LIFE CYCLE COST COMPARISON OF LEED CERTIFIED AND CONVENTIONAL OFFICE BUILDINGS IN SRI LANKA

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ABSTRACT

Green buildings are emerging concept to Sri Lankan construction industry. Although with a slow uptake, office building development is currently trending towards green buildings in the country. Lack of knowledge of the developers about advantages of green buildings in terms of the life cycle cost appears to be the largest obstacles which hinder green buildings in the country. In this context this study aims to compare the Life Cycle Cost of LEED certified office building with conventional office building in Sri Lanka in order to raise awareness of the advantages of green buildings mainly in terms of life cycle cost savings. Case study strategy was employed with semi-structured interviews and document survey as the data collection method. An expert survey was conducted to identify the life cycle cost components which are applicable to Sri Lankan context. Life Cycle Cost Analysis was carried out to evaluate the cost savings of green building over conventional building using Net Present Value method. The findings of this study reveal that although the construction cost of green building 5.33% higher of conventional building the cost is saved through operation and maintenance cost.

Keywords: *Green building; LEED certified building; Life Cycle Cost; Office buildings; Sri Lanka.*

1. INTRODUCTION

Construction activities have been accused for continuous and excessive consumption of global natural resources and causing a significant negative impact on environment during construction and operation of the construction industry (Zhang, Wang, Hu, & Wang, 2017). According to Neyestani (2017) and Birkeland (2014) green or sustainable design is the best way to mitigate the negative impact of construction industry on the environment. Green building (GB) is a concept which promotes sustainable build environment (Vyas & Jha, 2017; Evans, Strezov, & Evans, 2015; Chan, Qian, & Lam, 2009; Watkins, 2009; Sharrard, Matthews, & Roth, 2007; Teixeira, 2005; Cole, 2000). Although GBs are a way of reducing the negative impacts on environment, construction cost of GB is a matter of concern for the developers (Ahn, 2010).

However, there are evidences which show that Life Cycle Cost (LCC) of GBs is lower compared to the conventional building (Gou & Lau, 2014). LCC of building includes the total cost of a building during its lifetime, including the costs of planning, design, procurement, operations, maintenance and disposal, less any residual value (Madushan, 2012). According to the study of Bombugala and Atputharajah (2010), GB construction cost is 20-25% higher than the traditional buildings but over the entire life of the building 30-40% cost is reduced in operational cost of the GB building. Further, Weerasinghe and Ramachandra (2017) prove that the construction cost of green industrial manufacturing building is 28% higher than the conventional building while the running cost is 39% lesser than conventional building.

Lack of knowledge about the LCC of the GBs acts as a great barrier for GBs in Sri Lanka (Abeynayake, 2010). According to the United States Green Building Council's (USGBC) project directory, 38 buildings in Sri Lanka have achieved LEED certification in different categories. Among them 18 industrial and manufacturing buildings, 7 office buildings, 6 lodging, 3 retail building, 2 higher education centres, 1 laboratory and 1

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warehouse and distribution. This paper compares the Life Cycle Cost of LEED certified office building with conventional office building in Sri Lanka.

2. LITERATURE REVIEW

2.1. OFFICE BUILDING AND ITS IMPACT TO THE ENVIRONMENT

The control of environmental impacts from construction of building has become a major issue to the non-profit organization (Shen & Tam, 2002). Further, Teixeira (2005) and Shen and Tam (2002) has pointed out that the construction process usually results in negative impact to the environment i.e. extraction of environmental resources, production of waste, extensive consumption of natural resources and pollution to the living environment. Globally, in 2010 buildings accounted for 32% of total global energy use and 19% of energy-related Green House Gas emissions.

2.2. GREEN BUILDING CONCEPT

GBs are considered as one of the most effective concept of sustainable development (Low, Gao, & Tay, 2014; Liu, Li, & Yao, 2010). GB is a developing concept of environmental friendly building construction and the rating system for measuring the negative impact of construction towards its environment (Abeynayake, 2010). Vyas and Jha (2017) and U.S. Green Building Council (2009) identified efficient energy usage, water conservation, high quality inner spaces, and non-toxic gas emissions and recycled material usage as the environmental benefits of GBs. Further GB reduces the negative impacts through implementing improved site locations, design, construction, operation, maintenance, disposal and use of recycled and eco-friendly materials throughout its life cycle (Neyestani, 2017; Kibert, 2013).

2.3. GREEN BUILDING RATING SYSTEMS

According to Allen, et al., (2016) the aim of GB rating systems is, to reduce the negative impact of buildings and to improve the occupant health by providing design credits for adopting green design, operation and maintenance. Further, Ali and Nsairat (2009) stated that it produces significant long-term benefits for building owners and occupants, limiting environmental impacts, creating healthier and more productive places and reducing building operation cost.

Moreover, Bayraktar, Owens, and Zhu (2011) and Tatari and Kucukvar (2011) stated that GB rating systems aims to produce more environmental friendly buildings by using set of standards to evaluate the environmental performance of buildings by influencing the design and construction elements and process of building. GB assessment tools usually considers the site, water, material, energy and indoor environment quality and other attributes to measure the performance of the buildings (Gou & Lau, 2014). The following Table 1 presents the different GB rating systems used worldwide to rate the GBs. These rating systems are developed by respective GB council of the respective country.

Table 1: Worldwide Green Building Rating Systems

Rating Systems	Country of Origin
Building Research Establishment Environmental Assessment Method (BREEAM)	Britain
Leadership in Energy and Environmental Design (LEED)	USA
GB Tool	Canada
Comprehensive Assessment System for Built Environment Efficiency (CASBEE)	Japan
ESCALE	France
Hong Kong - Building Environment Assessment Method (HK-BEAM)	Hong Kong
National Australian Built Environment Rating System (NABERS)	Australia
DGNB	Germany
GREENSL®	Sri Lanka

2.4. LEED CERTIFICATION

United States Green Building Council (USGBC) developed LEED GB rating system to provide standards for environmentally healthy design, construction and operation (Green Building Council Sri Lanka, 2011). USGBC (2009) defines LEED as "a voluntary rating program, whose goal is to evaluate environmental performance from the whole building perspective over the building's lifecycle, providing definitive standard for what constitutes a GB". LEED is triple bottom line in action, promoting people, planet and profit (Zhang, Wang, Hu, & Wang, 2017).

LEED rating system is the most popular rating system in the world. Although Sri Lanka has GREENSL® Green Building Council Sri Lanka (GBCSL) decided to follow LEED rating system (Bombugala & Atputharajah, 2010). Similarly, other countries also use LEED as a standard rating tool, as it is widely used and globally recognized as significant assessment system among the other GB rating system (SGS Economic and Planning PVT LTD, 2008). According to the USGBC (2017) report, LEED has been recognized as the most widely used 3rd party certification for GB with approximately 2.2 million square feet being certified daily.

2.5. LEED CERTIFIED GREEN BUILDINGS IN SRI LANKA

There are only seven LEED certified office buildings in Sri Lanka (USGBC, 2017). Hatton National Bank (HNB) Jaffna, HNB Nittambuwa, Orion City Anton Building, Bureau Veritas consumer product service, HSBC head office, Logistics Park and Dialog Axiata PLC corporate head office are the seven buildings.

2.6. LEED CERTIFIED OFFICE BUILDINGS

The green design of office buildings includes finding the balance between the structure and the sustainable environment. Following are the benefits of LEED certified green office buildings:

- Reduced running costs by reducing energy costs
- Reduced health and safety risks to occupants from Sick Building Condition
- Lower absenteeism and improved productivity
- Positive image about the organization
- Higher rent due to more attractive building

Therefore, this research was carried out to compare the cost savings in LEED certified office buildings in Sri Lanka compared to conventional office building.

2.7. LIFE CYCLE COST ANALYSIS

There are several definitions for LCC. Widely used definition in the construction industry is given by ISO 15686 as the "total cost of a building or its parts throughout its life, including the costs of planning, design, acquisition, operations, maintenance and disposal, less any residual value" (Pelzeter, 2007). Wang, Rivard, and Zmeureanu (2005) defined life cycle of building as "The life cycle of buildings covers all processes from natural resource extraction, through material production, construction and operation until demolition, maintenance is usually required the operation phase while transportation is an activity associated with most other phases".

Moreover, LCC is defined as the summation of costs from inception to disposal of a building. Further, LCCA is defined as a method for calculating the entire cost of the building over its life time. LCC is the addition of all the cost of building over its life time including initial cost, running cost and demolition cost.

In addition, the following Figure 1 presents the stages of LCC proposed by Royal Institute of Chartered Surveyors (RICS) in Life Cycle Cost professional guidance (RICS, 2016).

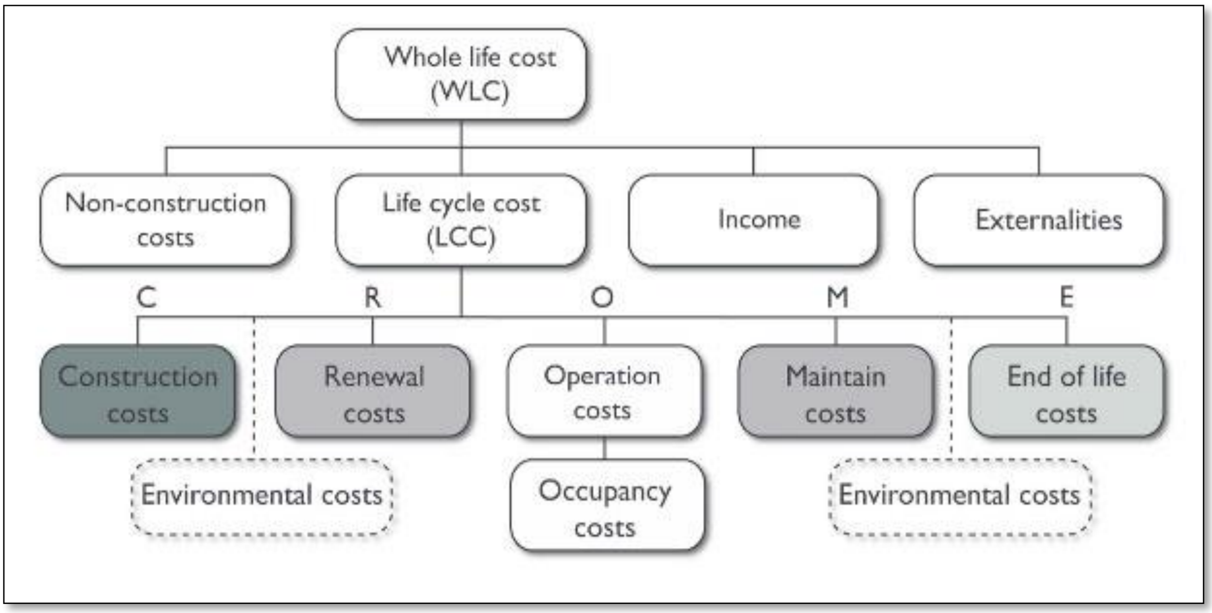

Figure 1: Stages of LCC of by RICS

According to RICS (2016), initial costs includes: site costs, opportunity costs, finance charges, professional fees, construction and infrastructure costs, tax allowances, statutory charges, development grants, planning gain and third party costs. Further, land acquisition cost, design cost and construction cost is identified as the initial cost of buildings.

Further, maintenance costs includes: redecoration, periodic inspection activity, periodic maintenance and component replacement activities, unscheduled corrective and responsive maintenance, planned and preventative maintenance and component replacement (RICS, 2016).

The following are the operational cost components identified in RICS (2016): cleaning and janitorial services, utilities, security, staff engaged in supporting the occupiers, waste management and disposal, property management of operation and occupancy, insurances, and taxes.

End of life costs specifically includes disposal and demolition, but may include residual values (RICS, 2016). Residual value is the value of the building at the end of the study period or at the life cycle period.

2.8. NON- COST FACTORS AFFECTING THE LCC OF OFFICE BUILDINGS

The building type, local climate, study period and number of stories affect the financial benefits from GBs. The longer the study period, the greater the energy savings and lower the LCC. Further, the following were identified as the non-cost factors affecting the accuracy of LCC of office buildings:

- Number of stories
- Type of building
- Gross floor area
- Project life
- Location
- Roof types
- Foundation types
- Number of elevators
- Type of structure
- Inflation rate

2.9. SENSITIVITY ANALYSIS

Life Cycle Cost Analysis (LCCA) involves the uncertainty in the assumptions i.e. future inflation rates and the anticipate life of the component or facility (Cole & Sterner, 2000). Therefore, economic risk assessment, either probabilistic approach or the sensitivity approach, can be used to reduce uncertainties in LCCA. Sensitivity analysis examines how LCC is influenced by changes in some of the variables (Cole & Sterner, 2000). Sensitivity analysis is used during model development, when the effects of several input parameters need to be analysed (Babashamsi et al., 2016).

3. RESEARCH METHODOLOGY

It was identified that mix method where both the qualitative and quantitative approaches are used to address the research questions was the best method for this study because the case study was chosen to carry out the qualitative approach and LCC calculation was selected to carry out quantitative approach. Due to the limited research conducted relating to the LCC of GBs in Sri Lanka, the case study analysis was selected to carry out qualitative approach. Interviews and document review was selected as the most reachable and reasonable data collection tools due to the nature of this research.

Content analysis and Life Cycle Cost Analysis were used as the data analysis techniques. In this research only four numbers of expert interviews were carried out to gather data, because few expertise are there in Sri Lanka with green building knowledge. Semi structured interview was select as one of the data collection tools for this research because the knowledge about GBs are less and only few researches were carried out in Sri Lanka relating GBs. Through semi structured interview the maintenance period, maintenance method, life time of the building, non-cost factors affecting the LCC of office buildings were collected from the selected buildings. As the aim of this research is to compare LCC between GB and conventional building, document survey was conducted for gathering life cycle cost details from the building owners.

4. RESEARCH FINDINGS AND ANALYSIS

4.1. *FINDINGS OF EXPERT SURVEY*

The most appropriate LEED certified green office building among the LEED certified green office buildings in Sri Lanka was selected for the case study through expert survey. There are 7 out of 38 LEED certified office buildings in Sri Lanka. Further, the LCC components which are applicable to Sri Lankan construction industry were identified.

Table 2: Expert Survey Respondents' Details

Respondents	Profession	Designation	Experience
E1	Architect	Project Consultant	15 Years
E2	Architect	Green Consultant	30 Years
E3	Engineer	Chief Executive Officer	15 Years
E4	Architect	Project Manager/ Green Consultant	32 Years

According to the findings of expert survey, the following Life Cycle Cost components were identified addition to the cost components identified in the literature review which are suitable to Sri Lankan context.

Table 3: Expert Survey Findings

Construction cost	Operation Cost	Maintenance Cost
Land acquisition cost	Administration costs	Electrical appliances & fittings
Solar tubes	Insurance	External works
Water treatment plant		Minor unscheduled maintenance
Eco roof		Minor scheduled maintenance
		Solar panels
		Eco roof
		Water treatment plants

4.2. FINDINGS OF SEMI-STRUCTURED INTERVIEW

The semi- structured interviews were analysed based on content analysis, through which the non-cost factors affecting the LCC of an office building in Sri Lanka were identified. Details of the semi-structured interview respondents are given in Table 4.

Table 4: Semi-Structured Interview Respondents' Details

Respondent	Profession	Designation	Experience
LEED Certified Office Building			
R1-C1	Engineer	Maintenance Engineer	9 Years
R2-C1	Architect	Green Consultant	30 Years
Conventional Office Building			
R1-C2	Engineer	Maintenance Engineer	25 years
R2-C2	Manager	Maintenance Manager	10 years

According to the findings of semi-structured interview, type of building and the project life are the non-cost factors which affect the LCC of office building in Sri Lanka. According to the Figure 2, foundation type of the building has the least impact on the LCC of an office building. Addition to the type of building and project life, gross floor area, location, roof types and type of structure have significant impact on the LCC of an office building in Sri Lanka.

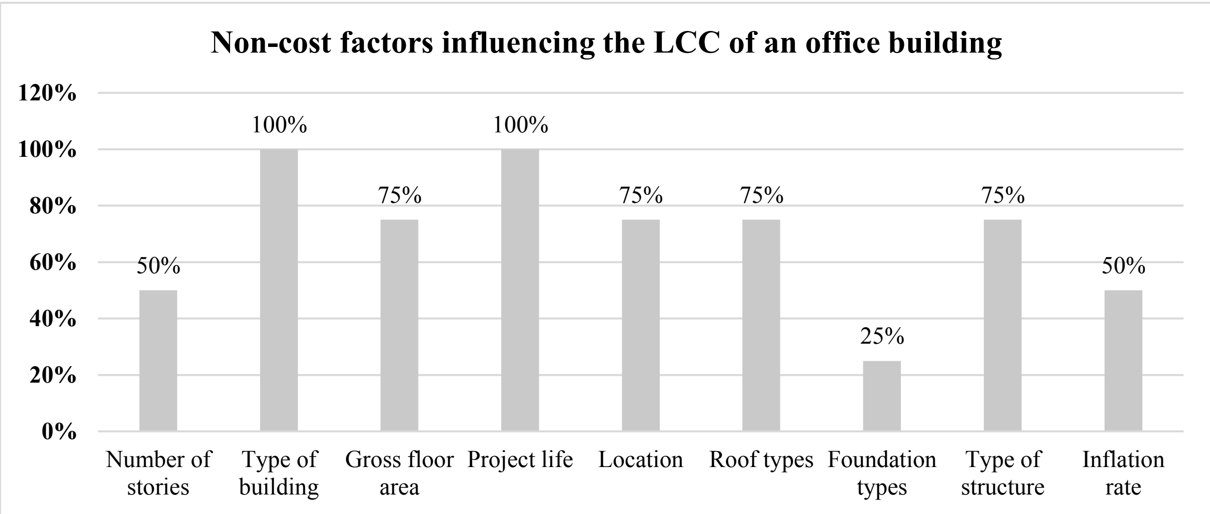

Figure 2: Non-cost Factors Influencing the LCC of an Office Building in Sri Lanka

4.3. LIFE CYCLE COST ANALYSIS FINDINGS

The case study was focused on LEED certified office building and conventional office building with similar physical and performance characteristics considering the year of construction and gross floor area. Case study analysis was carried out selecting two building projects. The LEED certified building was identified through expert survey and finally selected the conventional building with similar characteristics of LEED certified building. The analysis was carried out within the case and the results were compared with the other case. Document review was carried out to collect the actual construction, operation, and maintenance cost details from the cases.

The selected two projects were leading bank in Sri Lanka. Selected GB is the 1st LEED gold certified bank in Sri Lanka. A comparable conventional building was selected for LCC comparison.

Table 5: Profile of Selected Cases

Description	Building 01 (C1)	Building 02 (C2)
Type of building	LEED certified building	Conventional building
Building category	Bank	Bank
Gross floor area (m2)	1,022	1,208
Construction period	3 Years	2 Years
Number of stories	2 Storey	3 Storey
Construction year	2009	2009
Completed year	2012	2011
Location	Western Province	Western Province

The cost details collected through document survey was analysed using Net Present Value (NPV). Through NPV analysis the LCC of GB and the conventional building was calculated. The analysis period was assumed as 50 years which is the average life time of an office building. A cross case analysis of NPV between green and conventional buildings was carried out. There are factors which influence the LCC of an office building. Therefore, the conventional building for the analysis was selected considering the factors affecting. There were identical features in both green and conventional building, i.e. location, type of business, gross floor area, and number of storey, year of construction and life time of building.

The construction cost, maintenance cost and operation cost details were collected from document study. The pattern of cost occurring was collected from the maintenance manager. Further, the rate of return excluding inflation for both the buildings was stated as 20%. In addition, maintenance manager said that the life time of GB is designed to 50 years. Therefore, in the analysis to compare the LCC, the life time of conventional building was considered as 50 years.

To calculate the amount to be saved today to cover the annual expenses is calculated from the following Eq. (01): i.e. Years purchase formula.

*YP = FV * [(1+r) n-1*(r (1+r) n)]* Eq. (01)

Where, YP= Present value of an annual amount receivable, FV= Annually occurring amount, r= Discount rate (Nominal rate) and n= Total years of cost occurring

The rate of return excluding the inflation was provided by the building. To carry out the LCC calculation the inflation rate should be considered because with the change of inflation rate the LCC might change. Therefore, the inflation rate was taken from the Central bank report. The average inflation rate from 2009 to 2017 was used to discount the present cost to the base year. The average inflation rate from 2009 to 2012/2011 was used to discount the construction cost to the base year 2009. The annual inflation changes over time therefore, to reduce the impact of inflation on LCC calculation, the average rate was used. The following Eq. (02) were used to calculate the nominal rate of return for the LCC calculation.

(1+ireal) = (1+inominal)/ (1+iinflation) Eq. (02)

Where, r_{real}= Rate of return excluding inflation, $r_{nominal}$= Rate of return including inflation and $r_{inflation}$= Inflation rate

A cross case analysis between green and conventional building was carried out to compare the NPV. All the costs were discounted back to year 2009 and standardized to cost per square meters. The GB cost impact compared to conventional building was calculated using Eq. (03).

Green Building Cost Impact = (PV of Green Building – PV of Conventional Building) / PV of Green Building Eq. (03)

Where, PV= Present Value

Table 6: Life Cycle Cost Analysis Comparison

Description	GB Cost/m^2	Conventional Building Cost/m^2	GB Cost Impact
Construction cost	115,864.64	109,687.79	5.33%
Maintenance cost	4,006.51	4,803.49	-19.89%
Operation cost	6,709.93	15,243.61	-127.18%
End life cost	(29.65)	(14.94)	49.61%
Life Cycle Cost	126,551.43	129,719.96	-2.50%

The outcome of this analysis is that the LEED certified office GBs shows 2.50% cost saving compared to conventional office building in Sri Lanka. Although the construction cost is high for GB there is a significant cost saving in maintenance and operation cost that is due to the incorporation of sustainable features in GB. Further, greater cost saving is experienced in the energy cost of GB i.e. electricity cost and water cost.

There are sensible variables in the LCCA in which the NPV is depended. In performing the LCCA certain assumptions were taken regarding i.e. inflation rate and the building life time. Sensitivity analysis was performed to examine how the variables could affect the NPV values. The sensitivity analysis was carried out for ±10% or ±20% of the actual inflation rate -4.941% to track the change in the GB LCC, when the inflation rate varies between ±10% to ±20%, the LCC of GB vary between 0.468% to 1.069%, which is an insignificant change that can be ignored.

Further, the sensitivity analysis carried out for ±10% or ±20% of inflation rate -4.699 to track the LCC change of conventional building. Accordingly, when the inflation rate varies between ±10% to ±20%, the LCC of conventional building vary between 0.733% to 1.656%, which is also an insignificant change that can be ignored. The sensitivity analysis was carried out for ±10% or ±20% of the life time of building which is 50 years to track the change in the GB LCC, when the life time of the building varies between ±10% to ±20%, the LCC of GB vary between 0.017% to 0.1%, which is an ignorable change that can be ignored.

Finally, the sensitivity analysis carried out for ±10% or ±20% of the life time of building which is 50 years to track the LCC change of conventional building. Accordingly, when the life time of the building varies between ±10% to ±20%, the LCC of conventional building vary between 0.014% to 0.466%, which is also an insignificant change that can be ignored. Therefore, conclusion can be made that with the change in the life time of the building there is an insignificant change in the LCC of conventional building. Further, this analysis also justifies that the cost saving from the office GB compared to office conventional building in Sri Lanka is 2.50%.

5. CONCLUSIONS AND RECOMMENDATIONS

As the conclusion of this study, although the construction cost is 5.33% high for GB, 19.89% cost saving is experienced in maintenance cost and 127.18% cost saving is experienced from operation cost. Further, 49.61% income is experienced from end life cost. Finally, 2.50% cost is saved from GB throughout its life time.

GBs can be undertaken as a corporate social responsibility programme by the developers and the government can impose strict rules for building developers to incorporate sustainable features in their building and get green certification. LCC can be incorporated into the mandatory documents which are needed to acquire government approval for the project along with drawings and bill of quantities. GB council and green consultants need to do further research to implement GB with low running and initial cost in Sri Lanka.

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