IMPLICATIONS IN OPERATION AND MAINTENANCE OF GREEN BUILDING IN SRI LANKA

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DECLARATION

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ABSTRACT

The Green Building concept has turned out to be one of the appropriate principles for the sustainable development over the world. According to the interviewees' perspectives, there aren't any studies that methodically classify waste generated during building maintenance based on volume, structure, composition, and level of hazard. In this regard, it is possible to look into how this waste might be managed in accordance with the concept of sustainable waste management and contrast it with real-world scenarios in case studies. Green buildings are intended at accomplishing grading levels in green certifications but, most of the developers neglect to maintain the obtained certification category due to various reasons.

Therefore, this study attempts to look into the effects of running and maintaining green buildings. A preliminary analysis of the study's significant green aspects was included. Following that, six green-certified buildings were carefully chosen, and a thorough survey was carried out. A qualitative technique to research was adopted for this study. Manual content analysis and cross-case analysis were used to compile and analyze the data related to the operation and maintenance of green buildings. Through the case study analysis, the significant green features of the green buildings with relevant to operation and maintenance, current operation and maintenance practices, benefits of green building O & M, positive and negative implications of green building O & M, causes for the negative implications and the strategies for better O & M are discussed.

The current study recommends, green building developers to understand and be aware of the implications in operation and maintenance of green buildings. Further, this research attempts to increase the public awareness to influence the government and the private sector to practice O & M procedures and experience their positive implications and to know how to strategically eliminate the causes of negative implications as well.

Key words: *Green building, Green features, Green rating system, Operational and maintenance implications.*

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LIST OF ABBREVIATIONS

O & M	- Operational & Maintenance
GB	- Green Building
GBCSL	- Green Building Council of Sri Lanka
BREEAM	- Building Research Establishment Environmental Assessment Method
LEED	- Leadership in Energy and Environmental Design
UNEP	- United Nations Environment Programme
GBCSL	- Green Building Council of Sri Lanka
LCD	- Life Cycle Design
HVAC	- Heating, Ventilating & Air Conditioning
CO_2	- Carbon Dioxide
ICP	- Integrated Construction Process
BMS	- Building Management System
USGBC	- United States Green Building Council
LED	- Light Emitting Diode
VFD	- Variable Frequency Drive
ISO	- International Organization for Standardization
AC	- Air Conditioner
IEQ	- Indoor Environmental Quality
CEB	- Ceylon Electricity Board
BOD	- Bio Oxygen Demand
IAQ	- Integrated Air Quality
VOC	- Volatile Organic Compound

CHAPTER 01

INTRODUCTION

1.1 Background

According to Giduthuri (2019), B51, based on the results of the estimates, the existing buildings are liable for the world's total primary energy consumption more than 41% and Carbon Dioxide (CO_2) emissions more than 24%. A green building improves energy effectiveness, conserves the natural resources such as water, compared to a traditional building, it creates less waste and gives its occupants healthier living conditions. (Hedaoo & Sharad, 2016). A green building process ensures a healthiest environment while demonstrating the most effective & minimum disrupting of the water, land, energy and resources. According to Abualrejal, Udin and Mohtar (2017), in this globalization era, green constructions have taken some new steps to inspire green building practices. In study of Hajeri (2013), any type of structure or facilities has the probability to become a green building such as Houses, Commercial Buildings, Healthcare Facilities, Mosques, Laboratories, Hotels, Light Industry and Sports division related structures.

The resilience ability of green buildings may realize by decreasing the primary damage to both building organisms and its arrangement as well as using passive design philosophies to increase building resilience. Compared to traditional buildings, there are many passive design features existed in green buildings such as renewable energy, rain water harvesting, natural ventilation, day lighting etc which can be applied to increase the resilience ability of green buildings (Mallawarachchi, Silva & Rameezedeen, 2015).

Sauchyk (2017) explained that the Green building certifications are focused on single or multi scope building characteristics and used as a precondition for standards or rating systems assessment and the purpose of the rating systems is to evaluate project and building implications or performance with particular environmental standard, target or requirement.

Due to its superior ecological performance, recently, Sri Lanka has seen a rise in interest in the green building concept, (Waidyasekara and Fernanado 2013). Following technological developments in the construction industry have made it easier to obtain sustainable results (Rathnasiri, & Jayasena, 2019).

The Green Building Council of Sri Lanka (GBCSL) is the country's top authority on implementing green building principles (Green Building Council of Sri Lanka [GBCSL], 2009). Furthermore, Sauchyk (2017) justified Leadership in Energy and Environmental Design (LEED) has a set of requirements which must be come across to earn credits and The United States Green Building Council devised the LEED voluntary green building rating system (USGBC). Green building rating systems have wider scope compared to standards or certificates which are accumulate project parameters, building characteristics as an assessment object (Sauchyk, 2017).

According to Sullivan, Pugh, Melendez and Hunt (2010), Operational and Maintenance (O & M) are the judgements and actions related to the governing and maintaining of equipment and property. These are comprehensive and not limited to, mainly: i) activities focused on processes and systems control and optimization and ii) Presentation of routine, scheduled and unscheduled actions which intended at avoiding failures of equipment or enhancing efficiency, safety and reliability.

As pointed out by Akshey, Swati and Disha (2018), Green Buildings (GB) could have various benefits directly and indirectly. Additionally, Jatav and Rastogi (2014) highlighted that Cost savings from decreased electricity, water and pollution, lower maintenance rates and increased resident efficiency and wellbeing are some of the financial advantages that GB have that traditional buildings choose not to.

Similarly, Sullivan et al. (2010) justified the goals of GB are to be lower the whole effect for the natural environment, built environment and human health through energy, water and resources efficiencies and increase the employee productivity, reduce waste generation and environmental pollution, create attractive environment, using nontoxic or recyclable materials and environmental degradation.

Agreeing to Jatav and Rastogi (2014), the initial construction cost of GB is a slightly more than conventional building cost and the cost of the energy consumption is already accounted in the initial construction cost, but the routine maintenance cost of the building will be reduced in comparison with the conventional building.

The construction maintenance stage involves the operation of the building, including the use of electricity, water use, the production of environmental waste, the repair and replacement of building items and systems and the use of transport and equipment, tools for repair and maintenance replacement (Gogoi & Giri, 2017).

The effects of a building's function and upkeep on its occupant health and the atmosphere at large scale can be important, and green building implies finding a balance between the building and a healthy environment (Sharma & Sigh, 2016). Furthermore, Manav (2014) pointed out beyond the pleasant visual nature, green buildings offer many clear advantages both economical and ecological provided they are built in the right way and managing the green features in green buildings are much important for the environment.

1.2 Research Problem

In study of Ramachandra, Weerasinghe and Thurairajah (2017), a green building is one that uses resources sparingly and responsibly over its entire life cycle. As discussed in the background study, further to the design and built of environmental friendly green features, the green buildings should have well operating system as well as a better maintenance procedure. Though the applying of green building (GB) concept to construct operation and maintenance is more reliable and effective long term investment, it takes a slight period of time to earn a vast profit.

Operating and maintaining a green building with sustainable green technologies, environmental friendly clean technologies in all aspects through the life cycle together with good financial capability is a great challenge to an emerging country like Sri Lanka. The goal of successful operational and maintenance is to fulfill the original building design intention, as then building structures can provide services to building

occupants. Furthermore, O & M have long term investments such as saving money, energy and water quality, conserving resources and preventing waste while fulfilling the occupants' convenience, health and safety needs.

In study of Dwaikat and Ali (2016), initiate that between the various types of the buildings such as office, hospital, house, school and office buildings get the highest green premium (21%) compared to apartment structures. Therefore, this study emphasized on O & M of existing office buildings which have received the platinum and gold certification levels in green rating systems (GBCSL or LEED).

Though the applying of green building (GB) concept to construct operation and maintenance is more reliable and effective long term investment, it takes a slight period of time to earn a vast profit. Zainol, et al. (2014) had observed underperformance of green buildings specifically with reference to energy performance, during O & M stage. Numerous studies have revealed that many green buildings perform poorly during operation and maintenance, particularly in terms of energy performance, Although Esa, et al. (2011) highlighted that several individual researches have been done on benefits of green buildings in many aspects. According to Waidyasekara and Fernando (2012), less attention is paid on study the O & M implications both negative and positive aspects in Sri Lankan green buildings.(Hence, the problem of this study considered as what are the implications in operation and maintenance of Sri Lankan green buildings.

1.3 Aim & Objectives

1.3.1 Aim of study

Aim of this research is to investigate the implications in Operations and Maintenance of Green Buildings in Sri Lanka. To fulfill the purpose of the research, the ensuing goals were established as follows.

1.3.2 Objectives of Study

- Analyze the operational and maintenance features in green buildings according to green rating systems
- Investigate current operational and maintenance practices in Green Buildings in Sri Lanka.
- Analyze the positive and negative implications with operational & maintenance of the Green Buildings in Sri Lanka
- Investigate the causes for negative implications with operational & maintenance of the Green Buildings in Sri Lanka.
- Explore the strategies for better operational and maintenance of Green Buildings.

1.4 Research Methodology

1.4.1 Literature Review

A thorough literature synthesis was conducted by consulting books, journal articles, magazines, conference proceedings, and other sources in order to accomplish the aforementioned aim and objectives, related research papers, government publications and World Wide Web. A comprehensive literature survey on green building activities and special reference to operation and maintenance practices were presented.

- Data collection

  The research study adopted a case study strategy. Document review, preliminary survey and the primary data collection method employed was semi-structured

interviews tools in order to investigate implications in operation and maintenance of green buildings as well as their positive and negative aspects, causes for the negative aspects and the possible strategies.

- Data analysis

  The results of the case study data were analyzed through manual content analysis. Further, cross case analysis was also done to interpret the collected data.

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  The results of the case study data were analyzed through manual content analysis. Further cross case analysis was also done to interpret the collected data.

1.5 Scope and Limitations

The scope of the study was to investigate the operational and maintenance implications in green building, and the case selection was limited to GBCSL and LEED certified green buildings in Sri Lanka.

1.6 Chapter Breakdown

Chapter 1 – Introduction

This chapter presents background of the research, Aim and objectives, Research Methodology, Scope and limitations, Chapters Breakdown.

Chapter 2 - Literature Review

This chapter includes reviews of the literature related to the research topic, aim and objectives, operational and maintenance implications of green buildings in Sri Lanka, the behavior of building infrastructure in the face of it and the presently given solutions, further suggested strategies, etc.

Chapter 3 - Research Methodology

This chapter explains the research methodology and qualitative data analysis method used for this research.

Chapter 4 – Research Data Analysis and Results

This chapter presents the research data analysis and the results. The data collected through the literature review, preliminary survey and detailed survey are analyzed in here and the results are presented.

Chapter 5 – Conclusions and Recommendations

This chapter includes the conclusion of research study findings and proposed recommendations.

1.7 Chapter Summary

Under this chapter, the rationale for the research has been explained in brief. And the research background, research problem statement, research aim and objectives of the study, research methodology, scope and limitations of the study have been outlined in this chapter.

CHAPTER 02

LITERATURE REVIEW

2.1 Introduction

This chapter intends to provide a comprehensive explanation about the research area by using the available information and resources. Accordingly in this literature review, the existing knowledge relevant to the operation and maintenance of the green buildings, green rating system for operation and maintenance and the implications in operation and maintenance of green buildings will be investigated deeply. Further, the causes for negative implications with operation and maintenance of green buildings will be inquired and the strategies for better operation and maintenance of green buildings will be explored.

2.2 Green buildings and Sustainable construction

Agreeing to Oladokun, Gbadegesin and Ogunba (2015), green building is defined as a sustainable or high performance building. Green buildings indicates the practices and processes that lead to energy and resource conservation through out the building's life-cycle from planning to destruction (Nallathiga, Raipure, Prateek, & Singh, 2022). Research by Elshimy, Radwan, Kashyout and Ashour (2015), the building activities from design to operation and maintenance typically requires huge amounts of energy, water and raw materials and it generate big quantities of waste affecting air and water pollution. Green buildings is the best solution since it creates healthier and more resource efficient models of all building activities.

According to Prasad, Panda, Giri, Nawab and Mallick (2016), the buildings consume for 30-40% of the country's main energy consumption, including fuel input for manufacturing. As stated by Neogi and Patel (2015), green construction is the most effective and least destructive use of soil, water, electricity and resources over the period of its lifespan. The green building concept will advantage an organization through financial returns as well as improve human health and productivity, reduce harmful effects on the environment (Rodrigo & Jayaratne, 2015).

In addition, According to Moramudali and Manawadu (2018), Green Building is an all-inclusive concept that starts with realization that the built environment can have both good and negative reflecting effects on the surrounding environment as well as on the people who occupy such structures. The most significant pointers of sustainability are society, environment and the economy (Bombugala and Atputharajah, 2010) and presented in Figure 2.1.

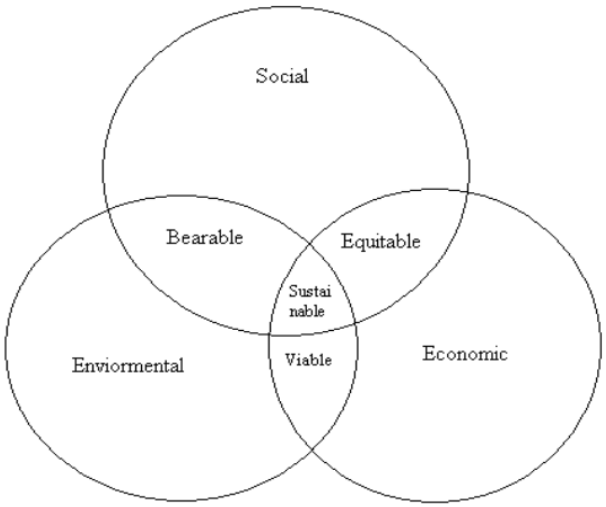

Figure 2. 1: Component of sustainable development

(Source: Bombugala and Atputharajah, 2010)

As pointed out by Pamu and Mahesh (2019), globally, there is a dearth for energy. Many studies are proceeding for the finding of substitute ways of energy generating. The process of substitute generating energy ways should be eco-friendly and the limited resources should be minimum affected.

By minimizing energy consumption, green buildings decrease worldwide Green House Gas (GHG) emissions and support to global sustainability (Nallathiga et al., 2022). A well designed green structure would construct an environment in which all species will coexist in safety (Killemsetty & Behare, 2014).

Green buildings are resource-efficient and environmentally responsible in its whole life cycle (United States environmental Protection Agency [USEPA], 2017). In parellel, Divyadarshi, Tiwari, Sharma, Washington and Samal (2018) identified with

the global trend that Sri Lanka has also focused on issues related to implementing the green building model for the country's structures and Green architecture refers to both the construction and the processes used in making a building that is environmentally responsible and convenient to use for the duration of its lifespan.

According to Awasthi (2016), Green design optimizes energy consumption in buildings by passive energy efficiency, such as choosing the most energy efficient unit and then installing it properly. According to the view of Prasad et al. (2016), many new developments are evolving, along with best practices for upgrading advanced technologies to renewable technologies to reduce the entire energy usage of the building while remaining environmentally and carbon neutral.

Green buildings, as a part of sustainable building, targets to increase the building importance that assists occupants as well as the environment. As stated by Singh (2018), the Green buildings objectives include wisely use natural resources, protecting and improving employee health and productivity and reducing the impact to the environment. Jacob (2016) has discussed life cycle and Sustainable Construction for a typical building and illustrated in Figure 2.2.

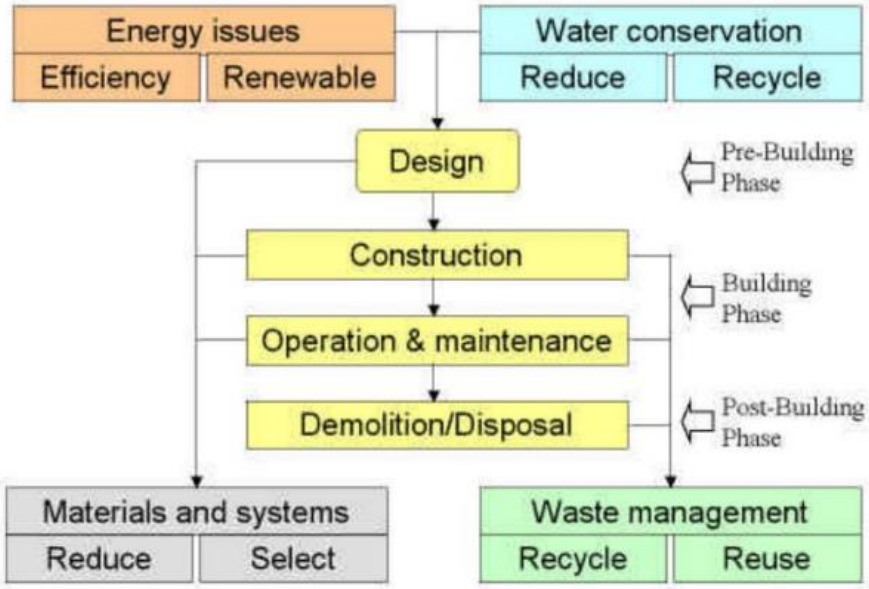

Figure 2. 2: A Typical Building life cycle and Sustainable Construction

(Source: Jacob, 2016)

Main features of Green Buildings contain followings,

- Reduced energy and water consumption with keeping the ease level.
- Improved lighting quality including better daylight harvesting and consumption of covering, better tenancy control over light levels.
- Enhanced thermal comfort and healthier ventilation.
- Limited waste generation caused by the recycling practice and reuse.
- Improved productivity of workers and machines according to using greenhouse norms.
- Decrease of operating and maintenance costs by about 25% to 30% (Nallathiga et al., 2022).

The report by Manav (2014) highlighted about the green building evaluation index system level. Green buildings rule layers can be separated into layers that represent the basic criteria it follows fairly accurately (Manav, 2014). As stated by Bansal, Singh and Tandon (2019), in the last ten years, the industry has seen a major increase in renewable engineering.

2.2.1 Characteristics of Green Buildings

In study of Hauashdh, Jailani, Rahman and Fadhali (2022) stated that existing green buildings perform a dynamic part in economic, environmental and social developments aspects. As stated by Giduthuri (2019), there is increasing proof that the built environment considerably influences the health and comfort of individuals as well as entire residents.

Divyadarshi et al. (2018) identified with the global trend that Sri Lanka has also focused on issues related to implementing the green building model for the country's structures and Green architecture refers to both the construction and the processes used in making a building that is environmentally responsible and convenient to use for the duration of its lifespan.

According to Awasthi (2016), Green design optimizes energy consumption in buildings by passive energy efficiency, such as choosing the most energy efficient unit

and then installing it properly and by active energy efficiency, which involves optimizing the use of installations and equipment, can boost performance by 15% to 25% and this can be accomplished by turning off machines while they are not in use, regulating motors or heating to the optimal standard, following a strict maintenance schedule and measuring and reacting to deviations.

Halil, Nasir, Hassan and Shukur (2015) stated that the client's ability is to determine whether or not the proposal is viable and worth undertaking based on the overall assessment and when the clients plan to move forward, the project's goals and scale must be improved to accommodate for any changes that could have occurred during the feasibility study period. Most green buildings enhance the initial construction cost by 20 percent to 25 percent, but the profit is ten times as much over the lifetime of the building, according to statistics and green buildings also reduce the operational cost of the building by 30-40 percent (Bombugala & Atputharajah, 2010).

2.2.2 Benefits of Green Buildings

Hauashdh et al., (2022) explained in order to improve the benefits of GB, it is important to maintain occupants using eco-friendly, practical methods that address the environmental, economic, and social aspects in a constructive way.

According to the view of Prasad et al. (2016) many new developments are evolving, along with best practices for upgrading advanced technologies to that utilize renewable energy to reduce energy consumption of the building while remaining environmentally and carbon neutral.

Esa et al. (2011) expand their studies upon the increased cost of construction as one of the key issues of many inventors who are not accepted green and despite the fact that budget is a problem. On the other hand, today's developers shift their mindsets and search for the best long term approach rather than the cheapest alternative. It is revealed that the Asian governments have applied unconnected government organizations with the purpose of promoting and assessing green developments in commercial buildings (Moramudali & Manawadu, 2018).

Supportively, Neogi and Patel (2015) stated that the diverse features of a green building are described below.

- Sustainable Site selection
- Energy effectiveness
- Water efficiency
- Materials effectiveness
- Design efficiency
- Occupants health and safety

According to green rating systems, factors to be considered under each element have been discussed below.

Sustainable Site Selection

Architects, engineers and administrators should have to consider the following factors when selecting a sustainable site,

- Quantity of buildings existing and proposed
- Nature of the surface and ground water quality
- The quality of air
- Eco system
- Usage of land
- Services exiting in surrounding area
- During the site selection process, consider plants protection

Energy Efficiency

- Apply a appropriately sized, energy effective cooling method to the building
- Usage of solar energy for lighting and water heating
- Optimum usage of the ordinary lighting and air
- Increase light colours for roofing and the wall finishing materials
- Minimise the use of light colours for roof and wall finishing materials
- Decrease the use of glasses on east and west exposures.

Water efficiency

The processes that can be taken to increase water efficiency showed as below.

- Potable water should be used only for the necessary requirements.
- Recycled water can be used for the other purposes such as watering to plants, washroom cisterns,etc
- Water saving materials can be applied to the buildings such as low capacity cisterns, showers and dry urinals.

Materials Efficiency

According to Neogi & Patel, 2015 the use of recycled, waste ingredients, as well as the selection of new construction materials, is two key considerations in the construction of green buildings and these items encourage resource management, productivity which creates recycling materials are also beneficial to the hazardous waste disposal scheme. Green products include green concrete, fly ash, coconut husk, blast furnace slag and marble dust and Green building constituents having the following profits which revealed below.

- Energy preservation
- Reduced costs
- Improved manageability in designs
- Less requirement of maintenance
- Increased occupant health and productivity (Neogi & Patel, 2015)

Design efficiency

Green building design is an important and it plays a vigorous part in decreasing the necessity of energy for the building lifetime. Design should reflect the subsequent factors.

- Maximum consumption of solar energy.
- Upmost usage of renewable energy.
- Implementation of energy proficient fitting plants and apparatus.
- Introducing energy efficient strategies and technologies.

Occupant health and safety

According to research findings of Neogi and Patel (2015), green buildings with better whole environmental value can reduce the worker's health issues and increase worker performances due to better choose of construction materials and application of good interior product items with zero or minor harmful emissions to develop indoor air quality. Several building constituents and maintenances ingredients produce poisonous vapors and these vapors can have a progressive influence on indoor air value (Neogi & Patel, 2015).

Several benefits of the Green building are revealed below,

- To reduce the energy usage
- To fewer the depletion of natural resources, biological diversities and soil erosion
- To lower the air and water pollution
- Enhances the user productivity
- Increase image and market value (Nisar, Ahmad and Sharif, 2017)

A quantity of these studies pointed to evaluating the integration of sustainable technologies in buildings, the economic advantages of green building and the environmental effects and benefits of implementing sustainable features in building (Abdallah, Rayes & Liu, 2013). According to Fafore, Aigbavboa and Remaru (2018), green buildings convey a substantial amount of paybacks and lucrative rewards compared to conventional buildings. The benefits of sustainable designs under each principle are summarized in Table 2.1 as discussed by Waidyaekara and Fernando (2012).

Table 2. 1: Benefits of Sustainable design

Key principles	Economic	Societal	Environmental
Sustainable Site	*Minimise the expenses for site groundworks *Protect the top soil and minimise disruption to existing plants *Recyle construction wastes *Lower the cost for landscape upkeep	*Increase the land architecture *Offer cool, law heat environment *Improve the transportation system for employees and neighbours	*Preserve the property *Use minimum resources *Protect the green resources *Minimise the energy usage *Lower the environmental pollution
Water Efficiency	*Apply water effient fixtures *Lower the primary costs *Minimise water usage *Minimise yearly costs related to water and wastewater	*Protection of water assets for the next generation *Preserve the water for farming purposes *Maximum use of waste water	*Preserve the natural, pure water *Lower the water pollution * Minimise the disturbance to ecological system
Energy Efficiency	*Introduce the energy effient fixtures and insulations * Minimise yearly costs related to water and wastewater *Reduce the energy demand in peak hours *Lower consumer's energy related costs	*Ensure the comfirt and occupant satisfaction by increasing the thermal condition *Minimise the need for new power plants and transmission mains	*Reduce the usage of electricity *Minimise carbon dioxide emissions *Less air pollution
Materials and Resources	*Reduce the primary costs by re-using the materials *Reduce the waste disposal costs by recling the materials * Lower the material replacement related costs by using long-lasting materials	*Minimise landfills and other disturbances *Develop the eco-friendly product market area *Minimise the excessive material usage	*Minmise the weight over the lands *Reduce continuous use of new materials *Produce well-managed,better and healthy environment * Reduce the transportation related energy usage * Decrease the energy pollution due to recycling

Indoor Environmental Quality	*Reduce the unnecessary costs by improving the productivity of the occupants *Improve the worker performance by fulfilling their needs *Reduce the litigation costs by solving issues and conflicts in the staff *Creating better environment and reduce the insurance costs	*Rub off the effects related to occupants' health *Enhance the occupant's comfort *Properly-working HVAC system *Environmentally preferable mechanical cooling systems	*Increase quality of air inside the building by reducing the harmful gas emissions *Acceptable temperature and relative humidity *Distributing adequate fresh air *Create a dust free environment
Commissioning, Operation and Maintenance	*Reduce operation and maintenance related costs by applying a well-managed systems *Minimise the costs for managing occupant's complaints *Increase building durability	*Ensure and enhance the productivity, safety and health of the building occupants	*Decrease the air pollution *Reduce the energy usage *Lower the environmental impacts of production of energy

(Source: Waidyasekara & Fernando, 2012)

Furthermore, Awasthi (2016) mentioned, even for Green Buildings with the highest number of energy efficiency certification ratings, which are made to minimize energy consumption by 30-50 percent while lowering the carbon dioxide emissions, account for over 80 percent of a building's carbon footprint over its lifespan. Also Early studies of Neogi and Patel (2015) concluded that Green construction employs a variety of techniques to decrease the use of carbon based energy, which will include highly efficient lighting elements, as well as different energy bases such as solar or storm powered units on or around the site.

Au-Yong, Chua, Ali and Tucker (2019) highlighted the scheduled maintenance task priorities that add to the successful development of the maintenance approach when it comes to corrective maintenance for serious facilities, maintenance priorities are often required. Professional experience is needed for the design of green buildings when a

project manager is the primary person responsible for ensuring that a project is completed on schedule and under budget it is to finish tasks on schedule, ensure product quality and stick to a tight budget, project managers need good project management techniques (Elgadi et al., 2019).

Sood, Chua and Peng, (2011) described this can be accomplished by forming a representative group comprised of delegates from all relevant parties to develop legislation, rules and standards. The government should then provide a forum for consultation and collaborative action among stakeholders in the building sector to resolve environmental concerns and the green building sector's framework. In relation to studies by Mallawarachchi et al., (2015), green buildings consist of lower operational expenses, increased indoor environmental quality, market benefits for the building developer, higher productivity and decreased health expenses etc.

Creating a green building is profitable and makes financial wisdom at present (Fafore et al., 2018). Halil et al. (2015) described that for the purpose of attracting buyers and providing value for money to customers, a suitable theme of green building construction should have its own personality or style. As stated by Fafore et al., (2018), the developers need to take attention on the paybacks of green buildings and start financing in green building construction.

2.2.3 Role of Green Building Rating Systems

According to Bansal, Singh and Tandon (2019), green technology and sustainable design have been incorporated into rating schemes. The rating system is a useful framework for assessing a building's environmental performance and integrating it with sustainable development. Additionally, it can be applied as a design tool by creating appropriate sustainable design techniques and setting sustainable goals. (Rodrigo and Jayaratne, 2015). As stated by Moramudali and Manawadu, (2018), around the globe, there are number of green rating systems that used widely.

Similarly, Yahya, Ariffin and Ismail (2013) explained a scoring scheme that can be conveniently measured on a finished building which is used to determine a building's

level of sustainability and by a building ranking will be referred to a fixed band for scoring by assigning points from a list of indexers. Each method came up with its own scoring system and rating scale and these scoring structures and rating systems, do not vary much from each other. Pamu and Mahesh (2019) have stated that in local conditions of different countries and regions, there are different rating systems having different weightages.

According to Bansal et al. (2019), all rating systems currently are voluntary rather than mandatory. The concept of green building is line up with five ecological goals including sustainable sites, clean energy, innovation and infrastructure, good health and wellbeing, responsible consumption and production,etc (Moramudali and Manawadu, 2018).

Moreover, Waidyasekara and Fernando (2012) pinpointed the Green Building Council has launched a new construction ranking scheme called GREENSL in 2010, which is kind of equivalent to LEED which is used to grant green certification. Similar to other organizations which had introduced green building rating system, the Green building council of Sri Lanka (GBCSL) was established in the year 2009, as a nonprofit nongovernment organization. Further, GBCSL has been a member of World Green Building Council since year 2010 (Moramudali & Manawadu, 2018).

Thus, the GBCSL was established in response to an increasing trend of using greener building ideas in the built environment (Waidyasekara & Fernando, 2012). Also, Guanwardana, Maheepala and Jayasinghe (2018) comparatively mentioned that GREENSL has been developed by concerning Sri Lankan own necessities and as a result, it is more relevant to the Sri Lankan circumstance which is similarly, it was discovered that the same rating system is used in the construction industry for all types of buildings. The GREEN Sri Lanka Assessment Catergories are summarized in Table 2.2 as discussed by Green Building Council, 2022.

Table 2. 2: GREEN SL Assessment Categories

Categories	**Weighting (%)**	**Credits**
Management	4	4
Sustainable Sites	25	25
Water Efficiency	14	14
Energy and Atmosphere	22	22
Materials, Resources and Waste Management	14	14
Indoor Environmental Quality	13	13
Social and Cultural Awareness	4	4
Innovation in Design	4	4
Total	100	100

(Source: Green Building Council, 2022)

It is possible to propose that various ranking structures with different parameters be created and used, since each building's construction differs and the time being it is essential to execute strategies to obtain green certification for each structure build (Guanwardana et al., 2018). According to Moramudali and Manawadu (2018), the United States Green Building Council (USGBC) have been introduced world renowned green rating system Leadership in Environmental and Energy Design (LEED) to assess the green building constraints in year 2000.

It awards points under six diverse categories such as, sustainable sites, materials and resources, water efficiency, energy and atmosphere, indoor environmental quality, innovation and design process (Elgadi, Ismail, Wahab, Nasidi, Abdelmuniem, & Abass, 2019). It is clear from these guidelines that all ranking schemes share the same goals (Guanwardana et al. 2018). Moreover, Guanwardana et al. (2018) stated that similarly, the quality of green buildings can be evaluated by GBCSL. Sustainable site, energy efficiency, water efficiency, indoor air quality and innovation design are the criteria common to other rating systems while GREENSL uses three additional criteria such as management, social and cultural understanding and geographic priority, which is exclusive to LEED. The LEED Assessment Categories are summarised in Table 2.3 as discussed by Apanaviciene et al., 2020.

Table 2. 3: LEED Assessment Categories

Categories	**Weighting (%)**	**Credits**
Sustainable Sites (SS)	25.45	28
Water Efficiency (WE)	9.09	10
Energy and Atmosphere (EA)	33.64	37
Materials and Resources (MR)	11.82	13
Indoor Environmental Quality (IEQ)	10.91	12
Regional Priority (RP)	3.64	4
Innovation in Design (ID)	5.45	6
Total	100	110

(Source: Apanaviciene et. el., 2020)

Rating tools may be different according to the type of buildings they are applied, such as housing, commercial buildings, etc. (Moramudali and Manawadu 2018). Furthermore Moramudali and Manawadu (2018) stated, green building rating tools or are used to assess the buildings which meet certain green requirements or principles. Rating tools recognize and reward companies and organizations those implement, build, operate and maintain greenery in the buildings, and encourage them to achieve enhanced sustainability.

Integrating sustainable and effective practices into a series of tactics will minimise the damaging impacts on the nearby environment and allow capable maintenance performs that meet usefulness standards, such as practical and quality (Hauashdh et al., 2022). There are several countries that have adopted green building for long term sustainability and it began with LEED. Since the green building phenomenon is comparatively in the present of Sri Lankan context, it is quickly spreading through different industries in search of more energy efficient buildings (Waidyasekara & Fernando, 2012) and currently Sri Lanka has begun to use green building techniques to change the construction industry.

2.3 Operational & Maintenance Features in Green Buildings

Several methods for evaluating green buildings have been developed with a point system for various aspects of green buildings and are intended for use in diverse projects. The first rating system, Building Research Establishment Environmental Assessment Method (BREEAM) was developed in United Kingdom in 1990. Subsequently, the LEED Green Building Rating System was introduced in 1998, by the United States Green Building Council (Weerasinghe & Ramachandra, 2020).

In addition, Asmone and Chew (2016) stated the key operation and maintenance features that are critical for a green building can be considered according to major categories such as SS, WE, EA, MR, IEQ, ID and RP which included in LEED rating system. Hence, green building maintainability is defined as accomplishing total building productivity and life cycle effectiveness at no incremental costs (Weerasinghe, 2020).

2.3.1 Operation and Maintenance Practices of Green Buildings

Hauashdh et al., (2022) explained operation and maintenance phase has the greatest environmental impact. In Awasthi (2016) study, pointed out that Green Buildings are designed to decrease a building's embodied and operational carbon dioxide emissions. Moreover, Ahn, Shin, Jeon and Jung (2017) mentioned in the built environment, a green construction strategy is critical for achieving short and long term sustainable targets, such as energy conservation, water and resource savings and improved indoor air quality.

Currently, building maintenance procedures are getting more complex due to demands of green building practices and complicated building systems, which give rise to more complex maintenance issues. (Hauashdh et al., 2022). Sullivan et al. (2010) defined that O & M is the judgments and activities concerning the control and continuous of work process. Some of these are mentioned below.

- Regulation and optimization of schedules, processes and work systems became the subject of the actions.
- Routine, preventive, predictive, planned and unscheduled activities are performed with the intention of increasing performance.
- Using cost effective and reliability centered maintenance technology, together with scheduled maintenance, recording and computerized maintenance control capability, system performance, protection and occupant satisfaction may all be improved over the life cycle of a green building (Sullivan et al., 2010).

Early studies of Ahn et al. (2017) concluded that the systematic structure or model that integrates GB practices and technology in any stage of a building's life cycle will support all stakeholders, including architects, engineers and contractors in order to effectively adopt green building methods. Sullivan et al. (2010) stated that there are five well defined facts of an effective O & M system such as operation, maintenance, training, engineering and administration, provide the foundation for a strong operational and Maintenance and below is an overview of the duties and responsibilities for each of the element.

Duties and responsibilities at the Operations stage:

• Administration - To confirm better execution and control of operation actions.
• Manner of operations - To confirm well-organized, protected and consistent operation process.
• Control of equipment condition - To be conversant of all equipment conditions.
• Awareness and act of the operator - To confirm that the operator is well-aware and his output is good enough to assist secure and trustful plant operation.

Duties and responsibilities at the Maintenance stage:

- Administration - To confirm that there is a better controlling system in the maintenance activities.
- Work Controlling System - To ensure that well-controlled maintenance activities are applied which gives a guarantee for a cost-effective, protected, dependable plant operation.
- Maintenance Behavior - To do the maintenance works in a secured and resourceful manner.
- Preventive Maintenance - To give maximum output and consistency of the structures and fittings.
- Maintenance Procedures and Documentation - To deliver suitable guidelines for the work performance and to confirm secured and effective maintenance (Sullivan et al., 2010).

In addition, Terrebonne Readiness Assistance Coalition (TRAC, 2017) explained that keeping green facilities in correct way which is includes products and system optimized and operating as they were intended to expand their life time which is the most reliable, cost-effective way to keep it as safe and energy efficient as possible. Additionally, the building maintenance process entails a number of steps, including building planning, execution, verification, tendering, and approval (Hauashdh et al., 2022).

Hauashdh et al., (2022) explained the virtual planning and scheduling of periodic building maintenance. Once a specified time has been chosen, maintenance operations must be performed within that timeframe to avoid construction changes to maintenance plans, including the delay and rearranging of maintenance work. This led the buildup of maintenance activity to be reduced.

2.3.1 Aspects to be concerned during the designing stage

Manav (2014) defined that since today, global warming and climate change have been a significant source of anxiety for human kind to assure the natural resources, growth and environmental protection. Many international organizations are funding to programmes that focusing on how to delay natural resource degradation on the face of global warming. Green architecture could be considered as a design ultimate which focuses on how to reduce excessive usage of energy, water and non-renewable resources. Consequently, the life cycling cost of buildings would be certainly reduced. Moreover, it is healthier for man and the environment as well. (Esa et al., 2011).

However, as Ramachandra et al., 2017 pointed out a 20% to 25% increment in construction costs when comparing green buildings with its traditional counterparts. Therefore, the developing countries like Sri Lanka find it as a challenge to embrace the green building concept as fast as the developed countries do. As explained by Sullivan, Pugh, Melendez and Hunt (2010), in public and private sectors, poor management of energy consuming systems, traditional structures have a major impact on the environment.

Structures have an economic, health and environmental effect on society. The following is an illustration of aspects of GB that are taken into account at the design stage (Bombugala and Atputharajah, 2010).

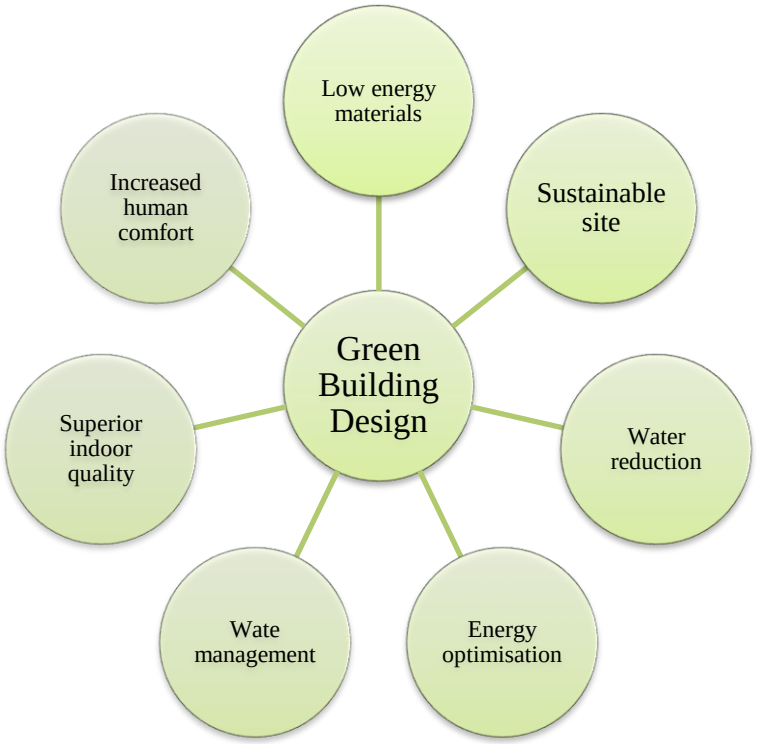

Figure 2. 3: Components of Green Building Design
(Source: Bombugala and Atputharajah, 2010)

A modern way of planning and building has emerged to address the demands of the built environment and it's a Green House, which means that the system adheres to design and development procedures that substantially minimize or remove the building negative effects on the environment and its inhabitants (Manav, 2014). Killemsetty and Behare (2014) expand their study also by reducing the quantity of hard surface landscape elements such as grasses, trees and shrubs decreases the impact of solar radiation on a house, which way result in excessive heating.

Furthermore, Killemsetty and Behare (2014) mentioned that the Life Cycle Design philosophy of a sustainable building allows it to reduce costs, increase efficiency and make the building accessible from cradle to grave, reuse and sustainable, a building should be able to follow the life cycle concept, then the used materials can be recycled and reused. The resources can be renewed and a constant lifespan of building can be sustained, among other things.

According to Manav (2014), a green building is special in that it is designed, built, and maintained so that its detrimental impact on human health and the environment is minimal. This applies to both the resources used during construction and during the building's operation and maintenance after it has been completed.

Esa et al. (2011) explained that the green buildings are designed to reduce the overall effect on both natural and built environment and on the human health by including following guidelines.

- Efficiently using the resources such as energy, water and light.
- Protecting occupant health, wellbeing and improving the employee productivity.
- Reducing the generation of waste, environmental pollution and environmental degradation.

According to the green rating calculations, certification grades are defines by context and the key categories exhibits building's features and keep their performance in stability (Lohmeng, Sudasna & Tondee, 2017).

2.3.2 Aspects to be concerned during the construction stage

Furthermore, Ahn et al. (2017) pointed out, target to ensure that a project is implemented safely, close focus must be provided to both design plans and development opportunities during the construction process of a building life cycle and variety of green techniques and innovations can be used to effectively incorporate green strategies when technologies during the development process in order to meet the aims of green building.

Activities of construction such as pre construction services, reducing the land disruption, erosion and sedimentation control, pollution prevention, sustainable site operation, indoor air quality management, construction waste management, green materials management and commissioning, which are used to achieve a widely recognized green building qualification such as LEED, is often essential to accurately record the techniques used and the building's efficiency (Ahn et al., 2017).

Manav (2014) stressed his studies on "Green building″ is architectural proposal developing trend under the guidance of green development, focusing on resources efficiency and energy efficiency, high quality living environment, respect of the local technology, less impact to the environment and the architectural history, expecting the understanding of the protection of environmental scheme gradually from single building to the entire environment.

Ahn et al. (2017) explained that identifying the major feature of the integrated design process in green building is to identify green building solutions and innovations, as well as stakeholders' positions and responsibilities, at the initiation of the construction phase. The primary goal should then be to develop an integrated construction process model for green buildings before moving on to the integrated construction process design section for a more in-depth examination of the pertinent technologies and procedures.

Sullivan et al. (2010) demonstrated that effectiveness as part of an integrated construction mechanism that can be effective for construction stakeholders in developed countries that are aware of the green construction process. The problems of adding new facilities, the high maintenance costs, and the lack of long-term planning in maintenance expansion were all factors that were tied to aging buildings. (Hauashdh et al., 2022).

2.3.3 Aspects to be concerned during the operational & maintenance stage

According to the study of Hauashdh, Jailani, Rahman and Fadhali (2022), increases in existing building ages are cause to increase the maintenance works, such as replacements, repairs and refurbishments, which create high maintenance wastes. According to property management & maintenance manual template (Landman Communications & Consulting, 2006), there are some general guidelines for building activities and maintenance practices that are standard procedure in following areas.

- Indoor Air Quality Management
- Green and Healthy Housekeeping
- Indoor Pest Prevention and Control
- Material Efficiency (Waste minimization and Recycling)
- Energy Efficiency
- Water Efficiency
- Green Grounds keeping

The GREENSL rating system for built environment is applied in order to evaluate and certify/ approve any building, commercial or institutional building in Sri Lanka. Given below are main eight aspects that reviewed under this rating system. (Green Building Council, 2022).

- Management
- Sustainable Sites
- Water Efficiency
- Energy and Atmosphere
- Materials and Resources
- Indoor Environmental Quality
- Innovation and Design Process
- Social and Cultural Awareness (Green Building Council, 2022)

According to Mazzola, Mora,Peron and Romagnoni (2017), LEED v 4.1 for building operation and maintenance used for existing buildings and it is based on the operative and management aspects. Prerequisites and credits are categorized as Sustainable Sites, Energy and Atmosphere, Water Efficiency, Indoor Environmental Quality, Materials and Resources, Location, Innovation and Regional Priority etc. significances according to the location and kind of rating method (Mazzola, et al., 2017).

Indoor Air Quality Management

Under GBCSL Rating System following criteria's need to be fulfill to cover indoor air quality.

- Minimum IAQ Performance - To prevent the emergence of problems with interior air quality in constructions, set minimum indoor air quality performance standards. (Green Building Council, 2022).
- Smoke Control - Reduce exposure to environmental tobacco smoke for building occupants.
- Outdoor air delivering Monitoring - Ensure the ability to monitor the ventilation system.
- Increased Ventilation - To increase interior air quality and occupant health, add more outside air ventilation.
- Construction IAQ Management Plan - Prevent issues with the building's tenants and construction workers' exposure to poor indoor air quality during construction.
- Low Emitting Materials - Reduce the amount of odorous indoor air pollutants.
- Indoor Chemical & Pollutant Source Control - Minimize exposure of building occupants to chemical pollutants.
- Lighting and Comfort Controls - Provide each occupant a great amount of control over the lighting system.
- Thermal comfort, design and Verification - Create a comfortable thermal environment that encourages building tenants' productivity.
- Air Purification and Disinfection - provide a safer atmosphere for building inhabitants both during regular operations and during pandemics to reduce the spread of viruses by using mechanical systems,
- Daylight & Views - Establish a connection between the inside and the outdoors for the occupants of the building. (Green Building Council, 2022).

As explained by Kho, Sullens and Fulton (2008), there are numerous chances to pollute a building and negatively impact indoor air quality (IAQ) during construction and some of these contaminants are only present for a short time, whereas others may remain for the whole life of the structure. As a result, strategic approaches have been

created based on both current issues and potential future difficulties, taking into consideration their negative effects, which hinder the use of green processes and efficient building maintenance practices. (Hauashdh et al., 2022).

Landman Communications & Consulting (2006) stated that maintaining basic strategies for securing indoor air quality, capable to apply selection of less toxic materials and products, entryway cleaning, smoking control, moisture control, mould control, carpet cleaning, heating ventilating and air conditioning (HVAC) maintenance, ventilation system, natural ventilation, repair or rehabilitation work. Mohamed (2016) evaluated health and welfare of a building's occupants and its financial success are all affected by Operational and management.

Green and Healthy Housekeeping

NC University (2011) mentioned that regular training for housekeeping personnel is recommended to guarantee that they are consistently providing a clean, healthy environment for building occupants. The majority of the Housekeeping staff takes a holistic reach to green cleaning, which includes as follows,

- Conservation of energy and water
- Enhancing indoor air quality
- Adopting recycling efforts
- Improving occupant productivity
- Applying environmentally-friendly products (NC University, 2011)

Moreover, to avoid unnecessary difficulties, individuals can follow green operations and maintenance guidelines such as cleaning processes, less toxic cleaning products, disposal of cleaning products, disposable janitorial supplies (Landman Communications & Consulting, 2006).

Indoor Pest Prevention and Control

Siemens (2011) identified that to withstand pests and promote natural predators, all landscaping techniques such as appropriate plant selection, irrigation, application of mulch and fertilizer, mowing, and other procedures should complement one another.

Kho et al. (2008) described that nontoxic pest prevention can be up to 25% more expensive than chemical pest management at first, but the long-term benefits of structural solutions usually outweigh the higher initial expenses and if alternative pest protection measures are used, ongoing chemical expenses will be lowered or eliminated. According to the Green Operations and Maintenance Guidelines, users should be willing to obey the precautionary action of Integrated Pest Management protocols and Pest Prevention Tips (Landman Communications & Consulting, 2006).

Material Efficiency (Waste minimization and Recycling)

The three R rule (reduce, reuse and recycle) used for the waste reduction and recycling. Even if some of these procedures, for example, reducing job site waste, it's important to have clearly (as cited in Kho et al., 2008). Under GBCSL Rating System following criteria's need to be accomplish to cover Materials, Resources & Waste Management.

- Operational Solid waste Management - Ensure effective operational solid waste administration.
- Building Reuse - Extend the lifespan of the existing buildings, save resources, keep cultural assets, minimize waste, and mitigate the environmental effect of new construction.
- Reused and Recycled Materials - To reduce the demand for new materials and to reduce solid wastes to landfills through the usage of recycled materials and resource reuse.
- Regional Materials - Increase demand for building materials and products.
- Rapidly Renewable materials - By substituting quickly renewable materials, reduce the use and depletion of scarce raw and long-cycle renewable resources.
- Green Labeled Products - To use Green labelled materials and products, certified as environmentally friendly products and equipment, to decrease dependence on materials that have related negative environmental influences.
- Certified Wood - To promote ecologically friendly forest management.
- Upfront Carbon Emissions - To quantify the environmental impact of the building due to carbon emissions during the building material production stage and construction stages.

- Sustainable Building Systems - To inspire the adoption of building designs, building structures and construction practices.
- Waste Management - To inspire the adoption of building designs, building structures and construction practices.
- Waste materials to construction materials - To reduce the demand for virgin materials by diverting different industry wastes to construction practices while avoiding wastes being sent to the landfills.
- Storage, Collection and safe disposal of hazardous wastes - Ease the safe disposal of hazardous waste generated by building (Green Building Council, 2022).

In resource conservation, 3R's rule helps to stop overusing materials to reduce pollution, when everything that is recyclable should be recycled, allowing unused items to be transformed into more useful materials and in addition to that it is reducing the amount of lands used for garbage dumps (Landman Communications & Consulting, 2006).

Energy Efficiency

Under GBCSL Rating System following criteireas need to be fulfill to cover Energy Efficiency.

- Fundamental Building Systems Commissioning and Verification - Verify and guarantee that crucial building systems and features are planned, constructed, and standardized.
- Minimum Energy Performance - Identify the systems' lowest possible energy efficiency level.
- Chloro fluoro carbons Reduction in HVAC Equipment - Reduce ozone layer depletion.
- Energy Metering - monitoring building-level energy use to aid in energy management and identify more opportunities to save energy.
- Optimize Energy Performance - Exceed the required criteria in energy performance by increasing levels.

- On site Renewable Energy - Inspire and recognize increasing levels of self-supply through renewable technologies.
- Enhanced Commissioning - Verify and ensure that the entire building is designed, constructed, and calibrated to operate as intended.
- Measurement & Verification - Provide the building energy consumption performance over time, for the ongoing accountability.
- Off-site Renewable Energy - Inspire investments in off-site renewable energy technologies for export purposes to the Domestic Grid.
- Greenhouse Gas Emissions Management - To decrease the impact on the environment due to the GHG Emissions during the operations stage of the building (Green Building Council, 2022). To promote global sustainability by reducing energy consumption and successful management of green house gas emissions (Nallathiga et al., 2022).

Water Efficiency

Property management and maintenance workers may take a variety of measures both inside and out to limit water consumption from building activities (Landman Communications & Consulting, 2006). To cover the water Efficiency, following criteireas need to be fulfilled under GBCSL Rating System.

- Water Efficient landscaping - To remove the use of drinkable water for landscape irrigation.
- Indoor Water Use Reduction - To reduce indoor water consumption.
- Building Level Water Metering - To support water management and identify opportunities for additional water savings.
- Water Efficient Construction - To limit or eliminate the use of potable water for construction activities.
- Cooling tower Water Efficiency in air conditioning system - Limit the use of potable water for Air conditioning make up.
- Indoor water use reduction - Optimize the water use efficiency within buildings to reduce the load on potable water supply and wastewater systems.

- Innovative Wastewater Technologies - Reduce the generation of wastewater and potable water demand.
- Innovative Water Transmission - Limit the use of non-renewable energy for water transmission.

Also, maintenance work include avoiding running faucets any longer than required and property managers can reduce water usage from building activities by reading water meters monthly, checking for leakage, installing faucet aerators, among other things (Landman Communications & Consulting, 2006). Further, studies done by Siemens, (2011) stated conserving water for future generations, saving money and protecting the environment, designers can help to sustain water supplies for future generations.

Green Grounds keeping

According to Siemens (2011), Green landscaping principles protect people's and the environment's health and from landscape design to maintenance decisions, the natural environment can be conserved by decreasing waste and pollution. Irrigation, plantings, storm water filtering, pest management and external lighting are under these standards for sustainable landscaping and grounds keeping (Landman Communications & Consulting, 2006).

- Irrigation- The irrigation system cannot replace by trained professionals' sound judgment and even a well-designed irrigation system will fail if it is not maintained on a regular basis.

- Plantings - when plantings need to be replaced, it is needed to decide either replace with the original planting types or select natural plantings. Furthermore, Siemens (2011) described, a well implemented O&M strategy will lengthen the life of the plantings, and the ultimate objective of constructing this maintenance plan is to create an efficient maintenance system that maintains plants' health while using the fewest resources possible.

- Integrated Pest Management - Needs to avoid the use of chemical fertilizers, herbicides and pesticides and individuals are often exposed to these materials (Landman Communications & Consulting, 2006). Siemens (2011) mentioned that well maintained landscape will reduce the need of pest control.

- Storm water Filtration - It is necessary to inspect the drainage system regularly to ensure that it is in good working condition and that it is not blocked with garbage (Landman Communications & Consulting, 2006).

All areas of grounds maintenance, including irrigation, plant care, turf management and pest management should be covered in the maintenance plan. The following sections should be included in the plan of O & M.

- Landscaping maintenance targets
- Responsibilities
- Landscape documentation
- Maintenance task list and schedule
- Evaluation task list and schedule
- Record keeping process
- Maintenance system audit (Siemens, 2011)

Studies of Au-Yong et al. (2019) explained, the distribution of money setting to maintenance activities is highlighted as part of maintenance management and maintenance prioritization is implemented due to time or budget limitations and it ensures the maintenance fund for the projects that are most essential.

Further, a developed guidelines are there to recognize the maintenance priorities to secure the resident safety, to ensure property, to retain buildings in an operative condition, to maintain the property's physical appearance and facilities (Au-Yong et al., 2019). In the studies of Mohamed (2016) clearly mention that as a part of that process of construction conditions, any building maintenance begins with the initiation phase and ends with the arranging and carrying out of maintenance work after the building is constructed.

Varying technological ages and exposed to deterioration or degradation at a slow or rapid pace and it must be taken into account that buildings must be properly maintained in order to extend their life expectancy, as well as proper planning for routine maintenance to minimize the scale of its activities and time, which could impact the building's performance and economic effectiveness. (Mohamed, 2016). Readings of Au-Yong et al. (2019) Prioritizing facility service management responsibilities is important and typically, maintenance actions are prioritized based on expense and risk factors, with the goal of maximizing maintenance efficiency while minimizing the risk of failure.

With references to previous studies, Mohamed (2016) mention that every building requires attention to avoid degradation and annual inspections might help identify issues early in addition to routine renovation by setting up a building maintenance timeline to alert for any inspections or work that needs to be completed

2.4 Green rating systems for green building operation and maintenance

Tools for assessing green buildings are usually voluntary and are used to determine if a facility complies with certain green requirements or standards. Using the assessment tools, organizations and businesses who maintain green buildings are acknowledged and rewarded. (Anshebo, Mengesha & Sokido, 2022).

According to Bansal, Singh and Tandon (2019), green technology and sustainable design have been incorporated into rating schemes. Similarly, Yahya, Ariffin and Ismail (2013) explained a scoring scheme that can be conveniently measured on a finished building which is used to determine a building's level of sustainability and by a building ranking will be referred to a fixed band for scoring by assigning points from a list of indexers. Each method came up with its own scoring system and rating scale. These scoring structures and rating systems, do not vary much from each other.

Moreover, Waidyasekara and Fernando (2012) pinpointed the Green Building Council has launched a new construction ranking scheme called GREENSL in 2010, which is kind of equivalent to LEED which is used to grant green certification. Guanwardana, Maheepala and Jayasinghe (2018) ccomparatively mentioned that GREENSL has been developed by concerning Sri Lankan own necessities and as a result, it is more relevant to the Sri Lankan context which is similarly, it was discovered that the same Figure 2.4 is an illustration of LEED V4 for operations & maintenance manual that are taken into account at the Green rating systems.

LEED v4 for Operations & Maintenance: Existing Buildings
Project Checklist

Project Name:
Date:

Y	?	N			
0	0	0	**Location and Transportation**		15
			Credit	Alternative Transportation	15
0	0	0	**Sustainable Sites**		10
Y			Prereq	Site Management Policy	Required
			Credit	Site Development-Protect or Restore Habitat	2
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
			Credit	Site Management	1
			Credit	Site Improvement Plan	1
0	0	0	**Water Efficiency**		12
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	5
			Credit	Cooling Tower Water Use	3
			Credit	Water Metering	2
0	0	0	**Energy and Atmosphere**		38
Y			Prereq	Energy Efficiency Best Management Practices	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Existing Building Commissioning—Analysis	2
			Credit	Existing Building Commissioning—Implementation	2
			Credit	Ongoing Commissioning	3
			Credit	Optimize Energy Performance	20
			Credit	Advanced Energy Metering	2
			Credit	Demand Response	3
			Credit	Renewable Energy and Carbon Offsets	5
			Credit	Enhanced Refrigerant Management	1
0	0	0	**Materials and Resources**		8
Y			Prereq	Ongoing Purchasing and Waste Policy	Required
Y			Prereq	Facility Maintenance and Renovations Policy	Required
			Credit	Purchasing- Ongoing	1
			Credit	Purchasing- Lamps	1
			Credit	Purchasing- Facility Management and Renovation	2
			Credit	Solid Waste Management- Ongoing	2
			Credit	Solid Waste Management- Facility Management and Renovation	2
0	0	0	**Indoor Environmental Quality**		17
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
Y			Prereq	Green Cleaning Policy	Required
			Credit	Indoor Air Quality Management Program	2
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight and Quality Views	4
			Credit	Green Cleaning- Custodial Effectiveness Assessment	1
			Credit	Green Cleaning- Products and Materials	1
			Credit	Green Cleaning- Equipment	1
			Credit	Integrated Pest Management	2
			Credit	Occupant Comfort Survey	1
0	0	0	**Innovation**		6
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		4
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0	**TOTALS**	**Possible Points:**	**110**

Certified: 40-49 points, Silver: 50-59 points, Gold: 60-79 points, Platinum: 80+ points

Figure 2. 4: LEED V4 for Operations & Maintenance

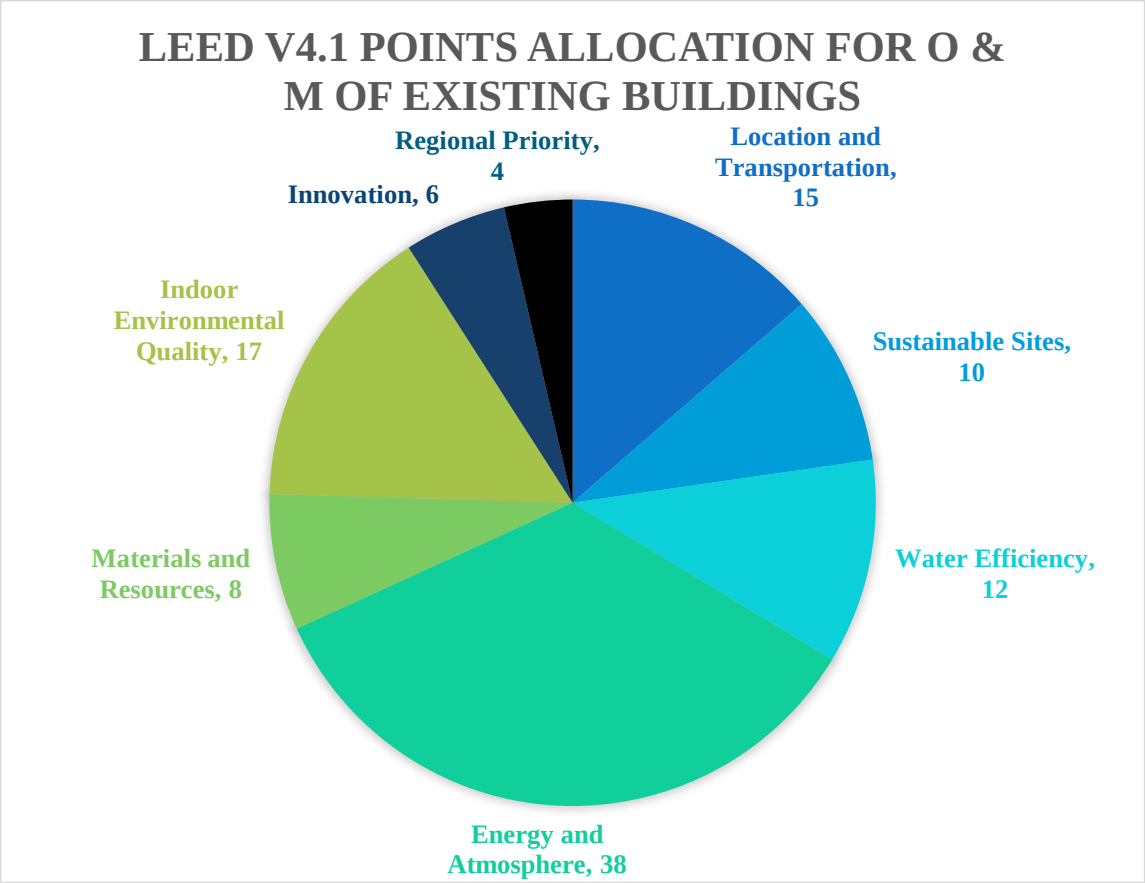

Figure 2. 5: The Points of LEED V4.1 O & M Rating

Figure 2.5 presented the points allocation for each category under the LEED V4.1 O & M rating system. The LEED V4.1 have 8 key categories. And how far the concerned building is performed in compliance with the specifications under the said categories is evaluated. (Lohmeng, Sudasna & Tondee,2017). The energy and atmosphere is the most focused category and it has 38 points. This emphasized that this rating system aims to create energy efficiency and healthy atmosphere with the adoption of adequate measures for saving of energy and resources.

2.5 Effects of Operational & Maintenance for Green Buildings

Mallawarachchi et al., (2015) explained that using healthier and more resource-efficient methods for construction, operation, and maintenance is known as "green building." Additionally, the need for tools and systems that simulate a building's operating expenses and budget construction will increase as local marketers desire

structures with low operating costs. Life Cycle Price (Geekiyanage, Ramachandra, & Thurairajah, 2018).

Agreeing to Cao, Kamaruzzaman and Aziz (2022), To meet the low energy consumption, low expenditure, low pollution, and high resident comfort criteria during operation and maintenance, green buildings demand a higher standard of facilities management than traditional structures. Therefore, LEED V4.1 mainly considered the potential population-level health impacts of LEED credits on four distinct spatial scales as follows,

- Site users, residents or visitors to the building, construction employees and the design team.
- Surrounding community, defined as those who live, work in the area surrounding the site.
- Supply chain and waste stream communities, products and materials required by a project as well.
- Global population potentially impacted by the building (Worden, Hazer,Pyke & Trowbridge,2020).

In study of Ramachandra et al., (2017) explained End-of-life cycle operating and maintenance costs are less than those of traditional buildings, which has a significant impact on the GB. The research reveals that a green building's construction costs are greater than those of a conventional structure of a comparable kind, but with proper operation and maintenance, green buildings' end-of-life costs show significant savings. (Weerasinghe & Ramachandra, 2018). But by the conventional buildings, its unsuitable quality of indoor environments may result in health issues to the employees, hence, reducing efficiency (Singh, 2018).

According to Geekiyanage, et al., (2018), Oldness of the building is one of the critical element, which impacts the maintenance budget and as older buildings would regularly require other operation and maintenance activity. Due to the increased awareness of the Green buildings, few builders may rent, lease, sell the certified buildings to a higher price (Pamu & Mahesh, 2019). Rathnasiri and Jayasena (2019)

recognized that outcomes of the Industrial Engineering and Operations Management of Green buildings shown below. The factors influencing Operational Expenses in buildings have been major affect for maintenance factors like true cause of defect, lack of preventive maintenance, poor workmanship, faulty maintenance, Low concern to future maintenance, Failure to execute maintenance at right time (Geekiyanage et al., 2018). The Effects from O & M are summarized in Table 2.4 and Table 2.5 separately.

Table 2. 4: Effects from O & M – I

Energy and Thermal Analyses	Energy use intensity
	Renewable energy potential
	Annual carbon emissions
	Annual energy cost and consumption
	Building heating and cooling loads
Lighting and Shading Analysis	Calculations of solar energy absorption
	Glare and discomfort spaces
	Spaces where solar directly enters
	Cooling and heating energy consumption
	Solar orientations for the building
Value and Cost Analyses	Life Cycle Assessment
	Life Cycle Cost
Acoustic Analysis	Noise dispersion and its effect inside the building
Water Harvesting	Monthly non- potable water usage
	Monthly potable water usage
	Monthly water savings
	Total water reuse potential
	Building water demand
	Rain water capture from the roof
	Comparisons of alternative windows and shades
	Dimensioning of air conditioning equipment
	Analysis of temperature
	problems of the building
System Simulation	Comparisons of alternative HVAC systems
	Optimization of zones for AHUs

Source: Rathnasiri and Jayasena (2019)

Similarly, Geekiyanage et al., (2018) shown how subpar building finishes can lead to faulty building components, which would require expensive upkeep to replace or renovate. Authors further stated that improper material selection over the life of a facility or a building component is one of the leading factors affecting building O & M costs (Geekiyanage et al., 2018). Further O & M related affects for the Green buildings are mentioned below (Hauashdh et al., 2022).

Table 2. 5: Effects from O & M - II

Finance-related aspects	Support to control the maintenance budget
	Control, aware the benefits and costs associated with making a decision
	Keep all buildings sustained and safe and delay ageing Enhance the integrity and transparency of maintenance works
	Minimize operating expenses
	Help to decrease the effects of the maintenance budget deficit problem
Building ageing related aspects	Prevent potential health and safety hazards to passengers
	Building inspectionprocedures enhance for the ageing buildings
	Avoid the possible deteriorations of ageing buildings
	Decrease building energy consumption and CO_2 emissions

Source: Hauashdh et al., (2022)

Geekiyanage et al., (2002) has identified 'use of the property' as a distinctive fact of building running costs due to the unavailability of proper operating manuals. It was found that the building operational and maintenance management has the most impact on the GB Section. The literature review facilitated to identify the relationship between O & M efficiency and compliance for GB. O & M efficiency is an inherited aspect in green buildings which address function efficiency technologies and other features mostly at the building operation and maintenance phases. To receive the maximum benefits from GB, the operational & maintenance should be properly specified, installed, commissioned, operated and maintained as well as matching with the type and requirements of users involved in the building.

2.6 Chapter Summary

Green building plays a huge role by using operational and maintenance more efficiently and effectively. This chapter presented the literature findings on O & M evaluation of the GB principles applied for operation and maintenance management, technologies used, cost increase, issues and strategies that can maintain the durability of GB. In addition, evaluate the literature to see how it affects the three pillars.

CHAPTER 03
RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research methodology which is used to achieve the research aim and objectives. The design of research which includes research approach, research strategy, and data collection methods and data analysis techniques is discussed here in detail.

3.2 Research Design

The purpose of the design of the research is to provide an appropriate framework for research. Aaker, Kumar and George, (2000) state that an important decision in the research design process is to decide whether to move the research method because it determines how accurate the study information will be. A good research design consists of a framework for the data collection, data measurement and data analysis. A flexible research design brings the chance for letting the altered aspects of a problem is measured suitable, if the determination of the research is to be clear (Mishra & Alok, 2017). Accordingly, this research is structured with a background study, a review of literature, research methodology, data collection, data analysis and results of research findings, conclusion and recommendations.

3.3 Research Approach

Research approach is vital in any research study since it determines the most suitable and effective research methodology. This is the process to be adopted in the data collection of the research. Accrediting Smith, Zheng, Love and Edwards (2004), research approaches can assist in establishing research activities, including data collection, with research objectives. Sahay (2016) stated there were some cases where the investigators were both committed with the positivist approach and not going beyond the boundaries of what can be observed or interpretivist style that is based on naturalistic data collection approach like interviews and observations.

According to many authors, such as Yin (2009), Rudestam and Newton (2007) and Flick (2006), research approaches can be mainly divided into qualitative and quantitative approaches. The most important aim of any type of research is to discover the reality and facts which is unknown and which has not been exposed (Mishra & Alok, 2017).

Amaratunga, Baldry and Sarshrand Newton (2002) have identified a research method which is a mixture of basic techniques. Combined methods usually refer to the use of both qualitative and quantitative research approaches surrounded by a single project but, can refer to the combination of different qualitative or quantitative approaches or different perceptions within the same project (Carins, Thiele & Fidock, 2016). The adoption of a mix-method approach, would help in minimizing the limitations or weaknesses in the use of qualitative and quantitative methods.

3.3.1 Quantitative Approach

Quantitative research is a way of examining test theory by examining the diversity of relationships within (Creswell, 2009). In study of Apuke (2017), Quantitative research approaches are define as the explaining of a matter or phenomenon by collecting data in statistical form and analyzing in mathematical methods(Apuke, 2017).

3.3.2 Qualitative Approach

In qualitative approach, the data collection methods are chosen mainly to discuss or investigate qualitative measures/ aspects of the research viz. the nature of impact, understanding of the underlying causes and motives etc. This approach has been developed after it became recognized that quantitative methods of data gathering only were incapable to definite people's approaches and sentiments. Monette, Gullivan and Dejong's (2010) methods of acknowledging abstraction and general modification.

Polanski and Waller (2011) distinguish image, pictures, systems and arrangements from several media sources, as well as verbal and written expression and audio recordings in data collection procedures. Qualitative research approach is defined

as "the study of the nature of occurrences", including "their quality, different indicators, the perspectives from which they can be perceived or the context in which they appear", but apart from "their range, rate of recurrence and place in an objectively determined series of reason and result" (Apuke, 2017).

It is noteworthy that "behaviors are frequently viewed as giving opulent data on genuine people's lives and positions and are capable to make common sense of deeds and recognize behavior within its broader framework (Monette et al, 2010). The ability to clarify the shapes of human behavior which is hard to quantify is one of the asset of qualitative research approach. The qualitative research approach allows participants to explain what they were feeling at a convinced time.

However, most often research studies are lack of generalizability, as they rely heavily on the interpretations made by researchers and the inability to retaliate by subsequent investigators. Well-known data collection approaches used in scientific studies contain interviews, emphasis groups and observations and research conducted. In addition, established concept and paper analysis can also be used as a means of collecting data from academic institutions.

3.3.3 Mixed-method approach

Mixed method approach is a combination of both quantitative and qualitative research approaches. As stated by Creswell and Plano (2011), incorporating the two procedures of data and using distinctive intentions that may contain theoretical assumptions and theoretical structures. Moreover, the authors stated that, the mixture of qualitative and quantitative approaches delivers a more broad understanding of a research problem than either approach alone.

3.3.4 Selection of the suitable research approach

The purpose of this research is to investigate the operational and maintenance implications of green buildings in Sri Lanka. The qualitative research approach was selected as the research approach method since the numerical data were not used. The

qualitative research approach based on the data and facts received from the case study interviews as well as some reports and records.

3.4 Research Strategy

Saunders, Lewis and Thornhill (2019) define research strategy as an approach for a researcher to address his or her study questions. A researcher can use one of seven different methods to study strategy and these are experiment, survey, case study, action research, grounded theory, ethnography and archival research. Dawson (2002) expressed these approaches and explained that qualitative research explores attitude, behavior, experiences and efforts to obtain a detailed response from the participants. A research method is a plan of inquiry which transfers from the underlying ethical expectations to research design and data gathering (Malhotra, 2017).

This study investigates the operational and maintenance implications of the Green Buildings in Sri Lanka and suggests the strategies that can be used to overcome the negative O & M implications. Therefore, it is vital to recognize the positive and negative implications of green building operational and maintenance assess the causes for negative compliance and present suggestions to overcome the negative implications of green building O & M.

Since case studies provide in-depth questions of the research problem and case studies can provide an opportunity for a holistic view of the research problem as described by Yin (2009), the case study approach is appropriate for this study and time availability is also the controlling factor for the case study method selection. Six cases were selected for this study to access the data acquisition and to obtain a comprehensive picture of the sources. All the selected cases are green certified (platinum and gold) office type and residential type buildings and both LEED and GBCSL certificate systems were considered. In addition, time and resource limitations have also been an important factor in selecting the number of cases in this study. Identification of 'case boundary' and the 'unit' of analyses is a preliminary requirement of research as described by Yin (2009).

In this research, as the aim has been set to investigate the O & M implications of green buildings in Sri Lanka, unit of analysis is the "negative O & M implications" and accordingly the case boundary is to be "Green Buildings in Sri Lanka" as illustrated in Figure 3.1.

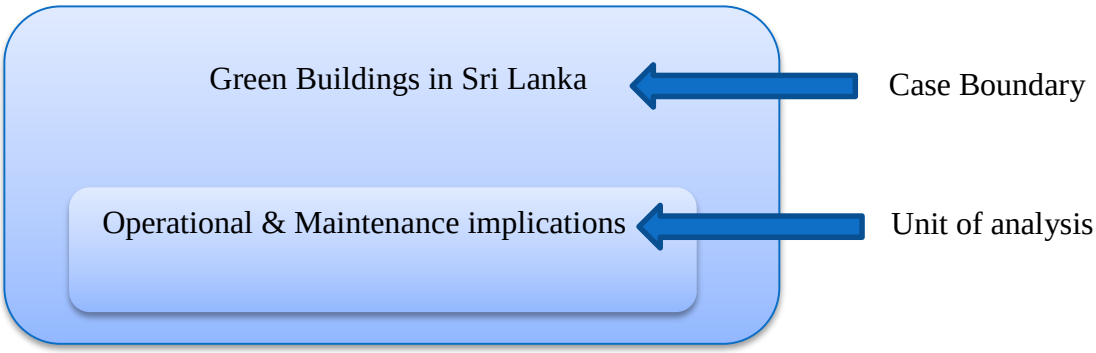

Figure 3. 1: Unit of Analysis

3.5 Data Collection Techniques

According to Kabir (2016), Data collection is the process of gathering and analyzing information on relevant variables in a recognized, methodical way that makes it possible to respond to stated research questions, test hypotheses, and assess results. Data collection and data processing methods are two types of research techniques and Interviews, paper surveys, observation, attendance and other data collection tools may all be used in research (Tan, 2002).

Taylor (2010) stated that general data collection techniques are observation, interviews, document survey and participation. The data collection part of a research study is common to all fields of study (Kabir, 2016). The most practical, cost effective and time-saving alternative is a preliminary survey (Rowan & Huston, 1997). The aim of data collection is to capture quality evidence and translates to strengthened data analysis and permits the building of a considerable and believable answer to queries that have been postured (Kabir, 2016).

The data processing of the study is a major part of research. To explain the results, non-statistical data were collected. Non-statistical evidence includes expert opinions and findings. These data are, nevertheless, critical in making decisions and assessing

risky instances. Since some data was inconsistent, a lot of works to be done to gather correct, reliable data. It is important to get data from the national institutions where the related researches are done. The data collection methods used in this research are point out beneath.

Literature Review / Documentary Review

The literature review consists with review of online publications, conference papers, thesis, books and journal articles. The research problem was established based on the conclusions of the literature review. Under the literature review section, the sustainable development and sustainable buildings, sustainable construction and green buildings, characteristics of green buildings, role of green building rating systems, benefits of green buildings and O & M management of green buildings is described. The literature review was expanded in order to provide a better understanding of research strategies. This summary served as the foundation for the preliminary survey.

Preliminary Survey

A preliminary survey was conducted with Sri Lankan field experts in the field of green buildings prior to the thorough survey. A preliminary poll was conducted to find out what the experts thought of the literature's conclusions and their suggestions for future research. The experts were asked for their input on any changes that should be made to the case study interviews' way of gathering data

Detailed Survey: Semi- Structured Interviews

Twelve interviews were held with professional officials who are engaged in operation & maintenance departments of buildings to explore the current status of operational and maintenance implications of green buildings in Sri Lanka. Data collection from these interviews were analyzed to identify the common problems. The interviews have indicated that the operation and maintenance industry faces certain challenges. The green building O & M, as well as the performance of the buildings, was identified.

Interviewing can be structured, with the questions prepared and presented to each interviewee uniquely using a predetermined manner. Further, interviews can be entirely shapeless as a free-flowing discussion. Qualitative researchers commonly employ "semi-structured" interviews, which include a number of open-ended questions constructed on the subject areas that the researcher wants to shelter. The open-ended questions provide direct answers to the topic of inquiry and at the same time would give chances for both interviewer and interviewee to elaborate or extend the topic further. When the interviewee is reluctant or found a problem in responding to a question or pays only a short answer, the interviewer may encourages the applicant to elicit the required data with extended questions. In a semi structured interview, the interviewer also has the liberty to ask the candidate to intricate on an original response or to follow a line of inquiry introduced by the interviewee. (Hancock, Ockleford & Windridge, 2009).

3.6 Data Analysis Techniques

Analysis has been done in cross case comparison method. Cross case is easy to compare each cases under the different topics. To analyze the qualitative data, the expert's views and ideas were considered. For the data analysis, considered the advices and information received from National Green Building Association as well. By the cross case analysis, comparison of the cases and results of the research findings could be elaborated. When analyzing the life cycle costs, O & M systems of case studies, the developmental areas, changes that required or recommendable and most suitable, efficient and effective techniques applicable could be identified.

Manual content Analysis

This phrase is frequently used to describe a procedure in quantitative research methods. When conducting a manual content analysis, the researchers would count the instances of a term, phrase, or theme. Here, a specialized rule for coding is used. This approach is especially appropriate when analyzing documents e.g. newspaper texts, responses to open-ended questions (Hancock et al., 2009).

3.7 Research Process

Kothari (2004) explained that research process consists with series of interrelated steps having a defined sequence in order to result an effective research. Research based on mostly on practical issues which faced by any professionals within their industry or expertise area. Background study provides an idea on the existing situation of such problem and emphasis the aim and objectives through that. The aim can achieve through several objectives. After the background study, detailed literature survey was carried out related to subject by latest researches and journal as much as possible. Data collection is a process consists of professional interviews and preliminary survey. The research process of this study is illustrated in Figure 3.2.

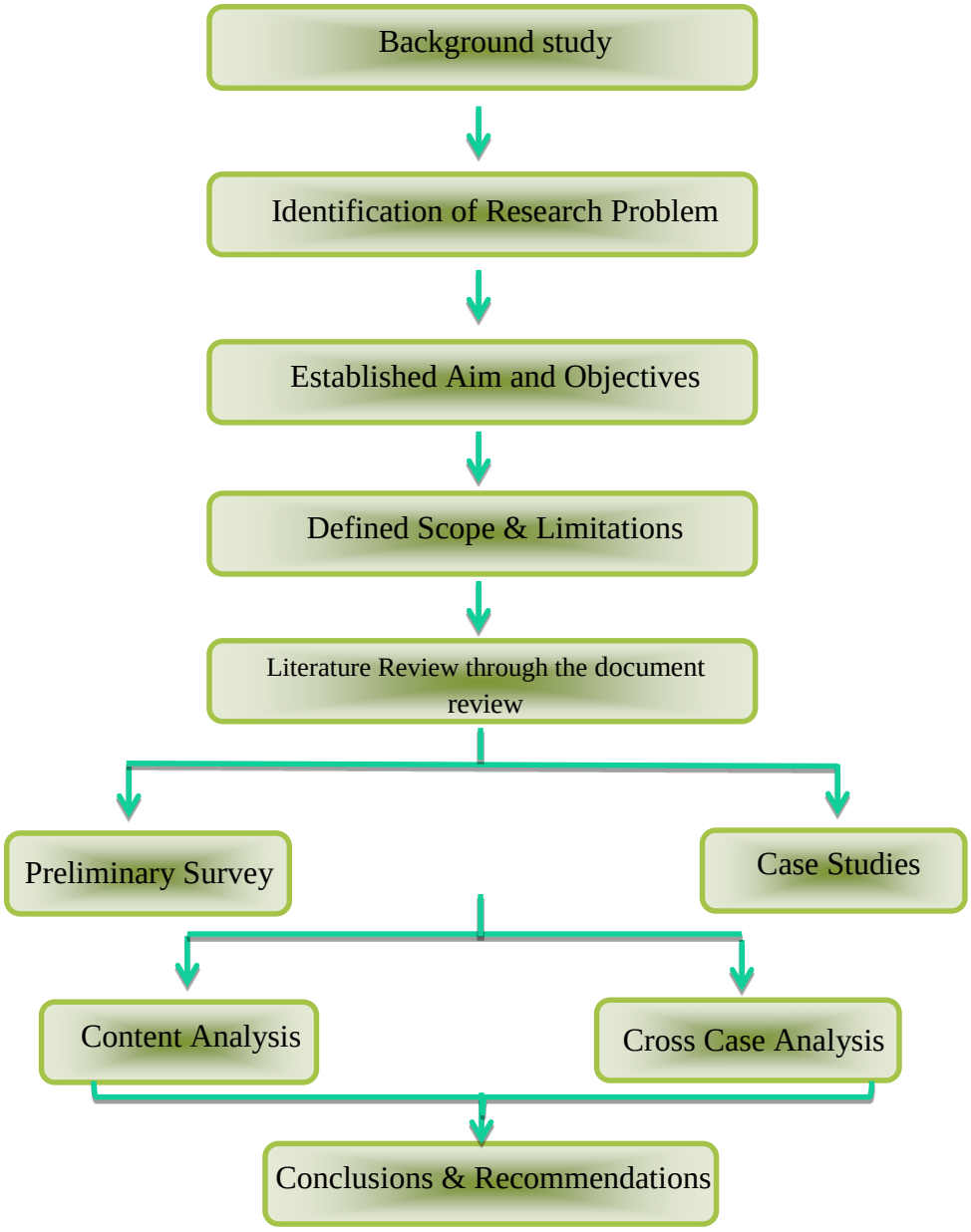

Figure 3. 2: Research Process

3.8 Chapter Summary

This chapter describes and explains the process of choosing a research technique in great depth, including a flowchart that shows the entire procedure. This chapter describes the difficulties encountered in obtaining the research's findings from beginning to end. This chapter's conclusion demonstrates how the goals and objectives of the study could be achieved.

Based on the aim and objectives of the research study, qualitative approach method has been selected as research approach with survey approach. Data were collected through the literature review and preliminary survey and from the interviews conducted with the professionals in the six case studies. Accordingly, in this chapter deeply described the research design, research approach, research strategies, data collection techniques, data analysis techniques and the research process which were used to achieve the core aim and objectives of this research.

CHAPTER 04

DATA ANALYSIS AND RESULTS

4.1 Introduction

This chapter describes a detailed analysis of the collected data and the discussion of the research findings. Data were collected from the interviews which conducted as preliminary survey and detailed survey. A preliminary survey was held with the field experts in green building field in Sri Lanka and the detailed survey was done with the participation of green certified building's operation and maintenance professionals. The data collected was analyzed using manual content analysis.

4.2 Preliminary Survey

The preliminary survey means gathering sufficient background information to be used for the design of the research. And this provides an opportunity to raise the awareness of the research topic. The discussions had with the field experts provided a guidance and encouragement to continue discussions regarding the research aim and objectives and to come up with a skillful research effort. The preliminary survey is more than just a survey; it builds the foundation for future work on the research.

4.2.1 Profile of the Interviewees for the Preliminary Survey

Four (04) numbers of interviews were conducted with the experts in the field of green building, having adequate experiences in designing, operation and maintenance systems both in local and international contexts. Some of them are actively engaged in green building industry as well as academia. The profile of the field experts participated in the preliminary survey is summarized in Table 4.1. The guidance, advices, different opinions and explanations received from the experts in the field of green building paved the way to carry out the research successfully.

Table 4. 1: Details of interviewees for the preliminary survey

Interviewee ID	Profession	Experience	Qualifications
PE1	University Lecturer	10years	Professor/Chartered Engineer / Member of the Green Building Council Sri Lanka (GBCSL)
PE2	Architect	12 years	Chartered Architect
PE3	Architect	15 years	Chartered Architect / Involved in the design of LEED certified buildings in Sri Lanka
PE4	Consultant Engineer	25 years	Senior Professor of Civil Engineering in Sri Lanka /research experience on green buildings O & M

4.2.2 Findings of the Preliminary Survey

The findings of the preliminary survey are discussed under two topics. These findings confirm the findings of the literature review as well. And this helped to clear out the doubted facts in researcher's mind and motivate to go after with the research aim and objective.

Significance of Green Buildings and the Awareness of the Operational and Maintenance Implications

Through the literature review, the researcher has found out that a green building;

- Is a high-performing, environmentally friendly structure that reduces the use of materials, water and energy during the construction, operation and maintenance?
- It improves the health and productivity of both workers during construction and occupants after the completion.
- It has many benefits as extended lifetimes and well – performed building systems.

The interviewees were questioned on whether a trend for the green building construction is evident in Sri Lanka. The answers of the interviewees were in positive manner. Interviewee PE1 commented as "*To address the current challenges, we all need to transit the way we live and work to be more sustainable. A major part of this transition is your role in building green.*" According to the interviewee PE2, a critical

component of green building is its durability and how it performs over its entire life. Green buildings reduce the use of materials, water and energy and it improves the health and productivity of workers and occupants and it increases the lifetime and performance of building systems. Interviewee PE3 commented as "*To my experience, I can say that the operation and maintenance of green buildings has a lesser environmental impact than the operation and maintenance of conventional buildings. Its most significant impact comes from less visible elements that improve efficiencies such as high performance windows, high efficiency heating and cooling systems, additional wall insulation, Indoor air filtration, etc.*" According to PE4, one of the most important concept in green buildings is all the systems (lighting, HVAC and plumbing) work together to provide an efficient and healthy environment for the occupants.

Regarding the level of awareness on the O & M implications in green buildings among the Sri Lankan construction professionals, all the interviewees were responded as "*It is currently not at a satisfactory level*". This concludes the research gap identified in this research.

Significance of investigating the O & M Implications in Green Buildings

Through the literature review, it is understood that to find out GB operation and maintenance implications is vital to evaluate how the GB principles are applied for the operation and maintenance. According to PE1, well managed green building operation and maintenance is much important to understand the positive and negative implications of them.

In order to get maximum benefits from GB, the operational and maintenance should be properly matched with the requirements of users involved in the building. PE2 commented as "*The building operational and maintenance management is the strongest impact on the GB Section*".

According to PE3, when considering the O & M implications, green buildings minimally impact to surrounding areas, provide a healthy indoor environment for workers and occupants, contains the materials with small environmental footprints,

resulting in higher productivity and a higher quality environmental friendly life. PE4 commented as "*The green buildings used strategies to enhance their performances by efficiently using energy, water and other resources. Some of them are water metering, energy metering, solid waste management, etc. Those are increases the building system durability as well as its performance*."

4.2.3 Summary of preliminary Interview Findings

Buildings use a huge amount of resources of energy, water, raw materials and the electricity. These are convincing, the requirements of the improvements in the buildings to be Green. Green buildings save all of these resources and if its operation and maintenance are well managed, the outcomes are significant. The biggest benefit of green building is protecting the environment and minimizing the harmful impacts to climate change. Good green building O & M practices provide practical and affordable solutions to some of the environmental challenges we are facing. A green building means a healthier workplace for the workers and a healthier living space for the occupants as well. It is sustaining the environment by saving energy and non-renewable resources. Green building O & M implications include use of environment friendly natural resources such as solar energy for heating and minimize energy losses such as using insulation systems and as well as use of renewable energy, use of non-toxic resources to treat all of its water and efficient operation with maximum magnificance.

The level of awareness on the O & M implications among the field professionals in Sri Lanka is currently not at a satisfactory level. But it can see that some of them are considering the higher performing buildings and their O & M.

4.3 Analysis of Case Study findings through Cross Case Analysis

Based on the literature review and the preliminary survey, six nos. of case studies have been done to gather the expected research findings in detail. In here, all the selected cases are green certified (platinum and gold). Both LEED and GBCSL certificate systems considered. For the interviews, two responsible persons were selected from each case. Cross case analysis was used to compare the data of all the case studies

Table 4. 3: Details of interviewees

under same topics. This data analyzing method was used to produce new knowledge through the accumulation of case knowledge, comparing and contrasting the cases.

4.3.1 Profile of Case Studies and Interview Administration

The Profile of Case studies and details of interviews participants are summarized in Table 4.2 and Table 4.3 respectively.

Table 4. 2: Profile of Case Studies

Case	Interviewee ID	Year of experience	Designation
A	DE1	6 years	Chief Engineer –MEP Designs
	DE2	4 years	Mechanical Engineer
B	DE3	5 years	Engineer – Maintenance
	DE4	4 years	Maintenance Engineer
C	DE5	12 years	Head of Facilities Management
	DE6	6 years	Technical Officer
D	DE7	2.5 years	Facilities Manager
	DE8	1 years	Mechanical Engineer
E	DE9	16 years	Mechanical Engineer
	DE10	8 years	Assistant Mechanical Engineer
F	DE11	5 years	Maintenance Manager
	DE12	3 years	Maintenance Engineer

4.3.2 Current Operational and Maintenance Procedures in green buildings in Sri Lanka

According to the respondents, the current O & M practices used in the selected green buildings are; Waste Management, Housekeeping, Pest Control and Cleaning, Energy Management, Water Reuse and Indoor Environmental Quality. These practices were managed in all the six cases in different ways. They have used various systems for the operation and maintenance works such as subcontracting, directly maintaining by the maintenance staff, mechanical systems and natural systems.

Table 4.3: Details of interviewees

Selected Cases	Age of the building	Green certification		Building type and No. of Occupants involved	Initial Cost
		Type	Achieved year		
Case A	8 Years	LEED-Platinum	2015	Office building: 250 nos of office staff	Rs. 3.5 Billions
Case B	4 Years	LEED-Gold	2019	Office Building: 500 nos of Staff and Tenants 50 nos	Rs. 4.76 Billions
Case C	15 Years	GBCSL-Gold	2010	Government offices, Private companies & Cooperate offices, etc. about 5000 people	Rs. 3.0 Billions
Case D	11 Years	GBCSL-Platinum	2019	Private office complex, 1200 nos. of office staff	Rs. 4.2 Billions
Case E	8 Years	GBCSL-Gold	2014	Office Building: 350 nos. of office staff	Rs. 2.3 Billions
Case F	l5 Years	GBCSL-Platinum	2018	Office Building: 875 nos. of office staff	Rs. 6.0 Billions

Case A: According to the interviewees DE1 & DE2, they have subcontracted Waste Management & Housekeeping, Pest Control and Cleaning. Energy Management and Water Reuse have been maintained by their maintenance staff and Indoor Environmental Quality maintained through a mechanical system.

Case B: According to the respondents DE3 & DE4, Waste Management, Housekeeping, Pest Control and Cleaning have been subcontracted. Energy Management & Water Reuse maintained by the maintenance staff. Indoor Environmental Quality is maintained through a natural system.

Case C: According to the respondents DE5 & DE6, they have managed Waste Management, Housekeeping and Energy Management through their maintenance staff. Water Reuse and Indoor Environmental Quality has been managed by a mechanical system. Pest Control and Cleaning has been subcontracted.

Case D: As per the DE7 & DE8, they have subcontracted Waste Management, Housekeeping, Energy Efficiency and Pest Control. Water Reuse and Cleaning is managed by the maintenance staff, and Indoor Environmental Quality is maintained through a mechanical system.

Case E: According to the respondents DE9 & DE10, they also have subcontracted the Waste Management, Housekeeping, Pest Control and Cleaning. Energy Management and Water Reuse are managed by the maintenance staff. They used a mechanical system to maintain the Indoor Environmental Quality.

Case F: According to the respondents DE11 & DE12, they have subcontracted the Waste Management, Housekeeping, Pest Control and Cleaning. Energy Management, Water Reuse and Indoor Environmental Quality are managed by using a mechanical system.

Summary of findings:

In all six cases, the details were received from executive level staff members who have experience in relevant position from 2.5 to 16 years range. Usage type of three buildings were offices and two of them are commercial type and one building is a residential type. The initial construction costs of those buildings were in 2.3 Billions

- 6 Billions range. Four establishments have achieved Gold green certification level and two have achieved Platinum level. Age of these buildings were spanned from 4 years to 15 years. The expected lifetime of these buildings have mentioned as 60 years to 80 years. The no. of occupants in these buildings were varied according to the usage of the buildings and minimum no. of occupants was 350 and maximum was 5000 nos. According to the relevant respondents, all these establishments have their own operational and maintenance plans.

According to the above details, it is observed that most of the cases are used giving subcontracts to others as a better O & M procedure for the waste management, housekeeping, pest control and cleaning purposes while the energy management, water reuse and indoor environmental quality are managed by the maintenance staff, through a mechanical system or by a natural way. Table 4.4 illustrates the summary of operational and maintenance procedure of the selected cases as per the interviewee comments and from their records.

Table 4. 4: Summary of Operational and maintenance Procedures

No.	Operational and Maintenance Procedures	Case A	Case B	Case C	Case D	Case E	Case F
1	Waste Management	SC	SC	MS	SC	SC	SC
2	Housekeeping	SC	SC	MS	SC	SC	SC
3	Energy Management	MS	MS	MS	SC	MS	TMS
4	Water Reuse	MS	MS	TMS	MS	MS	TMS
5	Indoor Environmental Quality	TMS	TNS	TMS	TMS	TMS	TMS
6	Pest Control	SC	SC	SC	SC	SC	SC
7	Cleaning	SC	SC	SC	TMS	SC	SC
Subcontracted – SC ; By Maintenance Staff – MS ; Through a Mechanical System : TMS Though a Natural System : TNS							

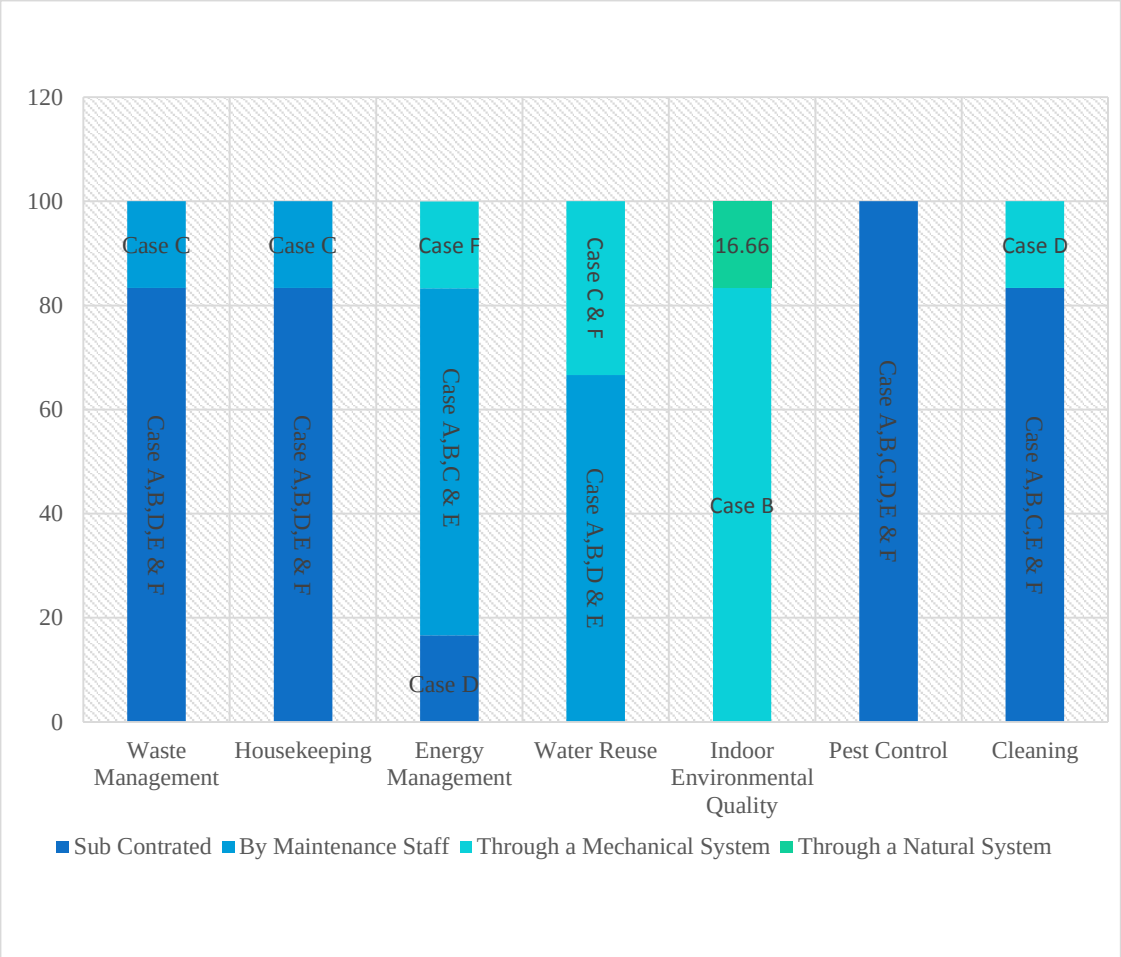

Figure 4. 1: Summary of Operational and maintenance procedure of each case

Figure 4.1 presented the operational and maintenance procedure of each case in this study.

4.3.3 Positive implications with operational & maintenance of the Green Buildings in Sri Lanka

The positive implications are the benefits that gained through complying with green certification standards. According to the literature findings and the comments of the interviewees DE1, DE2 & DE3, the positive implications with green building O & M are; enhancing the durability, reducing the effect of the buildings on its surrounding natural environment by applying the sustainable design concepts such as zero carbon emissions and reduced waste generation, reduced electricity and water usage, optimizing building space and efficient use of materials, etc. Interviewee DE4 commented as "E*nhanced indoor air quality brings to the green buildings a better-quality environment.*"

According to DE5 & DE6, the aspects of such as use of solar energy, application of energy conservation methods and reaching a sustainable building design are the admirable green building considerations. Interviewee DE6 commented as "*The organization is experiencing an improved financial performance due to the reduced operating and maintenance cost."*

Interviewee DE7 and DE8 commented as "*To determine occupants' life quality, well – being is an important aspect. When the tenants are healthy and happy with their surrounding environment, it is more productive and is considered as another positive implication*". According to DE9, DE10, DE11 & DE12, positive implications of green building O & M convince about the importance of introducing green building concepts, and finally it emphasizes the most important cost efficiency.

According to the details received from the case study survey interviewees, they are experiencing following positive implications by applying the O & M procedures into their buildings. Though they have applied various methods to manage the O & M procedures, they all have experienced below-mentioned seven nos of positive implications. Table 4.5 depicts the positive implications of operational and maintenance of the green buildings.

Table 4. 5: Positive implications of O & M of the green buildings

No	Positive Implications	Case A	Case B	Case C	Case D	Case E	Case F
1	Reduced electricity and Water usage	√	√	√	√	√	√
2	Enhanced Indoor Environmental Quality	√	√	√	√	√	√
3	Reduced waste generation and carbon emissions	√	√	√	√	√	√
4	Healthy and happy tenants	√	√	√	√	√	√
5	Material Efficiency	√	√	√	√	√	√
6	Enhanced durability	√	√	√	√	√	√
7	Cost Efficiency	√	√	√	√	√	√

Figure 4.2 is an illustration of positive implications in operational and maintenance of the selected cases in this study.

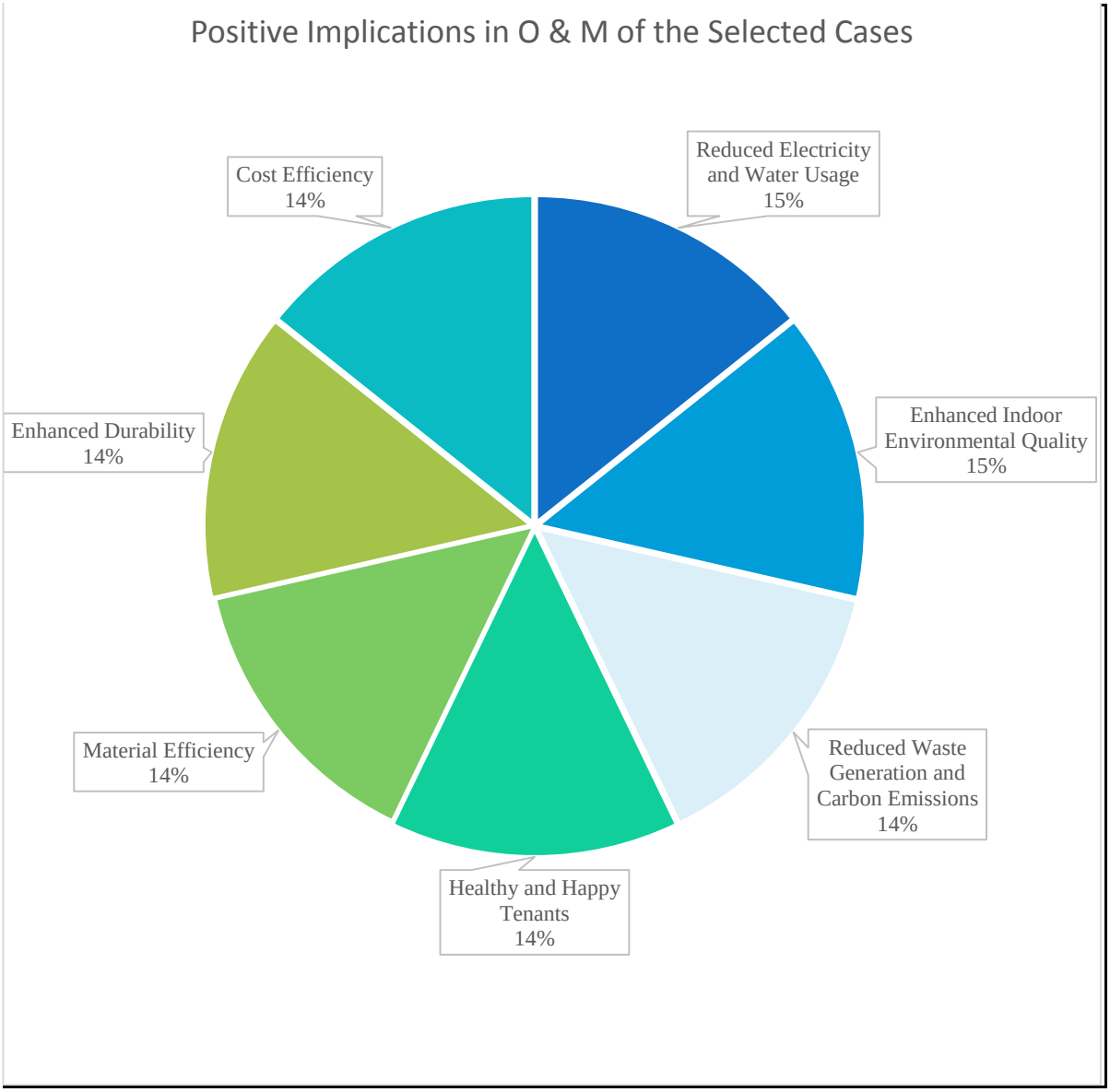

Figure 4. 2: Positive implications in O & M of the selected cases

Summary of findings:

Green buildings are designed to be sustainable, resource efficient, environmentally friendly and benevolent, economic in life cycling cost during O & M processes and throughout design life of the structure. The main positive implications of green building O & M are, material efficiency, energy and water efficiency and the health. Rather than these, it was observed that there were another 03 number of positive implications of O & M of the green buildings such as enhanced indoor environment

quality, reduced waste generation and carbon emissions, enhanced durability and cost efficiency. According to the respondents, all the six green buildings were experiencing all these 07 positive implications. It is widely accepted that these positive implications with O & M of the green buildings convince the importance of being green.

4.3.4 Negative implications with operational & maintenance of the Green Buildings in Sri Lanka

Negative implications mean the barriers to the meeting of green building standards' requirements during the operation and maintenance stage. In Sri Lanka, Operation and Maintenance of green buildings still having a lack of proper management system. There is a less attention to review the existing knowledge of negative implication of green building O & M. According to the interviewees DE7 & DE8, though some people want to spend a healthier life, the initial investment of a green building is very high and hard to afford. Interviewee DE7 further stated that "*Even though the returns of the green buildings are great after a time, the initial cost is still a major issue.*" Interviewee DE8 commented as "*The cost will increase with the number of eco – friendly technologies that wanted to implement in the building.*"

According to the DE1 & DE2, they have only two negative implications in their building, such as application issues and insufficient knowledge. Application issues mean the issues related to the best application of operation and maintenance methods and systems which are needed for the advanced O & M of green buildings. Insufficient knowledge affected as a negative aspect because green building operation and maintenance requires a skillful involvement. Interviewee DE3 commented as "*We have management and technological issues. And also we are facing hard to find skillful persons for our O & M crew*". Interviewee DE4 commented as "*It is very difficult to find the required technologies as well."*

The Sri Lankan builders are not much conversant with the technologies that related to the green building concept or rather are unable to afford to practice it as cost is expensive relatively. Some interviewees revealed that sometimes, the technologies are limited due to some factors and difficult to procure right materials due non availability

in local market and import restrictions/ regulations. According to interviewee DE5 & DE6, they did not have any negative implications due to their well-managed systematic O & M management procedures used in the buildings. Interviewee DE7 & DE8 commented as "*We have basically financial constraints, application and technological issues. When operating and maintaining the building, the costs involved are very high and out of our allocated budget. When applying sustainable theories for the O & M, it is required to know what is better and how to do it technically. In there we faced to a challenge.*" According to DE9 & DE10, they have management issues, application issues, technological issues and insufficient knowledge issues. Interviewee DE9 commented as "*Though our building owner financially fit to build a green building, he found hard to put correct management team to continue its O & M. That was the main issue".*

Owner need to keep up the building as sustainable but, since the management team's wrong decisions in selecting the human, material and technological applications, it is hard to solve these issues". As per the PE11 & PE12, they had some issues in the past but in the meantime they have corrected those identified issues and now they did not have any negative implications due to the better O & M management procedures used in their building. Based on the comments of all the interviewees, it was found that there were no attitude issues regarding the green building O & M. The profile of the negative implications of O & M which are gathered during interviews are summarized in Table 4.6.

Table 4. 6: Negative Implications of Operational and Maintenance

No	Negative Implication	Case A	Case B	Case C	Case D	Case E	Case F
1	Financial Constraints	-	-	-	√	-	-
2	Attitude Issues	-	-	-	-	√	-
3	Management Issues	-	√	-	-	√	-
4	Application Issues	√	-	-	√	√	-
5	Technological Issues	-	√	-	√	√	-
6	Insufficient Knowledge	√	√	-	-	√	-

Below figure 4.3 presented the negative implications in operational and maintenance of the selected cases of the research.

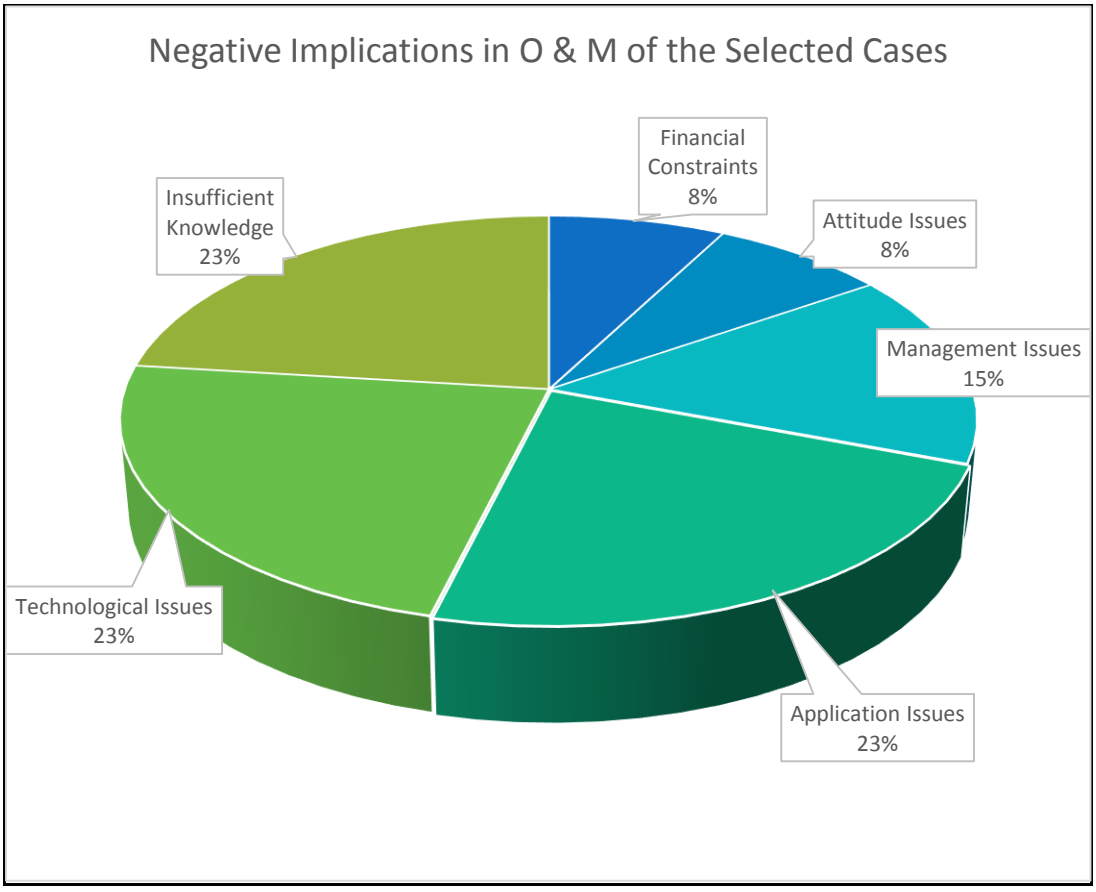

Figure 4. 3: Negative Implications in O & M of the Selected Cases

Summary of findings:

The green building operation and maintenance is highly beneficial but, there are some negative implications such as financial constraints, management issues, application issues, technological issues and insufficient knowledge, etc. Since the related technologies are slightly new, most of them had negative implications such as application, technological and knowledge issues. When there is an inexperienced team involved, due to lack of the skills to implement properly, there is a disturbance to the effectiveness of the green building. If the building doesn't perform as it was intended, there is a loss in expected financial gain. The building not performing as expected is

a huge impact of decision maker that means there is management issue negative implications of O & M.

4.3.5 Causes for negative implications with operational & maintenance of the Green Buildings in Sri Lanka

Though the green buildings perform better than non – green buildings, but due to some reasons there can be identified few negative implications of green building O & M. Based on the findings from 12 respondents from six case studies, it was identified that there are many factors affecting the negative implications with operational & maintenance of the green buildings. According to the comments of interviewees DE1 & DE2 in Case A, they are suffering from less knowledge regarding the resources' allocation system and inexperienced project team. Since the green building concept is new, the knowledge related to O & M is not equally spread among the project staff. As stated by DE2, the staff should give a well training and education. However, as reveled during the survey, enough resources are not allocated due to wrong assessment in long term effects and risks. Hence, the case A could not receive intended green building benefits at a satisfactory level.

Interviewee DE3 & DE4 in Case B confirmed the same as Case A, they are also experiencing the similar situation in their building.
In Case C, since there were no any negative compliance due to well managed O & M system, the causes for the negative implications were not in there.

In Case D, DE7 and DE8 commented as "*To make the return on investment more predictable, we need to know more about the historical viewpoint. Additionally, in order to achieve long-term success, business budgets should be structured to track the project's life cycle costs. That is the reason for the high initial cost we felt*." According to the DE9 & DE10 in Case E, they are experiencing negative implications with green building O & M due to the lack of awareness about the possible administrative supports for O & M, as well as due to the technology problems. Interviewee DE10 further commented as "Another reason is difficulty in finding the green materials which required for the O & M."

Interviewee DE11 & DE12 commented that "*We had negative implications in technological issues in long time ago. We have overcome them by applying better technologies*".

The profile of the causes for operational and maintenance negative implications summarized in Table 4.7.

Table 4. 7: Causes for Operational and Maintenance Negative Implications

No	Cause	Case A	Case B	Case C	Case D	Case E	Case F
1	High initial cost	-	-	-	√	-	-
2	Lack of knowledge of resources allocation system	√	√	-	-	√	-
3	Inexperienced or insufficient project team	√	√	-	√	-	-
4	Unavailability of green materials	-	-	-	-	√	-

The most critical causes for the negative implications of the selected cases are presented in Figure 4.4.

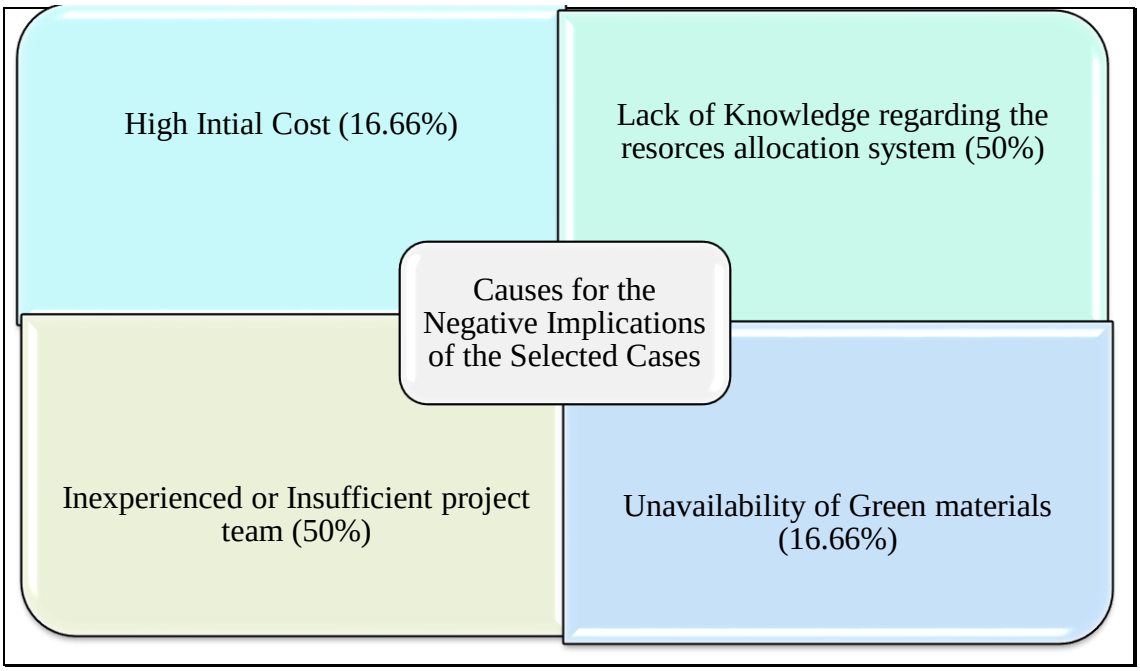

Figure 4. 4: Causes for the negative implications of the selected cases

Summary of findings:

According to the details received from the interviewees of all six case studies, it is revealed that lack of knowledge of resources allocation system and having the inexperienced or insufficient project team are the most critical causes for the O & M negative implications. Finding the green materials required for the green building O & M is also affected for the negative implications.

4.3.6 Strategies that can used for better operational and maintenance in Green Buildings in Sri Lanka

The improvements in operational and maintenance can be achieved through a variety of strategies. These strategies can influence the environmental impact of a building throughout its lifecycle. Since that, the most suitable techniques are used for the operation and maintenance procedures in green buildings. For a better green building O & M, there are some strategies that can be used. According to the detail findings received from the respondents of the selected six cases, following mentioned strategies were highlighted.

- Encouraging the developer's commitment.
- Site planning that minimizes the environmental impact
- Reused building materials
- Recycled gray water systems
- Obtaining collaborative approach as a team.
- Making well organized resources' allocation system.
- Implementation of the latest and advanced technologies (ex: higher insulating windows, low toxicity paints, bio degradable carpets, energy efficient heating and cooling systems).
- Training and Educating team members.
- Enhance and ensure green technologies and policies.
- Preparing database for green materials.

According to the DE1 & DE2 in Case A, they have taken positive approaches for better O & M procedures, such as obtaining collaborative approach as a team, using higher insulating windows, using biodegradable carpets, using low toxicity paints and making well organized resource allocation system. By that, they could eliminate their knowledge based issues and as well as application issues. In Case B, Interviewee DE3 & DE4 commented as "We think that encouraging the developer's commitment to receive his contribution throughout the lifetime of the building, making well organized resources' allocation system and giving training and education to the team members can be used as the strategies for a better O & M." They have prepared a database for the green materials and from that they could be aware about the latest green materials which can be used for their building. They have gained positive outcomes through it as well. According to the interviewee DE5 & DE6 in Case C, they have described that enhancing and ensuring the green technologies and green policies would be a great strategy to eliminate the technical implementation issues regarding the operation and maintenance.

They have well planned management system, and they have used many strategies to become that level. In Case D, Interviewee DE7 & DE8 commented as "Implementation of innovative technologies is a good practice. There are new sustainable technologies that can be used for the green buildings and if we could find and apply them with an analysis, we can gain more benefits." Interviewee DE9 & DE10 in Case E commented as "Preparing a database for the green materials is a good strategy to find the suitable green materials easily. That will help to avoid untested materials, and will make it easier to predict the outcome of the green building efforts as well." According to DE11 & DE12 in Case F, well organized resources' allocation system and use of advanced technologies, training education regarding the green building O & M to the staff are the identified most important strategies.

It has been observed from the research findings that, for a better O & M in green buildings, they have used some strategies as mentioned in Table 4.8.

Table 4. 8: Strategies used for a better operational and Maintenance in Green Buildings

No	Strategy	Case A	Case B	Case C	Case D	Case E	Case F
1	Encourage developer's commitment	-	-	√	√	√	-
2	Obtaining collaborative approach as a team	√	√	√	√	√	-
3	Training and Education	-	-	√	√	√	-
4	Making well organized resource allocation system	√	√	√	√	-	-
5	Enhance and ensure green policies for new buildings	-	-	√	-	√	-
6	Enhancing technologies	-	-	-	-	√	-

The Strategies used for O & M of the selected cases are illustrated in Figure 4.5.

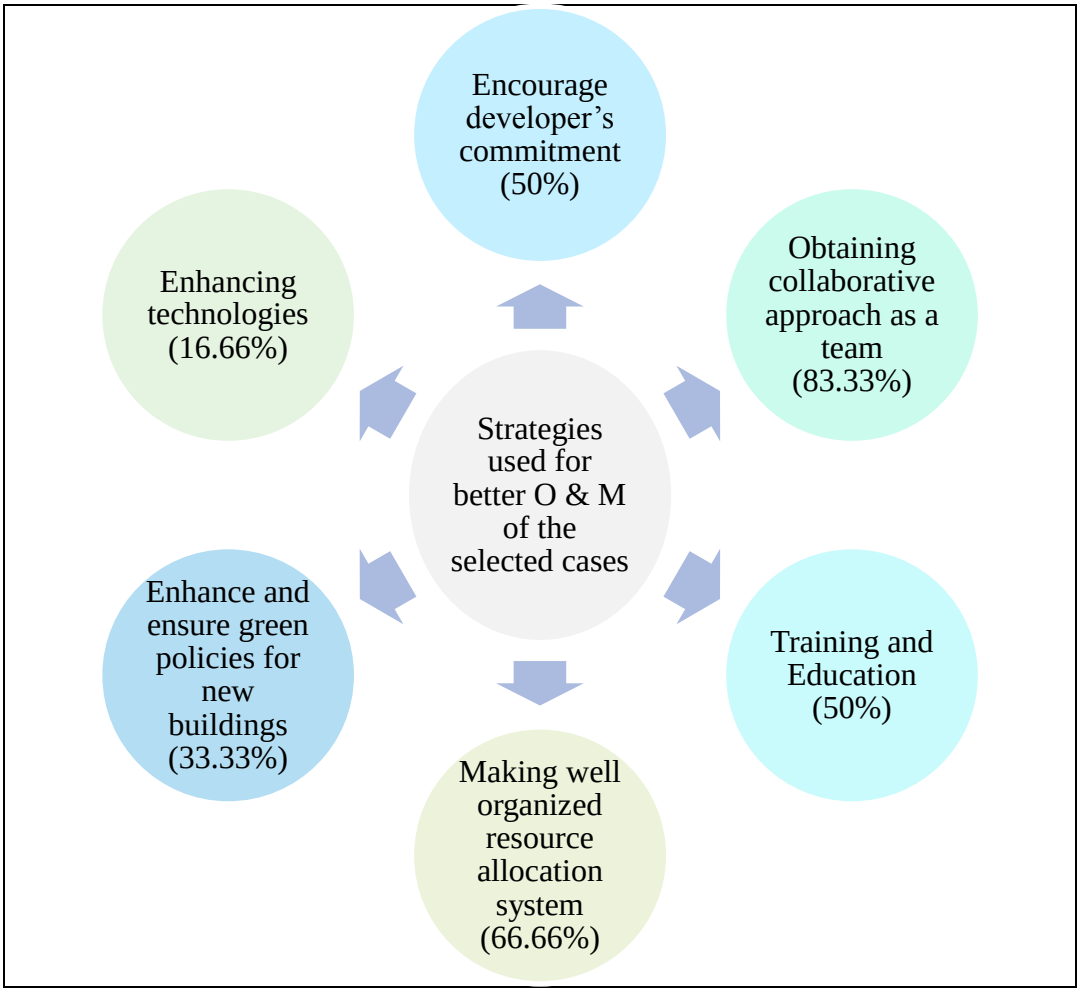

Figure 4. 5: Strategies used for better O & M of the selected cases

Summary of findings:

According to the details received from the interviewees, it is revealed that there are some strategies that can be used for a better O & M of green buildings. By using these strategies it can be eliminated the causes of negative implications as well as enhanced the O & M procedures. The selection of green building concept could be gained a more value by applying the strategies. Obtaining collaborative approach as a team and making well organized resources' allocation are highlighted in here as the main strategies.

4.4 Chapter Summary

This chapter consists of the data analysis on operational and maintenance implications of the selected green buildings in Sri Lanka. In here, a preliminary survey with of 4 nos. of professionals and its findings, case study survey of 6 nos. of cases, 12 nos. of interviewees and findings were discussed under the various sub topics to eliminate research objectives. The data collected through the literature review, preliminary survey and case study survey were analyzed under this chapter.

CHAPTER 05
CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter brings the conclusions and recommendations on the findings of the cross case analysis. The research outcomes are concluded in here under some topics. The recommendations were given to enhance the positive implications of O & M of green buildings and to minimize negative implications of O & M of green buildings as well as strategies that can be applied for a better O & M of green buildings in Sri Lanka.

5.2 Conclusions under the research objectives

This research examines the green buildings in Sri Lanka from the operational and maintenance perspective. The aim of this research was to "Investigate the operational & maintenance implications in green buildings in Sri Lanka." To accomplish the research aim, the researcher has collected data from a preliminary survey (with four field experts) and a detailed survey (with six green buildings) except to the literature review. The results are concluded in here under the same research objectives.

5.2.1 Analyze the operational and maintenance features of green buildings according to green rating systems

The first objective was to review the features of the green buildings according to the green rating systems. Based on literature review, sustainable sites, water efficiency, energy efficiency, materials and resources efficiency, indoor environmental quality, location and transportation, etc. are the principal features of the green buildings.

It was understood based on what the literature review revealed that a green building is designed, constructed and operated in such a way that it has a lower negative impact on the environment and human health. The Green architecture is environmentally responsible and convenient to use in its whole lifespan. Another conclusion is that the green design optimizes energy consumption in buildings by passive energy efficiency.

Most green buildings increase the initial construction cost around 20-25 percent, but the profit is ten times as much over the lifetime of the building. According to the documentary records found in the case studies, green buildings reduce the operational cost of the building nearly by 30-40 percent.

5.2.2 Investigate current operational and maintenance practices in Green Buildings in Sri Lanka

The second objective of the research was to investigate the current operational and maintenance practices in green buildings in Sri Lanka. There are various O & M practices as identified by the researcher, and they are as follows.

- Energy Management (Lighting Management)
- Increased indoor environmental quality
- Water management (best use of water)
- Material management (efficient use of materials)
- Waste management and toxic reduction
- Enhanced occupant health and comfort
- Better green grounds keeping
- Environment friendly pest controlling system
- Environment friendly cleaning procedures

Energy management was done by reducing the operating energy usage. For that energy efficient lighting and appliances, tuning equipments, installing timers and sensors are used. To reduce the environmental impact of the building, it is used renewable energy such as solar power. The building spaces are efficiently used by maximizing sunlight, winds and natural sheltering. The ventilation systems of the building designed for efficient heating and cooling.

Water management includes reducing the water consumption and protecting water quality, use of gray water, etc. The use of non-sewage and grey water, rainwater harvesting, use of water saving plumbing fixtures will minimize the demand of water.

For the material management is used renewable materials which are recyclable and friendly to the environment. For the waste and toxic reduction, non – toxic materials are used, and the resources are reused and recycled.

Green buildings improve air, thermal and acoustic environments and enhance the occupant's comfort and health. This is also having a direct monetary value along with an indirect effect on productivity and profit.

Green grounds keeping and cleaning also well maintained to reduce dust and to maintain the greenery features. Environment friendly pest control was another practice that the green buildings were applied to avoid the deterioration of natural materials due to pest attacks.

5.2.3 Analyze the positive and negative implications in operation and maintenance of green buildings in Sri Lanka

The third objective was to analyze the positive and negative implications in operation and maintenance of green buildings in Sri Lanka. According to the research findings through the literature review, preliminary survey and case study survey, it was found that there are many positive implications with operation and maintenance of green buildings and also some negative implications were identified as follows.

<u>Positive implications with O & M</u>

- Energy efficiency
- Reduced electricity and water usage
- Higher fraction of eco – friendly material usage
- Enhanced indoor environmental quality
- Reduced waste generation and carbon emissions
- More efficient recycling
- Healthy and happy tenants
- Material efficiency
- Enhanced durability
- Maximum use of daylight
- Cost efficiency

Negative implications with O & M

- Financial constraints
- Attitude Issues
- Management Issues
- Application Issues
- Technological Issues
- Insufficient Knowledge
- Unclear long term effects
- Difficulty in maintenance
- Energy supply depends on weather condition

The green buildings are energy efficient and provide the cost savings on electricity, gas and water when compared to the other expenses of its non – green items. However, the average total operational and maintenance expenses of the green buildings is higher than the non-green buildings. This reveals that green buildings may incur some additional expenses related to conventional buildings. The green buildings need to manage more carefully, and they required a more sophisticated building O & M system. The results of the study reveal that a building's operational and maintenance is highly correlated with its sustainability. Thus, the higher sustainable, the lower its operating and maintenance expenses.

5.2.4 Investigate the causes for negative implications with O & M of the green buildings in Sri Lanka

The fourth objective was to investigate the causes for negative implications with O & M of the green buildings in Sri Lanka. Green buildings have many positive implications, but there are some negative implications involved. As described in the data analysis, causes for negative implications with O & M of the green buildings were as follows.

- High initial cost
- Lack of knowledge of resources allocation system
- Inexperienced or insufficient project team
- Unavailability of green materials

High initial cost is a common belief that the investors felt since they have to face financial problems in O & M of the green buildings. This happens since it required considerable time period to receive the results of green building applications. Lack of knowledge of resources allocation system and inexperienced project team were another major reason for the negative implications occurred due to the negative implications with O & M of green buildings. Deciding most suitable green material/resource to a specific place requires skillful knowledge and to select the best choice for an articular place, it requires sufficient experience as well.

5.2.5 Explore the strategies for better operational and maintenance of Green Buildings

This is the last objective of the research. Strategies for better O & M of green buildings means, lower the impact on the environment, increase the health and well-being of occupants and assure the safety of the occupants by making a durable, low-maintenance required, resource efficient building while making the optimum use of its infrastructure and the community services. The research findings shown that, to mitigate or overcome the O & M negative implications, it is needed to apply some strategies such as;

- Encouraging the developer's commitment.
- Obtaining collaborative approach as a team.
- Making well organized resources' allocation system.
- Implementation of new technologies (ex: energy – efficient heating and cooling systems).
- Training and Educating team members.
- Enhance and ensure green technologies and policies.
- Preparing database for green materials.

5.3 Recommendations

Based on the conclusions of this study, it can be recommended that to improve the effectiveness of operation and maintenance of green buildings there should be a well-managed maintenance system. It can be done by a maintenance organization or else by a well experienced maintenance management team, etc.

The study's conclusions could be applied by building developers who now manage building maintenance based on subpar conditions. Future studies need to cover some of the phases and boundaries that this research revealed. The outcomes of this study allow for the following recommendations for future research.

- Along with records and reports which could referred at case study interviews and based on literature findings, this study proved that well-organized building maintenance reduces considerable amount of energy consumption in green buildings. However, it is still in the initial stage level. Therefore, it can be recommended if future research can concentrate on experimental evaluations to produce figures for building energy consumption for the upkeep and operation of green buildings.
- Another observation is that, there has not been done any study focusing the green building occupants' contribution for the operation and maintenance. Studies on this areas would raise occupant's awareness on the operation and maintenance.
- According to the interviewees' perspectives, there aren't any studies that methodically classify building maintenance waste based on volume and structure in terms of composition and level of hazard. Investigating how this waste can be handled in line with the sustainable waste management idea and comparing it to actual situations in case studies can be done in this regard.

These studies will benefit transfer understanding and capabilities of operation and maintenance among the green buildings in Sri Lanka as well as developers, maintenance organizations. Defining the recognized issues related to operation and maintenance of green buildings will enable best solutions to be proposed.

Further researches can focus to investigate the causes and possible solutions for the negative implications of green building O & M as well as can direct to study the strategies to overcome the negative implications of green building O & M.

5.4 Chapter Summary

This last chapter consists of the conclusions and recommendations of the study. The conclusions of research findings were explained according to the order of research objectives. Finally, based on the observations and received facts, some recommendations were given to affiliate the future researches.

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APPENDIXES

INTERVIEW GUIDE

[1] SECTION A – GENERAL QUESTIONS

1. Name of the Establishment/Organization:

……..……..……

2. What is your position in the company and how many years of experience you have?

……..……..……

3. Project Details -

a. The usage type of your building (office/commercial)?

……..……..……

. b. What is the total construction cost of the project?

……..……..……

c. What is the type of green certification achieved and when?

…..…….

d. What is the age of your building?

……..…….

e. What is the expected life time of the building?

……..……..

f. Type and Number of occupants involved in the building?

……..……..

g. What are the Green Building features added to the building?

……

……

h. Details of operational and maintenance expenditure?

……..……...

……..……

[2] SECTION B – POSTIVE AND NEGATIVE IMPLICATIONS RELATED TO THE OPERATIONAL AND MAINTENANCE OF GREEN BUILDINGS

1. Does the building have operational and maintenance plan?

……..…

2. What is the current operational & maintenance procedure in this building?
   I. Waste management - ……..……..……
   II. Housekeeping - ……
   III. Energy -……..……..
   IV. Water -……..……..
   V. Indoor environmental quality - ……...…….....
   VI. Pest control - ……..…
   VII. Cleaning - ……

3. Have you gained benefits by applying operational and maintenance methods and what are they?

   ……..…
   ……..
   ……..

4. What are the common operational and maintenance implications (both positive and negative) happened in this building?

   ……..……

   ……..

   ……..

5. What are the causes for each negative compliance?

   .....

   …….

6. What are the precautions that can be taken to mitigate those negative implications?

   ……..…..

   ……

7. Recommendations and suggestions?

   …….

   ……..

Thank You.

Yours faithfully,

……..

Promodh Senaratne.