the organization (optional):___________________________

Name: ____

Designation: ____

Type of Company: ____
(developer, contractor, etc.)

ICTAD Registered ____

Typical residences constructed: ______________________________
(townhomes, single-family, apartments, etc.)

Number of residences constructed: _____________________________
(years of 2013 to 2017)

Average Sq.ft. area of residence constructed: ____________________
(years of 2013 to 2017)

Annual Total of Work in Sri Lankan Rupees: _____________________
(years of 2013 to 2017)

Typical size of residences: ___________________________________

Typical price of residences in Sri Lankan Rupees: ________________
(years of 2013 to 2017)

Experience in construction Industry: ____________________________

Perception of the Respondents

Please rate below statements on your level of agreement according to your company’s views

Question	**No Exp.** **0**	**Hardly Exp.** **0 - 10**	**Somewhat Exp.** **11 - 20**	**Exp.** **21 - 30**	**Very Exp.** **31 - 40**
1. Company experience in sustainable buildings projects?	☐	☐	☐	☐	☐
2. How an experience is (are) the primary designer/s in your company with sustainable concepts?	☐	☐	☐	☐	☐
3. How experiences is (are) the primary contractor/s in your company	☐	☐	☐	☐	☐

Question	**Not Important** **1**	**Rarely Important** **2**	**Somewhat Important** **3**	**Important** **4**	**Very Important** **5**
4. How important is green design or building sustainable homes to your company?	☐	☐	☐	☐	☐

Question	**Strongly Disagree** **1**	**Disagree** **2**	**Somewhat Disagree** **3**	**Agree** **4**	**Strongly Agree** **5**
5. Do you agree that your company actively incorporates green or sustainable design?	☐	☐	☐	☐	☐
6. Do you agree that green or sustainable practices equate to increased costs?	☐	☐	☐	☐	☐
7. Do you agree that green or sustainable homes should be sold at a premium?	☐	☐	☐	☐	☐
8. Do you agree there is a growing demand for green or sustainable homes?	☐	☐	☐	☐	☐

Question	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Agree 4	Strongly Agree 5
9. Do you agree that consumer demand for sustainable homes has affected construction and/or design of your homes?	☐	☐	☐	☐	☐
10. Do you agree there is increased confusion over which green standards to use?	☐	☐	☐	☐	☐
11. Does your company agree that the rating systems are worth the extra costs?	☐	☐	☐	☐	☐
12. Do you agree that there is a consumer preference of green or sustainable homes over traditional or non-green homes?	☐	☐	☐	☐	☐
10. Green or sustainable designs and/or construction help you to sell your homes faster?	☐	☐	☐	☐	☐
11. Green or sustainable designs and/or contruction benefit the environment?	☐	☐	☐	☐	☐

Question	Unfamiliar 1	Less Familiar 2	Somewhat Familiar 3	Familiar 4	Very Familiar 5
12. How familiar is your company with the green building council in sri lnaka, leadership in energy & environmental designs for homes (leed-h)?	☐	☐	☐	☐	☐
13. How familiar is your company with national green building standards?	☐	☐	☐	☐	☐
14. How familiar is your company with energy star brands? (appliances, HVAC systems)?	☐	☐	☐	☐	☐

Question	Never 1	Rarely 2	Sometimes 3	Often 4	Frequently 5
15. How often does your company actively use a rating system for assessing green or sustainable design?	☐	☐	☐	☐	☐
16. How often does your company actively train its employees in green techniques?	☐	☐	☐	☐	☐

17. Familiarity of Respondents

Please tick below Sustainable/Green building concepts your company is familiar

Answer Option	Response
Site Selection	
Minimal Disturbance To Surrounding Area	
Access To Open Space	
Drought Tolerant Plants & Landscape Design	
Drip Irrigation	
Xeriscaping	
Permeable Pavement	
Erosion Control	
Reduction Of Heat Island Effect	
Pest Control Alternatives	
Gray water Reuse	
Energy Star Appliances	
Storm Water Treatment	
SIP's	
Value Engineering	
Green label TM	
Refrigerant Management Systems	
Solar Water Heating Systems	
Low-E-Gases	
Rainwater Collection Systems	

Answer Option	Response
Photovoltaic Energy	
Thermal Bridge	
Vegetated Roof	
Rain Garden	
Compact Development Density	
Pipe Insulation	
Day lighting	
Framing Efficiency	
Energy Modeling	
Solar Orientation	
VOCs	
Green Globes	
Carbon Dioxide Monitoring	
Use Of Readily-Renewable Material	
Radon Protection	
Use Of Recycled Or Salvaged Material	
FSC Certified Wood	
Renewable Energy Systems	
Passive Design	
Construction Waste Management	

Please rate below statements on your level of agreement according to your company's views

Most important aspect to your company in the design phase of residential projects against other factors (ex: sustainability)

Question	Most Imp. 1	Imp. 2	Somewhat Imp. 3	Rarely Imp. 4	Least Imp. 5
18. Aesthetically pleasing designs	☐	☐	☐	☐	☐
19. Energy/Sustainable certified designer	☐	☐	☐	☐	☐
20. Energy Rating System approved (i-e LEED-H)	☐	☐	☐	☐	☐
21. Energy efficient designs	☐	☐	☐	☐	☐
22. Low initial cost	☐	☐	☐	☐	☐
23. Marketable designs	☐	☐	☐	☐	☐

Most important aspect to your company in the construction Phase of residential projects against other factors (ex: sustainability)

24. Energy /Sustainable Certified Contractor (ex: LEED-H)	☐	☐	☐	☐	☐
25. Energy Rating System Approved (ex: LEED-H)	☐	☐	☐	☐	☐
26. Cost	☐	☐	☐	☐	☐
27. Energy Efficient Building	☐	☐	☐	☐	☐

Most important aspect to your company in the marketing Phase of residential projects against other factors (ex: sustainability)

Question	Most Imp. 1	Imp. 2	Somewhat Imp. 3	Rarely Imp. 4	Least Imp. 5
28. Options & Extras	☐	☐	☐	☐	☐
29. Energy Efficiency Of Entire Building	☐	☐	☐	☐	☐
30. Energy Efficient Appliances	☐	☐	☐	☐	☐
31. Energy Rating System Approved (ex: LEED-H)	☐	☐	☐	☐	☐

Open Ended Questions

Please rate below statements on your level of agreement according to your company's views

32. Does your company access sustainable or energy rating systems?
(i.e. LEED-H, GREEN-SL, ISO, EMIS etc.)

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33. What is your company's opinion of sustainable rating methods?
(i.e. LEED-H, GREEN-SL, ISO, EMIS etc.)

---

34. Do you believe there is confusion within the sustainable or energy rating systems?

---

35. What is the main reason for using sustainability design concepts in your projects?

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36. How does your company go towards green or sustainability in residential projects?

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37. What is your company's approach toward sustainability in the residential construction sector?

APPENDIX E

SUSTAINABLE RATING SYSTEMS

Table 2.1: Similarities and differences of categories in sustainable rating systems

Category	LEED-H	ISO	EMIS	GREEN-SL
Site selection	Sustainable sites	Preparation development andsustainable lot design	Testings for site componants/lot choice	Sustainable site
Material selection	Materials and resources	Resource efficiency	Material evaluation, selectio n and resources	Conservation of materials and resources
Energy	Energy and atmosphere	Design guidelines for design energy-related efficiency in parts of buildings	Energy efficiency and emission, energy efficiency technology	Energy efficiency and usage of renewable energy
Water	Water efficiency	Harmonized technology and terminology, allowing countries sharing the same water resources to work together efficiently/pipes and irrigation to water quality, water re-use, water management and sanitation.	Water efficiency standards	Safeguarding water and water efficiency
Indoor environment	Indoor environment al quality	environmental sp -ecifications of different building materials, analysing their possibilities for improvement	Indoor environmental quality	Indoor environmental quality
Owner education	Awareness and education	Operation, Maintenance and referbishment education	Operation, maintenance and homeowner education	Educate end users

Site design	Location and linkages	Decision making process from inception of a project (site selection and framework-for design process)	Conceptual overview and location	Sustainable site planning
Innovation	Innovation and design process	Framework for sustainability indicators to assess economic, environmental and social impacts of buildings, calculation of energy consumption ratio's, ISO 9126 model to the evaluation of an e-learning system.	Simplify and automate, environmental management	Additional points
Regional sensitivity	Regional priority	Regional labour productivity	Site selection, design and performances	Not specified
Social and cultural awareness	Not specified	Social responsibility efficiency		Enhancing social and cultural-values
Management	Not specified	Management standards, Eco-management and audit scheme, health and safety management, Environmental management system	Organizational-technical systems for systematically obtaining, processing, and making available in companies	Project-specific management plan (EMP) is implemented and internal audit trail tracking compliance at construction.

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APPENDIX F

STATISTICAL ANALYSIS

Table 4.1: Responses to Likert Scale Questions Related to Experience in Sustainable Practices Between Developers & Contractor

Question	No Exp. 0	Hardly Exp. 0 - 10	Somewhat Exp. 11 - 20	Exp. 21 - 30	Very Exp. 31 - 40	Rating Avg	Response Count
Q1. Does your Company Have Experience in Sustainable/Green Buildings?							
Developer	0	4	5	16	0	3.48	25
	0.00%	16.00%	20.00%	64.00%	0.00%		
Contractors	0	15	9	6	0	2.70	30
	0.00%	50.00%	30.00%	20.00%	0.00%		
Q2. The Primary Designer(s) Experienced With Sustainable/Green Practices?							
Developer	0	0	2	4	19	4.68	25
	0.00%	0.00%	8.00%	16.00%	76.00%		
Contractors	3	6	7	7	7	3.30	30
	10.00%	20.00%	23.00%	23.00%	23.00%		
Q3. The Primary Contractor Is Experienced With Sustainable/Green Practices?							
Developer	0	2	4	19	0	3.68	25
	0.00%	8.00%	16.00%	76.00%	0.00%		
Contractors	0	2	14	12	2	3.47	30
	0.00%	6.70%	46.70%	40.00%	6.70%		

-

Table 4.2: Responses to Likert Scale Questions Related To Importance Of Sustainable Practices Between Developers & Contractor

Question	**Not Imp. 1**	**Rarely Imp. 2**	**Somewhat Imp. 3**	**Imp. 4**	**Very Imp. 5**	**Rating Avg**	**Response Count**
Q1. How Important Is Green Design Or Building Sustainable Homes To Your Company?							
Developer	0 0.00%	3 12.00%	11 44.00%	0 0.00%	11 44.00%	3.76	25
Contractors	2 6.67%	8 26.67%	14 46.67%	3 10.00%	3 10.00%	2.90	30

Table 4.3: Ratings Of Importance Of Sustainable Practices Against Other Factors During The Design Phase Between Developer & Contractor

Question	**Most Imp.** 1	**Imp.** 2	**Somewhat Imp.** 3	**Rarely Imp.** 4	**Least Imp.** 5	**Rating Avg**	**Resp. Count**
Q1. Aesthetically Pleasing Designs							
Developer	20 80.00%	5 20.00%	0 0.00%	0 0.00%	0 0.00%	1.20	25
Contractors	4 13.33%	13 43.33%	9 30.00%	2 6.67%	2 6.67%	2.50	30
Q2. Energy/Sustainable Certified Designer							
Developer	0 0.00%	11 44.00%	11 44.00%	3 12.00%	0 0.00%	2.68	25
Contractors	0 0.00%	1 3.33%	4 13.33%	13 43.33%	12 40.00%	4.20	30
Q3. Energy Rating System Approved (i-e LEED-H)							
Developer	8 32.00%	8 32.00%	1 4.00%	8 32.00%	0 0.00%	2.36	25
Contractors	4 13.33%	2 6.67%	2 6.67%	4 13.33%	18 60.00%	4.00	30
Q4. Energy Efficient Designs							
Developer	1 4.00%	8 32.00%	8 32.00%	8 32.00%	0 0.00%	2.92	25
Contractors	2 6.67%	4 13.33%	8 6.67%	14 46.67%	2 6.67%	3.33	30
Q5. Low Initial Cost							
Developer	23 92.00%	2 8.00%	0 0.00%	0 0.00%	0 0.00%	1.08	25
Contractors	16 53.33%	4 13.33%	9 30.00%	0 0.00%	1 3.33%	1.87	30

Q6. Markatable Designs							
Developer	25	0	0	0	0	1.00	25
	100.00%	0.00%	0.00%	0.00%	0.00%		
Contractors	8	14	8	0	0	2.00	30
	26.67%	46.67%	26.67%	0.00%	0.00%		

Table 4.4: Ratings Of Importance Of Sustainable Practices Against Other Factors During The Construction Phase Between Developer & Contractor

Question	Most Imp. 1	Imp. 2	Somewhat Imp. 3	Rarely Imp. 4	Least Imp. 5	Rating Avg	Res. Count
Q1. Energy /Sustainable Certified Contractor (i-e LEED-H, State Program)							
Developer	13 52.00%	2 8.00%	8 32.00%	2 8.00%	0 0.00%	1.96	25
Contractors	2 6.67%	0 0.00%	8 26.67%	8 26.67%	12 40.00%	3.93	30
Q2. Energy Rating System Approved (i.e LEED-H, State Program)							
Developer	13 52.00%	8 32.00%	2 8.00%	2 8.00%	0 0.00%	1.72	25
Contractors	2 6.67%	1 3.33%	1 3.33%	14 46.67%	12 40.00%	4.10	30
Q3. Cost							
Developer	25 100.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	1.00	25
Contractors	28 93.33%	2 6.67%	0 0.00%	0 0.00%	0 0.00%	1.07	30
Q4. Constructability							
Developer	17 68.00%	8 32.00%	0 0.00%	0 0.00%	0 0.00%	1.32	25
Contractors	30 100.00%	0 0.00%	0 0.00%	0 0.00%	0 0.00%	1.00	30
Q5. Energy Efficient Building							
Developer	4 16.00%	4 16.00%	17 68.00%	0 0.00%	0 0.00%	2.52	25
Contractors	0 0.00%	0 0.00%	20 66.67%	8 26.67%	2 6.67%	3.40	30

Table 4.5: Responses Related Ranking Of Importance Of Sustainable Practices During The Marketing Phase Between Developer & Contractor

Question	Most Imp. 1	Imp. 2	Somewhat Imp. 3	Rarely Imp. 4	Least Imp. 5	Rating Avg	Res. Count
Q1. Options & Extras							
Developer	3 12.00%	3 12.00%	13 52.00%	3 12.00%	3 12.00%	3.00	25
Contractors	2 6.67%	2 6.67%	2 6.67%	8 26.67%	16 53.33%	4.13	30
Q2. Energy Efficiency Of Entire Building							
Developer	8 32.00%	7 28.00%	7 28.00%	0 0.00%	3 12.00%	2.32	25
Contractors	0 0.00%	0 0.00%	9 30.00%	17 56.67%	4 13.33%	3.83	30
Q3. Energy Efficient Appliances							
Developer	0 0.00%	3 12.00%	3 12.00%	16 64.00%	3 12.00%	3.76	25
Contractors	0 0.00%	0 0.00%	2 6.70%	17 0.00%	11 36.70%	4.30	30
Q4. Energy Rating System Approved (i.e. LEED-H Gold, Local or State Program)							
Developer	13 52.00%	3 12.00%	3 12.00%	6 24.00%	0 0.00%	2.08	25
Contractors	0 0.00%	0 0.00%	6 20.00%	6 20.00%	18 60.00%	4.40	30

Table 4. 6: Responses To Likert Scale Questions Related To Opinion Of Sustainable Practices For Developer & Contractor

Question	Strongly Disagree 1	Disagree 2	Somewhat Disagree 3	Agree 4	Strongly Agree 5	Rating Avg	Res. Count
Q1. Do You Agree That Your Company Actively Incorporates Green Or Sustainable Design?							
Developer	0 0.00%	13 52.00%	7 28.00%	3 12.00%	2 8.00%	2.76	25
Contractors	6 20.00%	9 30.00%	9 30.00%	6 20.00%	0 0.00%	2.50	30
Q2. Do You Agree That Green Or Sustainable Practices Equate To Increased Costs?							
Developer	0 0.00%	0 0.00%	2 8.00%	7 28.00%	16 64.00%	4.56	25
Contractors	0 0.00%	0 0.00%	0 0.00%	15 50.00%	15 50.00%	4.50	30
Q3. Do You Agree That Green Or Sustainable Designs Are More Complicated To Build?							
Developer	0 0.00%	0 0.00%	7 28.00%	18 72.00%	0 0.00%	3.72	25
Contractors	0 0.00%	0 0.00%	9 30.00%	15 50.00%	6 20.00%	3.90	30

Q4. Do You Agree That Green Or Sustainable Homes Should Be Sold At A Premium?							
Developer	0 0.00%	0 0.00%	0 0.00%	7 28.00%	18 72.00%	4.72	25
Contractors	0 0.00%	0 0.00%	2 6.67%	16 53.33%	12 40.00%	4.33	30
Q5. Do You Agree There Is A Growing Demand For Green Or Sustainable Homes?							
Developer	0 0.00%	0 0.00%	3 12.00%	14 56.00%	8 32.00%	4.20	25
Contractors	0 0.00%	6 20.00%	16 53.33%	8 26.67%	0 0.00%	3.07	30
Q6. Do You Agree That Consumer Demand For Sustainable Homes Has Affected Construction And/Or Design Of Your Homes?							
Developer	0 0.00%	11 44.00%	8 32.00%	3 12.00%	3 12.00%	2.92	25
Contractors	0 0.00%	18 60.00%	8 26.67%	2 6.67%	2 6.67%	2.60	30
Q7. Do You Agree There Is Increased Confusion Over Which Green Standards To Use?							
Developer	8 32.00%	8 32.00%	3 12.00%	3 12.00%	3 12.00%	2.40	25
Contractors	2 6.67%	5 16.67%	8 26.67%	8 26.67%	7 23.33%	3.43	30
Q8. Does Your							

Company Agree That The Rating Systems Are Worth The Extra Costs?							
Developer	4 16.00%	5 20.00%	11 44.00%	0 0.00%	5 20.00%	2.88	25
Contractors	6 20.00%	13 43.33%	2 6.67%	7 23.33%	2 6.67%	2.53	30
Q9. Do You Agree That There Is A Consumer Preference Of Green Or Sustainable Homes Over Traditional Or Non-Green Homes?							
Developer	0 0.00%	4 16.00%	20 80.00%	0 0.00%	1 4.00%	2.92	25
Contractors	4 13.33%	20 66.67%	6 20.00%	0 0.00%	0 0.00%	2.07	30
Q10. Green Or Sustainable Designs And/Or Construction Help You To Sell Your Homes Faster?							
Developer	0 0.00%	0 0.00%	19 76.00%	4 16.00%	2 8.00%	3.32	25
Contractors	0 0.00%	21 70.00%	7 23.33%	2 6.67%	0 0.00%	2.37	30
Q11. Green Or Sustainable Designs And/Or Contruction Benefit The Environment?							
Developer	0 0.00%	0 0.00%	0 0.00%	0 0.00%	25 100.00%	5.00	25
Contractors	0 0.00%	0 0.00%	0 0.00%	2 6.67%	28 93.33%	4.93	30

Table 4. 7: Responses To Likert Scale Questions Related To Familiarity With Sustainable Practices For Developers & Contractors

Question	Unfamiliar 1	Less Familiar 2	Somewhat Familiar 3	Familiar 4	Very Familiar 5	Rating Avg	Res. Count
Q1. How Familiar Is Your Company With The Green Building Council In Sri Lanka, Leadership In Energy & Environmental Designs For Homes (LEED-H)?							
Developer	0 0.00%	0 0.00%	19 76.00%	0 0.00%	6 24.00%	3.48	25
Contractors	0 0.00%	9 30.00%	12 40.00%	5 16.67%	4 13.33%	3.13	30
Q2. How Familiar Is Your Company With National Green Building Standards?							
Developer	0 0.00%	0 0.00%	11 44.00%	3 12.00%	11 44.00%	4.00	25
Contractors	0 0.00%	11 36.70%	11 36.70%	7 23.30%	1 33.30%	2.93	30
Q3. How Familiar Is Your Company With Energy Star Brands? (i.e. Appliances, HVAC Systems)?							
Developer	0 0.00%	2 8.00%	19 0.00%	2 8.00%	2 8.00%	3.16	25
Contractors	6 20.00%	6 20.00%	11 36.70%	6 20.00%	1 33.30%	2.67	30

Table 4 .8: Familiarity With Green Building Concepts & Practices For Developers & Contractors

Answer Option	**No of Developer Response**		**No of Contractor Response**	
Q1. Site Selection	25	**100**	30	**100**
Q2. Minimal Disturbance To Surrounding Area	25	**100**	30	**100**
Q3. Access To Open Space	25	**100**	30	**100**
Q4. Drought Tolerant Plants & Landscape Design	25	**100**	30	**100**
Q5. Drip Irrigation	16	64	25	83
Q6. Xeriscaping	8	32	17	57
Q7. Permeable Pavement	2	8	15	50
Q8. Erosion Control	25	**100**	30	**100**
Q9. Reduction Of Heat Island Effect	10	40	25	83
Q10. Pest Control Alternatives	2	8	11	37
Q11. Graywater Reuse	25	**100**	30	**100**
Q12. Energy Star Appliances	13	52	25	83
Q13. Storm Water Treatment	25	**100**	30	**100**
Q14. SIP's	5	20	2	7
Q15. Value Engineering	25	**100**	14	47
Q16. Green lable TM	2	8	1	3
Q17. Refrigerant Management Systems	2	8	2	7
Q18. Solar Water Heating Systems	25	**100**	30	**100**
Q19. Low-E-Gases	0	0	11	37
Q20. Rainwater Collection Systems	25	**100**	30	**100**
Q21. FSC Certified Wood	0	0	1	3
Q22. Renewable Energy Systems	5	20	2	7
Q23. Passive Design	24	96	14	47
Q24. Construction Waste Management	10	40	25	83
Q25. Photovoltic Energy	2	8	0	0
Q26. Thermal Bridge	1	4	0	0
Q27. Vegetated Roof	25	**100**	30	**100**
Q28. Rain Garden	16	64	15	50
Q29. Compact Development Density	7	28	1	3
Q30. Pipe Insulation	25	**100**	30	**100**
Q31. Daylighting	25	**100**	30	**100**
Q32. Framing Efficiency	8	32	0	0
Q33. Energy Modeling	3	12	0	0
Q34. Solar Orientation	25	**100**	30	**100**
Q35. VOCs	0	0	0	0
Q36. Green Globes	0	0	0	0
Q37. Carbon Dioxide Monitoring	14	56	1	3
Q38. Use Of Readily-Renewable Material	16	64	18	60
Q39. Radon Protection	1	4	0	0
Q40. Use Of Recycled Or Salvaged	24	96	25	83

Table 4-9 Responses To Likert Scale Questions Related To Frequency Of Use Of Sustainable Practices For Developers & Contractors

Question	**Never** **1**	**Rarely** **2**	**Sometimes** **3**	**Often** **4**	**Frequently** **5**	**Rating Avg**	**Res. Count**
Q1. How Often Does Your Company Actively Use A Rating System For Assessing Green Or Sustainable Design?							
Developer	3 12.00%	11 44.00%	8 32.00%	3 12.00%	0 0.00%	2.44	25
Contractor	13 43.33%	11 36.67%	0 0.00%	6 20.00%	0 0.00%	1.97	30
Q2. How Often Does Your Company Actively Train Its Employees In Green Techniques?							
Developer	7 28.00%	7 28.00%	0 0.00%	8 32.00%	3 12.00%	2.72	25
Contractor	9 30.00%	12 40.00%	6 20.00%	2 6.67%	1 3.33%	2.13	30

APPENDIX G

RANKING OF EXPERIENCE, IMPORTANCE AND FERMILIARITY ON BAR CHARTS

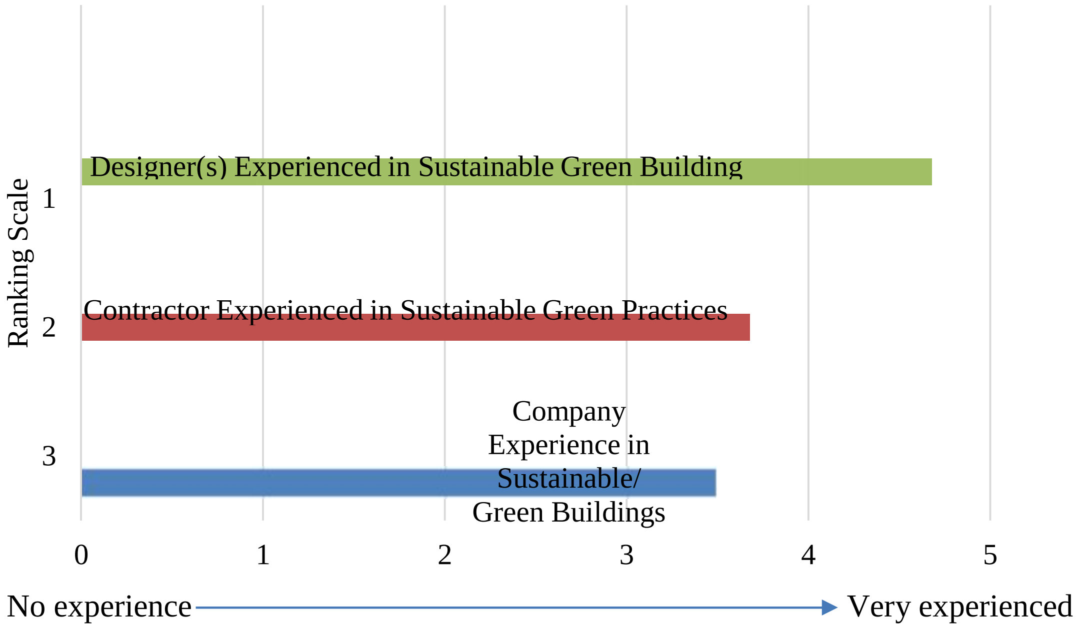
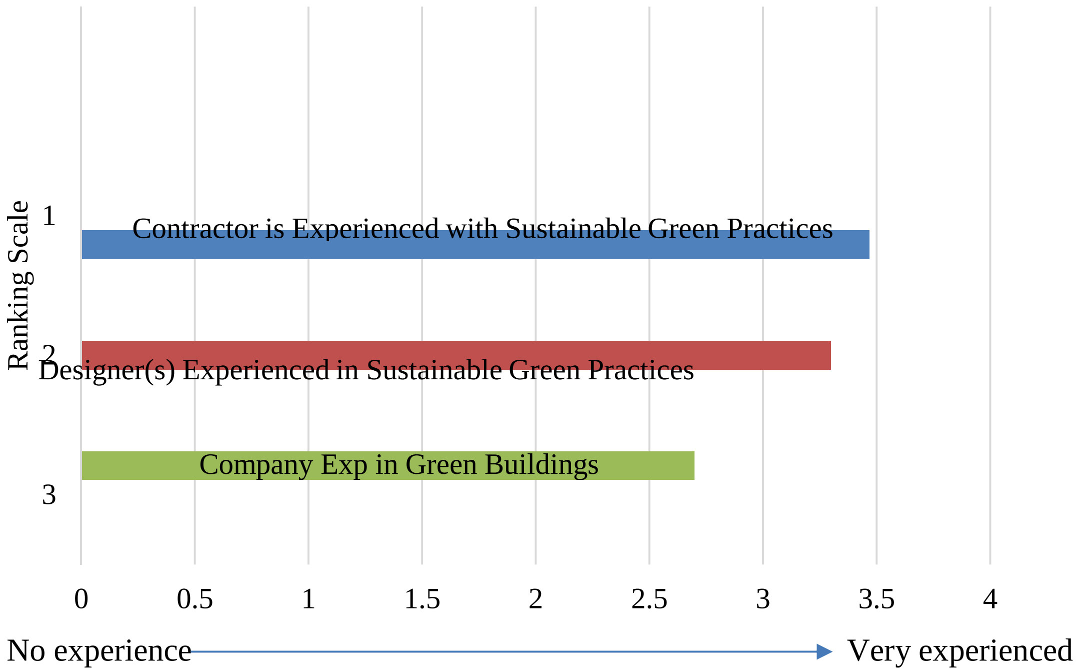


Figure 4.1.1: Ranking of Experience in Sustainable Practices for Developers



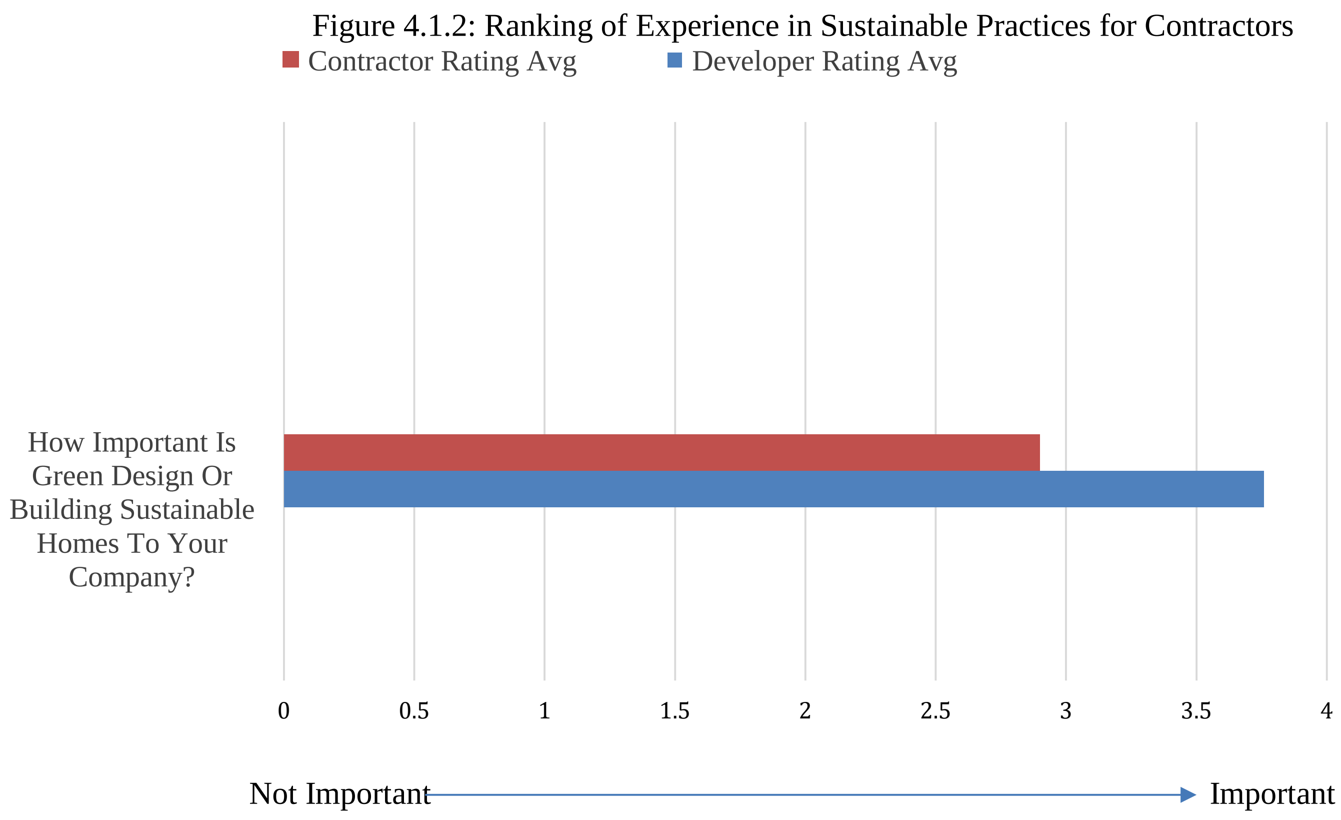


Figure 4.2: Importance of Sustainable Practices between Developers & Contractors

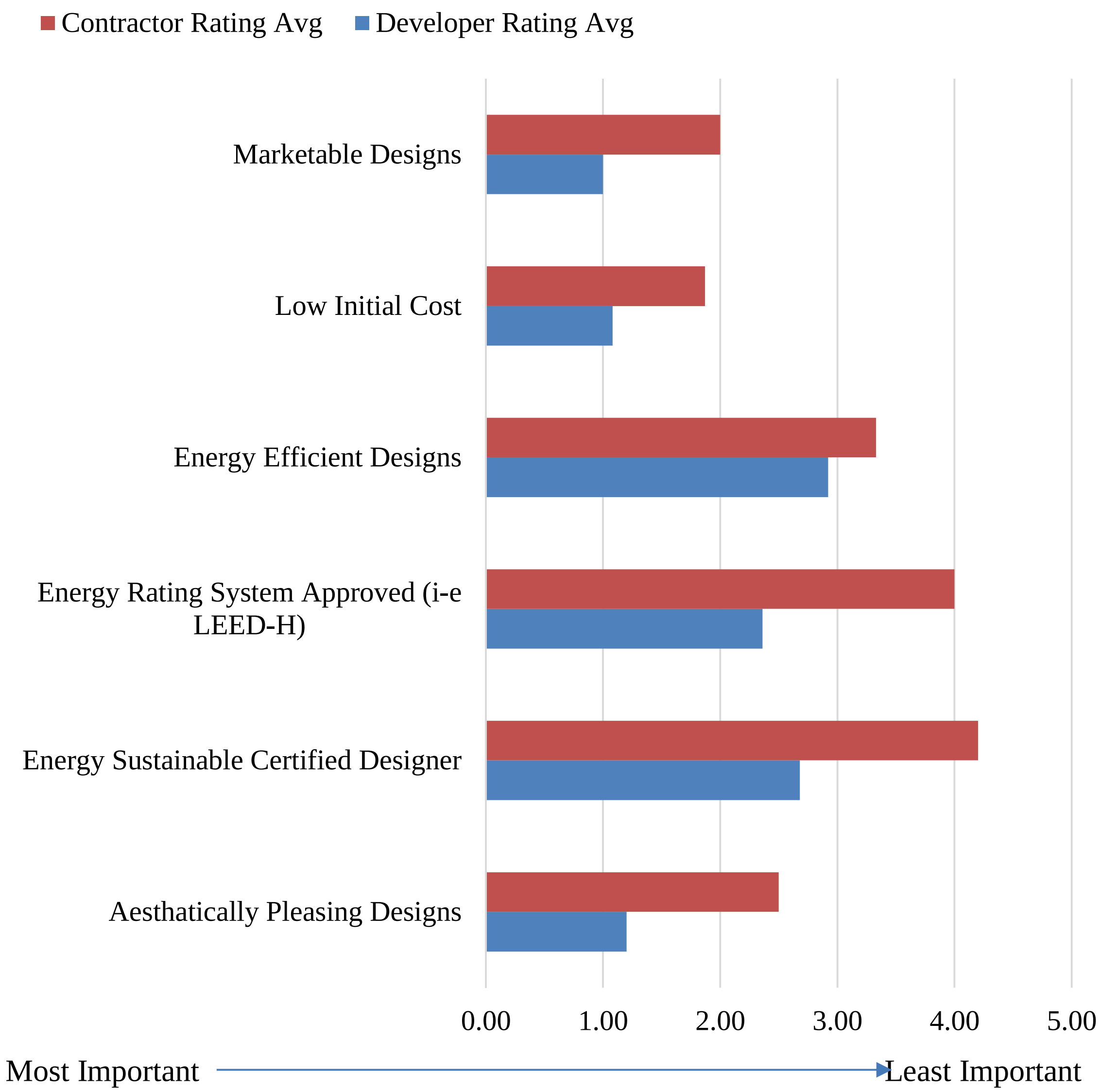


Figure 4.3: Importance of Sustainable Practices Against Other Factors During the Design Phase between Developers & Contractors

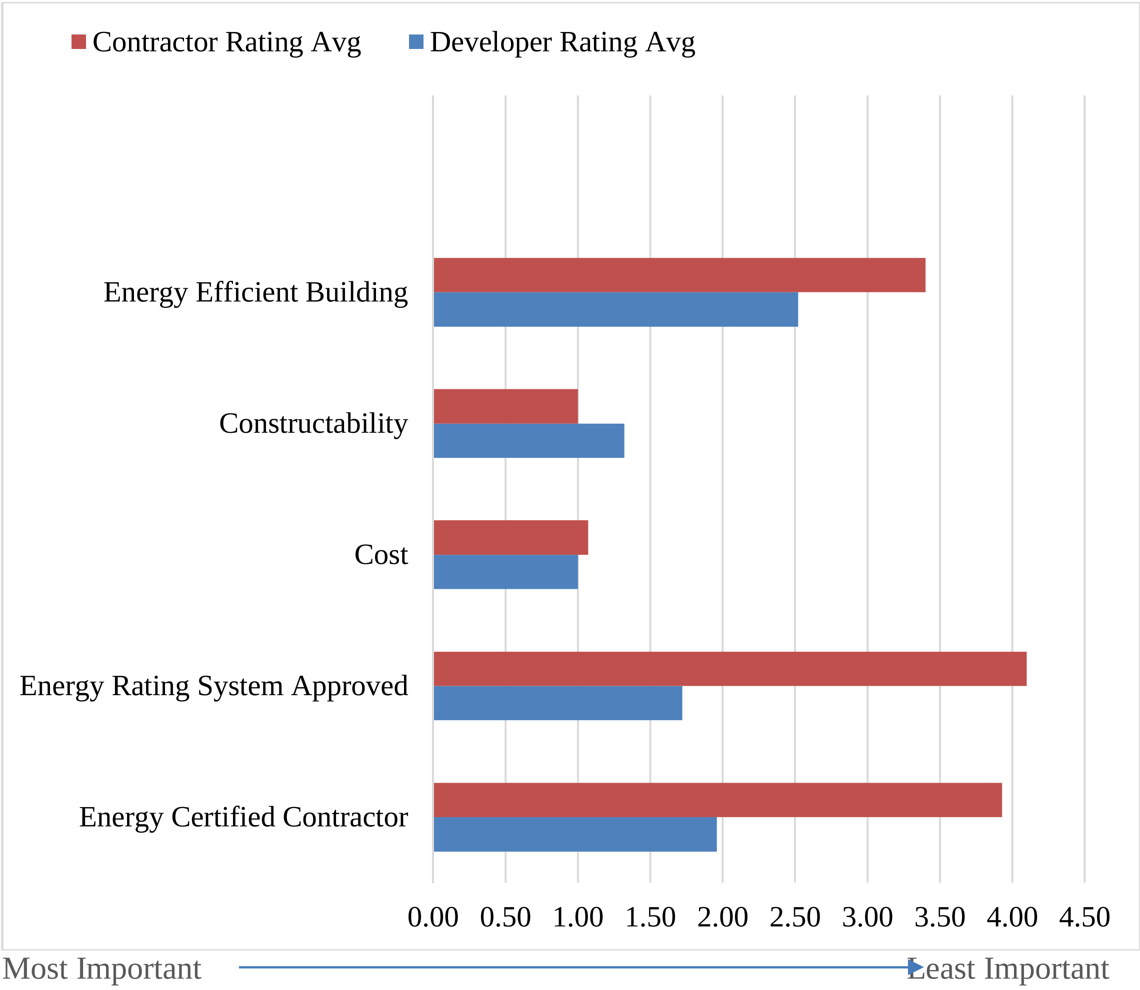


Figure 4.4: Importance of Sustainable Practices Against Other Factors During the Construction Phase between Developers & Contractors

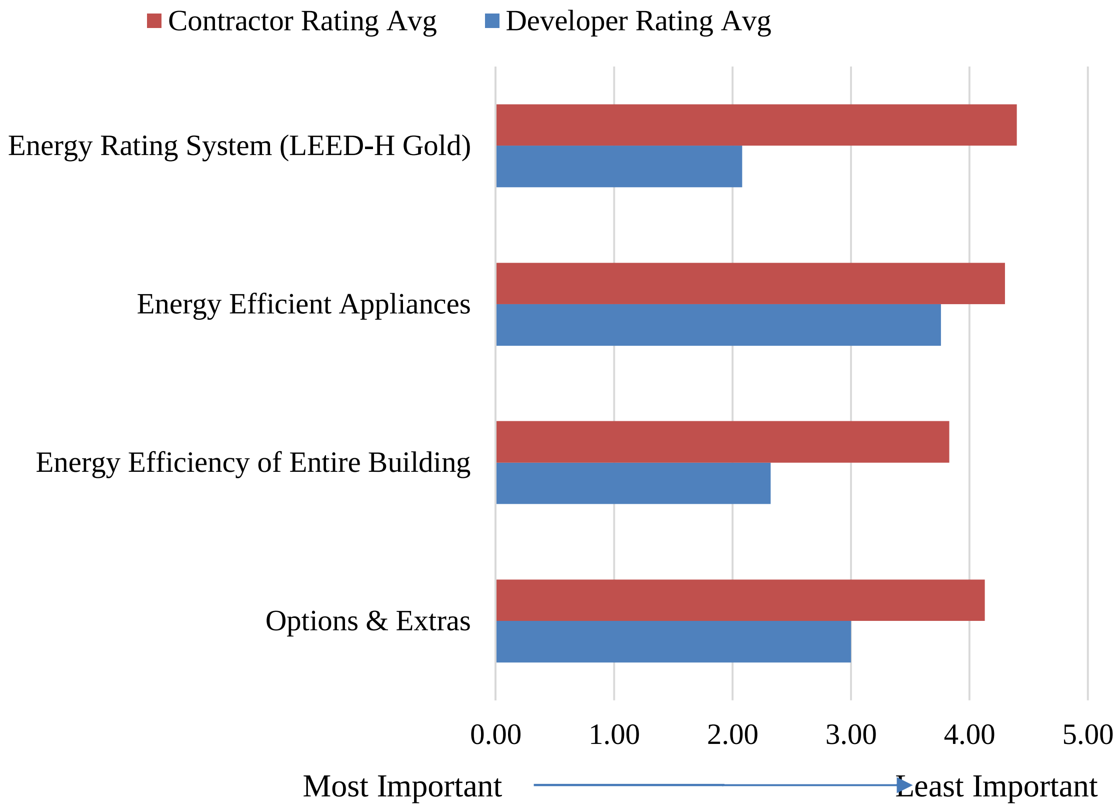


Figure 4.5: Importance of Sustainable Practices Against Other Factors During the Marketing Phase between Developers & Contractors

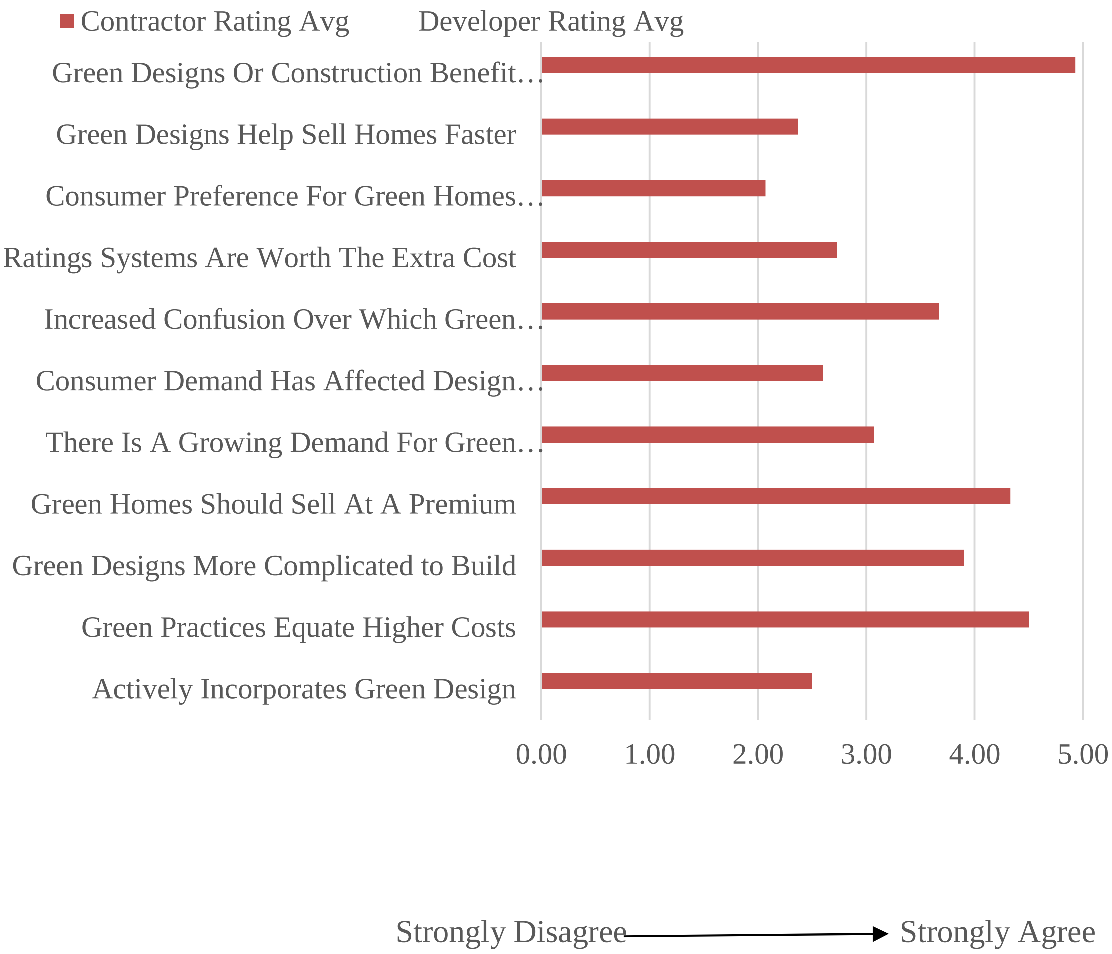


Figure 4.6: Opinion of Sustainable Practices for Developers & Contractors

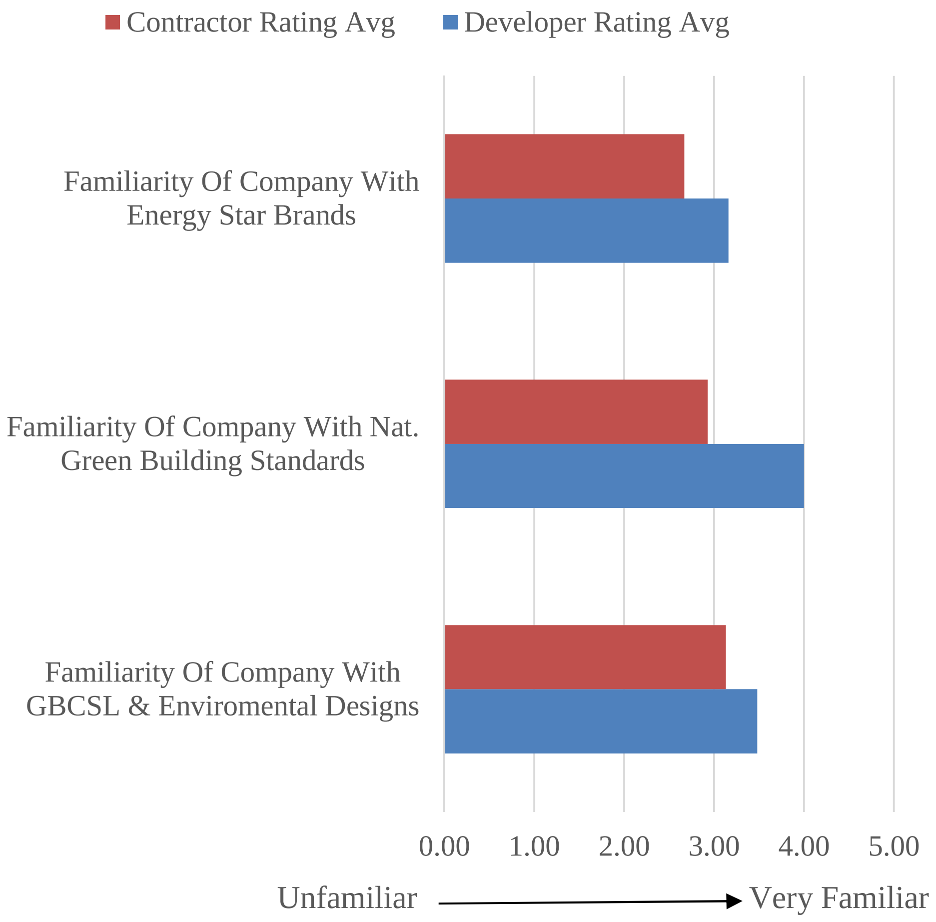


Figure 4.7: Familiarity with Sustainable Practices for Developers & Contractors

Figure 4.8: Frequency of Use of Sustainable Practices for Developers & Contractors

APPENDIX G

STATISTICAL CALCULATION

Table 4.10 Data based on experience with sustainable practices using a chi-squared test between developers and contractors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. Does your Company Have Experience in Sustainable/Green Buildings?	3.48	2.70	-0.78	0.608	0.17	1
Q2. The Primary Designer(s) Experienced With Sustainable/Green Practices?	4.68	3.30	-1.38	1.904	0.41	1
Q3. The Primary Contractor Is Experienced With Sustainable/Green Practices?	3.68	3.47	-0.21	0.044	0.01	1
				Total	0.59	3
		7.81 at 95% with 3 D.F			7.81 > 0.59	

Table 4.11 Data based on importance of sustainable practices using a chi-squared test between developers and contractors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. How Important Is Green Design Or Building Sustainable Homes To Your Company?	3.76	2.90	-0.86	0.740	0.20	1
				Total	0.20	1
		3.84 at 95% with 1 D.F			3.84 > 0.20	

Table 4.12 Data based on ranking of importance of sustainable practices during the design phase with chi-squared test between developers and contractors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. Aesthatically Pleasing Designs	1.20	2.50	1.30	1.690	1.41	1
Q2. Energy/Sustainable Certified Designer	2.68	4.20	1.52	2.310	0.86	1
Q3. Energy Rating System Approved (i-e LEED-H)	2.36	4.00	1.64	2.690	1.14	1
Q4. Energy Efficient Designs	2.92	3.33	0.41	0.168	0.06	1
Q5. Low Initial Cost	1.08	1.87	0.79	0.624	0.58	1
Q6. Marketable Designs	1.00	2.00	1.00	1.000	1.00	1
				Total	5.05	6
		12.59 at 95% with 6 D.F			12.59 > 5.05	

Table 4.13 Data based on ranking of importance of sustainable practices during the construction phase with chi-squared test between developers and contractors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. Energy /Sustainable Certified Contractor (i-e LEED-H, State Program)	1.96	3.93	1.97	3.881	1.98	1
Q2. Energy Rating System Approved (i.e LEED-H, State Program)	1.72	4.10	2.38	5.664	3.29	1
Q3. Cost	1.00	1.07	0.07	0.005	0.01	1
Q4. Constructability	1.32	1.00	-0.32	0.102	0.08	1
Q5. Energy Efficient Building	2.52	3.40	0.88	0.774	0.31	1
				Total	5.66	5
		11.07 at 95% with 5 D.F			11.07 > 5.66	

Table 4.14 Data based on ranking of importance of sustainable practices during the marketing phase with chi-squared test between developers and contactors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. Options & Extras	3.00	4.13	1.13	1.277	0.43	1
Q2. Energy Efficiency Of Entire Building	2.32	3.83	1.51	2.280	0.98	1
Q3. Energy Efficient Appliances	3.76	4.30	0.54	0.292	0.08	1
Q4. Energy Rating System Approved (i.e. LEED-H Gold, Local or State Program)	2.08	4.40	2.32	5.382	2.59	1
				Total	4.07	4
		9.48 at 95% with 4 D.F			9.48 > 4.07	

Table 4.15 Data based on ranking familiarity of sustainable practices with chi-squared test between developers and contactors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. How Familiar Is Your Company With The Green Building Council In Sri Lnaka, Leadership In Energy & Environmental Designs For Homes (LEED-H)?	3.48	3.13	-0.35	0.122	0.04	1
Q2. How Familiar Is Your Company With National Green Building Standards?	4.00	2.93	-1.07	1.145	0.29	1
Q3. How Familiar Is Your Company With Energy Star Brands? (i.e. Appliances, HVAC Systems)?	3.16	2.67	-0.49	0.240	0.08	1
				Total	0.40	3
		7.81 at 95% with 3 D.F			7.81 > 0.40	

Table 4.16 Data based on ranking frequency of use of sustainable practices with chi-squared test between developers and contactors

Question	Developer (D)	Contractor (C)	C-D	(C-D)2	Chi-Squared	Degrees of Freedom
Q1. How Often Does Your Company Actively Use A Rating System For Assessing Green Or Sustainable Design?	2.44	1.97	-0.47	0.221	0.09	1
Q2. How Often Does Your Company Actively Train Its Employees In Green Techniques?	2.72	2.13	-0.59	0.348	0.13	1
				Total	0.22	2
		5.99 at 95% with 2 D.F			5.99 > 0.22	