LIFE CYCLE COST ANALYSIS: GREEN VS CONVENTIONAL BUILDINGS IN SRI LANKA

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Recently, the focus to green buildings has fore-fronted in the Sri Lankan construction industry. The green building investors continue to focus on minimising construction cost and fail to appreciate the impact on life cycle economic performances. The construction cost of green buildings tends to be higher than traditional buildings, with comparatively lower operation and maintenance costs. Therefore, this study assesses the life cycle cost of green certified industrial manufacturing building and that of a conventional building to establish the impact of sustainable features on life cycle cost. The quantitative data on construction, running and end of life cycle costs of the selected green and conventional buildings were collected and analysed using Net Present Value. The analysis shows that the construction cost of green industrial manufacturing building is about 28% higher than that of a conventional building. However, operation, maintenance and end of life cycle costs are in the range of 35 to 41%, 26 to 30% and 6 to 18% respectively lower than that of conventional building. The study found that the life cycle cost of green building is 24 to 28% less compared to conventional building. It is expected that the outcome of this research would contribute to the organisational learning of green built environment and thereby uplift the use of sustainable construction in Sri Lanka.

Keywords: green building, green rating systems, life cycle cost, Sri Lanka

INTRODUCTION

The global implication on how heavily the built environment contributes to the natural environment had led to the evolution of green buildings over conventional buildings (Means, 2011). Green building is defined as the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from design to construction, operation, maintenance, renovation and deconstruction (U.S. Environmental Protection Agency, 2016). For example, United Nations Environment Program [UNEP] (2012) found that conventional buildings use about 40% of global energy, 40% of other resources, 25% of global water, and emit approximately 1/3rd of Green House Gas (GHG) emissions while green buildings have 19% lower aggregate operational costs, 25% of less energy, and 36% of fewer CO2 emissions (U.S. General Services Administration [USGSA], 2011).

As per Dodge Data and Analytics (2016), the number of green buildings continues to double every three years and responsible for 24% of the total construction activities.

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However, there exists some barriers in deciding whether to execute a green building project. This includes higher perceived construction costs, lack of political incentives, lack of market demand, lack of public awareness, perception of green is for high-end projects only, unproven business case due to split between capital and operating costs, lack of trained or educated green building professionals, and the difficulties in accessing capital. As Wilson and Tagaza (2006) identified, perception on higher capital cost, investment on short term paybacks rather than lifecycle costing and lack of tenant demand contribute to financial barriers. Similarly, Durmus-Pedini and Ashuri (2010) pointed out that the return on investment needs more of a historical perspective to become more predictable and company budgets are not usually structured to track life cycle cost (LCC) for a project making longer term gain.

Cole (2000) highlighted that there is a widespread belief that the green buildings cost much more to build than traditional buildings. On a similar view, Kansal and Kadambari (2010) added that the initial cost of a green building is more compared to that of a conventional building while the operation cost of green building is less. A study conducted by Kats (2006), reviewing 30 green schools across the United States showed that the green schools cost more than 2% of conventional schools, but provided benefits that were 20 times more over a 20-year period. Another study that analysed 150 recent conventional and green office and school buildings in 33 states across the United States and 10 other countries, concluded that green buildings cost up to 4% more than conventional buildings and most of buildings only costing from 1-2% more than the similar type of conventional ones. The study also found that green buildings reduce energy use by an average of 33%, and that energy cost savings alone over a 20-year study period outweighed the initial cost premium (additional cost incurred to construct a green building) paid in these buildings (Kats, *et al*., 2008).

Kats (2010) also found that green cost premium of school building is ranging from 0% to 18% and argued that the cost premium of more than 75% of the green buildings in his sample falls within the range from 0% to 4%. However, the above findings derived through a questionnaire survey with a single question responsible for quantifying cost premium. The participants of the survey were principal architects of the LEED-certified green buildings. Therefore, the reliability of the findings is questionable due to bias and method employed. Moreover, most of the studies used cost estimation methods such as comparing actual cost of green buildings against modelled cost of conventional buildings and comparing modelled cost of green buildings and conventional buildings, while a very few were able to compare the actual cost of green buildings with that of conventional buildings (Dwaikat and Ali, 2016). Moreover, previous authors have reported that higher levels of sustainability are usually linked to higher cost premium. Foregoing review further indicates that cost premium of green buildings varies within the type of buildings. For example, Bartlett and Simpson (1998) compared the estimated capital cost for energy efficient and environmentally friendly buildings and concluded that industrial green buildings incur the highest capital cost than the commercial buildings and houses. However, Dwaikat and Ali (2016) found that amongst the office, hospital, library, school, laboratory, house and apartment buildings, the highest green premium (21%) is from the office buildings. Despite, the current study analyses the LCC of green verses traditional industrial manufacturing buildings which have received the highest number of LEED certifications in Sri Lanka.

With the growing global interest on sustainability, the concept of green building construction has come to the forefront of the construction industry in Sri Lanka (Abidin, 2010). However, as studies highlighted there are some challenges for a developing country like Sri Lanka when leading towards the sustainable construction. For example, Bombugala and Atputharajah (2010) concluded that the construction cost of green buildings is about 20-25% higher than traditional buildings. Waidyasekara and Fernando (2012) found that the green building investors focus on minimising construction cost while fail to consider the life cycle economic performances. Therefore, they completely ignore the other benefits which can be achieved through green buildings such as lower energy cost, lower annual electricity cost, reduce annual water cost and wastewater cost, lower annual fuel cost, and lower cost for waste disposal. Since cost is one of the most crucial concern in promoting green buildings there is a need to provide robust evidence to counter the high initial cost barrier. The foregoing review indicates that cost commitments of green buildings is the prime concern and of contradictory views with respect to different context, type of building, weather condition, site conditions etc. Hence, a comparative analysis of LCC of green buildings and conventional buildings in Sri Lanka would provide a clear understanding of the cost impact and thereby enable potential green investors to take informed decision about their green investments.

SUSTAINABLE FEATURES AND THEIR COST IMPACT

Green buildings promote sustainability through principal areas such as sustainable sites, management, energy efficiency, water efficiency, materials and resources, indoor environmental quality, health and wellbeing (Fowler and Rauch, 2006; Nguyen, 2011). The high initial cost of green building is attributed to applications of sustainable features in the above areas. This section therefore reviews the various sustainable features that could be incorporated into green buildings and their impact on LCC. The identification of sustainable features was done based on a green rating system which is recognized worldwide. As, Fowler and Rauch (2006) highlighted LEED is the dominant and most widely used rating system around the world. To date, LEED encompasses more than 72,500 building projects over 150 countries and territories. Therefore, LEED BD+C: New Construction & Major Renovations (V.3-2009) rating system was used to identify the sustainable features that are available in the green buildings and their impact on LCC. This rating system has six (06) sustainable categories such as sustainable sites (SS), water efficiency (WE), energy and atmosphere (EA), materials and resources (MR), indoor environmental quality (IEQ), innovation in design (ID), and regional priority (RP)(USGBC, 2009). Table 1 summarises the literature findings on sustainable features and their cost impact. The cost impact of sustainable features was assessed on the four-point qualitative scale of Minimal (M), Low (L), Significant (S) and Minimal to Significant (M to S) and two-point scale of "Yes" or "No"(Davis Langdon, 2007). Further, BMCIS standard cost classification system was used in relating the sustainable features to respective LCC (main) element(s).

As observed from the Table 1, several of the sustainable elements of sustainable sites have very low initial cost impact (Davis Langdon, 2007). And those can be readily achievable at a little cost. 10 out of 14 applicable criteria in the sustainable site category contribute to the LCC of green buildings through fuel oil, electricity, service attendants, internal/ external surface and window cleaning, gardening, repairs and decoration, roads pavement, external glazing (shading), fuel, loose appliances, lamp replacement (BMCIS, 1984).

The applicable criteria of water efficiency also have a low initial cost impact, excluding the instances where the project involve high-end technologies like innovative waste water technologies (Davis Langdon, 2007). The LCC of the green building is affected by all three applicable criteria in the water efficiency category, through water charges, service attendants, repairs and decoration, cold-water services, sanitary fittings, water meter readings, and built in fittings (BMCIS, 1984).

Energy applicable criteria requires a high degree of focus and can be challenging for many projects (Davis Langdon, 2007). In fact, those have very high initial cost with most readily calculated LCC to electricity, air conditioning and ventilation, gas meter readings, electricity meter readings, refrigerant equipment, loose appliances, repairs and decoration, and built in fittings (BMCIS, 1984).

Table 1: Summary of LCC impact of sustainable features

Sustainable Features		Impact on Initial Cost		LCC Impact		LCC Elements (Main)	% of Cost Savings
Main Feature (Points)	No. of Applicable Criteria	Impact	No of Elements	Yes	No		
SS (26)	14	M	6	10	4	Utilities, Administrative works, Fabric, Services Cleaning, External works	Life cycle environmental benefits
		L	0				25% reduction of Cooling cost
		S	5				36% of fewer CO_2 emissions
		M to S	3				
WE (10)	3	M	0	3	0	Utilities, Administrative works, Services, External works	Reduce water cost by 22%
		L	1				
		S	1				
		M to S	1				
EA (35)	6	M	0	5	1	Utilities, Services, External works	30% energy cost reduction
		L	1				
		S	5				
		M to S	0				
MR (14)	7	M	1	6	1	Administrative works, Fabric, External works	50%-75% solid waste management cost reduction
		L	0				
		S	1				
		M to S	5				
IEQ (15)	15	M	6	11	4	Utilities, Administrative works, Fabric, Services Cleaning, External works	Productivity and health 70%
		L	5				
		S	0				
		M to S	4				

Adapted from: BMCIS (1984); Kats (2006); Kats (2010); Davis Langdon (2007); USGBC (2009)

Almost all the applicable criteria (5 out of 7) associated with material and resources have minimal and significant cost impact considering the compliance or other physical conditions (Davis Langdon, 2007). Considering the LCC impact of material and resources, all most all the applicable criteria contribute to the cost of waste disposal and fabric maintenance (BMCIS, 1984). With the building and material reuse greatly reduce the construction and demolition waste.

The applicable criteria in IEQ are readily achievable with low costs (Davis Langdon, 2007) and contribute to the LCC through glazing and windows, built in furniture, ceiling, wall and floor finishes, air conditioning and ventilation, meter readings, lighting, lamp replacement, built in fittings, internal/ external surface and window cleaning, electricity, gas and service attendants (BMCIS, 1984). The points allocated for sustainable features; innovation in design and regional priority are either achieved with a minimal cost impact or the application of these two features is covered by other sustainable features which discussed earlier (Davis Langdon, 2007).

However, in return sustainable applicable criteria can bring benefits like conserve natural resources, enhance occupant comfort and health, reduce operating costs, create value within the compatible market, positive impact on the construction industry etc. (Durmus-Pedini and Ashuri, 2010). According to Hwang and Tan (2012), energy efficiency applicable criteria bring incremental economic as well as environmental benefits. Similarly, Waidyasekara and Fernando (2012) indicated that preservation of water resources for future generation and lower potable water resources are benefits due to water efficiency applicable criteria on green buildings. However, Kats (2006) analysed the cost benefits of green buildings and highlighted that green buildings ensure to achieve13%saving of maintenance cost, 19% of lower aggregate operational cost, 22%reductionof water cost, 25% reduction of cooling cost, 36% of fewer CO_2 emissions, 30% of energy cost reduction, 50%-75% of solid waste management and cost reduction of productivity and health is 70%. Table 1 divides those benefits to the identified categories of sustainable features.

As identified in the above, the impact of sustainable features to the LCC of green buildings are attributed to number of costs elements in the operation and maintenance stage of green buildings. Therefore, it is difficult to measure the impact of sustainable features on a single entity of cost elements and the most appropriate way to reflect this impact is by considering the costs of green building over its life cycle and compare with that of a conventional building.

RESEARCH METHODS

A comparative analysis between a green building and conventional building was adopted for this study. Prior to this, a preliminary analysis was carried out into green certified buildings to identify the most significant green space type, and the level of sustainability achievement in terms of main sustainable features within it. This analysis enabled to identify the relationship between sustainable features and its impact on initial cost as well as LCC. The preliminary analysis was performed on the secondary data collected from 38 of LEED Green certified buildings in Sri Lanka. Amongst eight (08) green industrial manufacturing cases which certified under LEED BD+C: New Construction & Major Renovations (V.3-2009) rating system were screened for further study. The eight (08) industrial manufacturing cases included Garment (04), Printing and Packaging (03) and Cleaning Products (01) buildings. The age, Net Internal Area (NIA), and occupancy rates differ for each case. However, the building height is mostly limited to 01 or 02 floors. Subsequently, a comparative analysis was performed by selecting two (02) green buildings and a conventional building with similar physical and performance characteristics. When selecting these two cases, the age, NIA, and occupancy rate factors were considered. The conventional case was identified conveniently, then careful selection of two (02) green cases with similar characteristics was carried out by eliminating the cases which have considerable differences in physical characteristics. Relevant real-life cost data: construction, annualised and periodic operation and maintenance, and simulated end of life cycle cost data were collected through document analysis according to the standard cost categories suggested by Building Maintenance

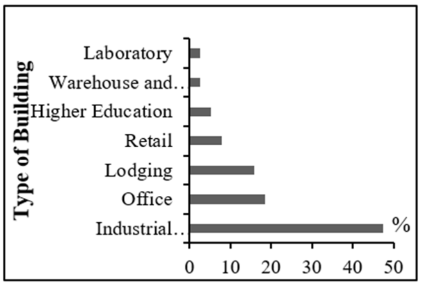
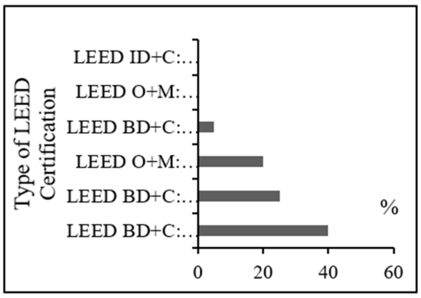
Cost Information Service (BMCIS). The documents relevant to the initial green building construction budget, and operation and maintenance expenditure budget records were used to collect the cost data. Simultaneously, physical and performance data such as constructed year, number of floors, NIA, life cycle, building height and number of occupants were collected from the selected green and conventional buildings. Statistical analysis techniques: NPV and sensitivity analysis was used to measure the LCC of green buildings. All the costs were escalated at assumed inflation rate and then discounted for the base year. The analysis was carried out for 50 years and the discount rate (4.26%) was obtained from the Central Bank of Sri Lanka.

DATA ANALYSIS AND FINDINGS

Preliminary Analysis and Findings

According to published information at USGBC Directory, under LEED category a total of 74 buildings have been registered to date. Of which only 38 buildings have achieved the certification (USGBC, 2017). Table 2 presents the profile of LEED certified green buildings which include green space type, and certification type.

Table 2: Demographic profile of the LEED certified green buildings in Sri Lanka

Demographic Information		Number	Percentage
Green Space Types	Laboratory	1	
	Warehouse and Distribution	1	
	Higher Education	2	
	Retail	3	
	Lodging	6	
	Office	7	
	Industrial Manufacturing	18	
Green Industrial Manufacturing Buildings	LEED ID+C: CI(v3)	0	
	LEED O+M: EB (v2)	0	
	LEED BD+C: C&S (v3)	1	
	LEED O+M: EB (v3)	4	
	LEED BD+C: NC (v2)	5	
	LEED BD+C: NC (v3)	8	

According to Table 2, mostly (47%) available green space type in Sri Lanka is the industrial manufacturing buildings. Respectively, office (18%), lodging (16%), retail (8%), higher education (5%), warehouse (3%) and laboratories (3%) obtained the remaining of green space available in Sri Lanka. Most, over 40% (8 out of 18) of the industrial manufacturing facilities are certified under the LEED BD+C: New Construction (v3 -2009) rating system. Therefore, the study focuses on the LCC of green industrial manufacturing buildings in Sri Lanka, which certified under LEED BD+C: New Construction (v3 -2009). This provides the total population of 08 buildings. However, this initial research focused on a single case from this population. The logical justification for the case selection is specified in the 'Methods' section.

Level of Achievement of Sustainable Features

The points allocated for each sustainable feature was compared with earned points and identified the under scored areas of eight (08) industrial manufacturing buildings in the LEED BD+C: New Construction (v3 -2009) rating system. Figure 1 illustrates the on average points earned out of the possible points allocated for each main sustainable feature.

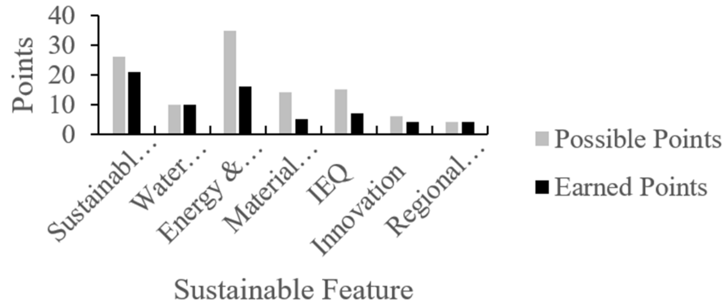


Figure1: Level of achievement of sustainable features

As shown in Figure 1, water efficiency and regional priority features have achieved 100% satisfaction by earning the possible points allocated. Similarly, sustainable sites and innovation in design features have also been in a satisfactory level with the score of over 80% of achievement. In terms of energy efficiency and IEQ features, the industrial buildings have earned less than 50% of the allocated points while only a 36% is achieved in terms of material and resources.

In terms of energy efficiency, IEQ and material and resources, the certified l buildings have scored fewer points. This is due to the implication of those features consumes significant initial costs. Materials and resources, this feature is classified into two distinct categories with; A) most projects pursuing the credits related to construction waste management, local content and recycled content, and B) very few pursuing the other credits like material reuse, renewable materials, building reuse and certified wood. Often, the investors go for the projects in the category A due to the achievement of those features requires less cost compared to projects in the category B. Following this preliminary analysis, a detailed analysis on LCC was performed of a green industrial building compared to that of a conventional building. The next section presents the LCC analysis.

Case Study Analysis and Findings

A cross case analysis of NPV between green and conventional buildings was performed. Though, it is difficult to find 100% identical buildings in the real world, the study managed to find a matching conventional building for the cost analysis. Having considered the factors influencing the sustainability, a conventional building constructed in similar location and climatic condition, with similar tenure, i.e. management style and quality of the selected green building was chosen. In addition, physical and performance characteristics such as year of construction, number of floors, shape, NIA, designed life cycle, building height and number of occupants were matched between the two buildings. Table 3 presents the profile of the selected three buildings.

Table 3: Profile of the cases

Building	Year	No. of Floors	Shape	NIA (m2)	Life Cycle	Building height(m)	No. of Occupants	Type of Function
Green 1	2013	1	Rectangular	3,809	50	3.8	1,400	Garment
Green 2	2013	1	Rectangular	3,567	50	4.0	1310	Garment
Conventional	2013	2	Rectangular	4,032	50	7.8	1,340	Garment

According to Table 3, the established year, shape of the building and designed life cycle are same for the selected three cases, whereas green building is a single storey building and the parameters: NIA and building height are less than that of conventional building. However, the number of occupants in the organizations are closely related.

LCC comparison between green and conventional buildings

As discussed in the methodology section, the NPV of the two cases were calculated to 50-year life cycle of buildings using the discount rate of 4.26%. Relevant cost data required for the NPV calculations were collected according to the standard cost categories suggested by Building Maintenance Cost Information Service (BMCIS). Table 4 illustrates the summary of comparison.

Table 4: LCC between green and conventional buildings

LCC	Green Building (GB) cost per Unit Area (LKR/m2)		Conventional Building	Green Building Cost Impact	
	GB1	GB2		$\frac{\text{PV of GB1} - \text{PV of CB}}{\text{PV of GB1}} * 100\%$	$\frac{\text{PV of GB2} - \text{PV of CB}}{\text{PV of GB2}} * 100\%$
Construction	80,306.53	81,081.68	58,699.34	27%	28%
Operation	347,042.41	333,689.04	469,918.75	-35%	-41%
Maintenance	69,408.48	67,278.20	87,763.17	-26%	-30%
End of life cycle	180.88	251.03	192.04	-6%	-18%
NPV	496,938.29	482,299.95	616,573.31		
Green Building LCC Impact = $\frac{\text{LCC of Green Building} - \text{LCC of Conventional Building}}{\text{LCC of Green Building}} * 100\%$				-24%	-28%

All the costs were discounted back to year 2013 and normalised into net internal area. According to Table 4, the construction cost of the green building is 27 to 28% higher than the construction cost of the conventional building due to storm water design, heat island effect-roof, sewage treatment plant, optimize energy performance, certified wood and LEED professional fees. However, other costs: operation, maintenance and end of life cycle cost of the green building are comparably less than the conventional building, respectively by 35 to 41%, 26 to 30% and 6 to 18% due to energy cost reduction by 40 to 50%, water consumption reduction by 50 to 60%, 95% waste recycling, reduced absenteeism by 2%. And considering the LCC of green building it's less than the LCC of conventional building by 24 to 28%.

DISCUSSION AND CONCLUSIONS

Previous studies suggest that the upfront cost issue is one of the main barriers exist when deciding whether to execute a green building project (Dodge Data & Analytics, 2016; Durmus-Pedini and Ashuri, 2010; Wilson and Tagaza, 2006). However, Dwaikat and Ali (2016) stated that a reasonable level of sustainable design can be incorporated into most building types at little or no additional cost. Moreover, the high initial cost barrier is a result of sustainable features incorporated into green buildings. Previous studies found that most of the applicable criteria in sustainable features like sustainable sites, water efficiency and IEQ are readily achievable with low costs, whereas, many applicable criteria in energy and atmosphere require a high degree of focus and can be challenging for many green building projects. The initial cost impact of almost all the applicable criteria of material and resources changes from minimal to significant in green buildings. This research indicates that the green building applicable criteria under energy and atmosphere, material and resources and indoor environmental quality is incorporated less in the green buildings in Sri Lanka. It seems that high initial cost of those criteria Prevents green buildings from achieving better sustainability levels.

Further, Bombugala and Atputharajah (2010) concluded through participants' survey that the construction cost of green buildings is 20-25% higher than traditional buildings in Sri Lanka. The findings of this study show that the construction cost of green building is 27 to 28% higher than that of traditional building. Therefore, the findings of the study are similar with the literature findings. However, the operation, maintenance, and end of life costs are less than that of conventional buildings by 35 to 41%, 26 to 30% and 6 to 18% respectively. Altogether, the LCC of green building is 24 to 28%less than the conventional buildings due to the LCC benefits of green buildings. Therefore, the investors can use those cost analyses as a base to execute green building projects.

However, this study is limited to three cases due to the lack of green industrial manufacturing buildings in Sri Lanka and the accessibility constraints of the cost data of industrial manufacturing buildings. It is believed that other factors such as project location, building type, site conditions, local climate and time integrate sustainable building practices into projects and architectural and engineering design time necessary etc. (Kats, *et al.*, 2008) could also affect the green building cost. Therefore, it is recommended the future studies to consider these and identify its impact on LCC and thereby facilitate green building investors to take better decisions of their green investments.

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