A Case Study of Life Cycle Cost Comparison Between a Green Building and a Non-Green Building in Sri Lanka

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Abstract— *As the world moves toward more sustainability, Increasing the adoption of green construction has risen to the top of the construction sector in worldwide. Green building is a key strategic step towards achieving sustainable development by saving resources, energy, and environment. As the world moves to greater sustainability, green building has gone to the construction industry's priority list. While currently Sri Lanka is facing an economic and energy crisis, the green building concepts can help the economy by boosting the construction sector. If the implement process of green building concept in Sri Lanka, within the next 30 or 40 years, it may be capable of converting revenue generating opportunities on construction sector. People only consider the construction's initial cost rather than the total cost over its entire life cycle. When it comes to construction time span, it's near to 3 to 4 years, while the total life span of a building counts over 60 to 70 years. It's better to consider the Life Cycle Cost (LCC) of a building which consists of maintenance, overhaul, services, and repair cost parameters. Thus, the primary goal of this study is to analyses the cost of a green building and a non-green building in Sri Lanka. A case study was done on two selected university buildings. A cost benefit analysis would be carried out, accounting for the initial cost in comparison to LCC. Site visits & semi structured interviews which selected by purposive sampling used for the data collection. This was done with mix method of qualitative & quantitative, analysed through comprehensive study. With the aim of economic consideration of green building concept, this will be a timely research study to Sri Lanka to overcome this emerged economic & energy crisis.*

Keywords— **Sustainable Construction; Green Buildings; Cost Benefit Analysis; Life Cycle Cost; Sri Lanka**

I. INTRODUCTION

Green building development is a key strategic step toward achieving sustainable development, saving resources and energy, and environmental protection. Many countries have issued green building grading standards in order to support the healthy growth in green buildings (Liu, Guo and Hu, 2014). 40% of worldwide energy use by buildings according to World Business Council for Sustainable Development (WBCSD) (2009). Many researches on sustainable construction have been undertaken to examine methods to reduce the amount of energy consumed in the construction industry (Tathagat and Dod, 2015). Several studies give an idea about green buildings and it stated that there are significant benefits in green buildings than non-green buildings (Simpeh and Smallwood, 2018). The economic benefits in economic efficiency green buildings can decrease the first cost, because of integrated energy solutions, systems can be shrunk. And also lower annual fuel and electricity costs due to the reduced peak power demand and reduced demand for new energy infrastructure, resulting in lower consumer energy costs (Waidyasekara and Fernando, 2012).

Sri Lanka is experiencing a critical energy and economic crisis. Sri Lanka's economy is collapsing. Green building concepts can be used to support the economy through the construction industry, so green building concepts are a current topic. In typical structures, most of the objects are destroyed during refurbishment, whereas green buildings have a lot of re-usable components. If we adopt a green building concept in Sri Lanka before 30 or 40 years, we may be able to convert these as revenue generate an opportunity on new construction. It may be a significant benefit in an energy crisis which we currently facing now (Tathagat and Dod, 2015)

When it comes to constructing buildings, the time frame is nearly 3 or 4 years. A building's functional life span, on the other hand, can be 60 or 70 years. Then there are other costs of maintenance, overhaul, and repair over the span of a building's life cycle. When comparing the cost of a green building to a conventional building, it's important to include not only the construction cost but also the life - cycle costs. The problem statement of this study is Sri Lanka's construction industry does not focus much on sustainable development, so it contributes greatly to an energy crisis as well as economic crisis. There is a critical energy and economic crisis in Sri Lanka. There are regular power cuts; resource scarcity; and several issues caused by inflation and the currency rate. And this situation justifies the problem mentioned above. In Sri Lanka, the existing energy and economic crises are significant reasons to employ green building concepts starting now onwards.

Green building materials that can be reused are mostly found in green structures. There are also numerous criteria in green buildings for energy conservation, such as solar panels, fly-ash & silica fume cement and blocks, and so on. We can save energy and costs by utilizing this green building concept

(Tathagat and Dod, 2015). However, in Sri Lanka, the concept of green building is not commonly recognized. They primarily use conventional building methods due to a lack of understanding, lack of awareness, ineffective procurement systems and lack of trained professionals. People only examine the project's initial cost rather than the whole cost across its entire life cycle (Tathagat and Dod, 2015). By using sustainable development in construction industry, it can support to overcome this energy crisis and economic crisis in Sri Lanka. So that cost saving through sustainable development is a current topic.

II. LITERATURE REVIEW

A. Sustainable Construction in Sri Lanka

Green building conception is not popular in Sri Lankan industry because of the inadequate knowledge and erroneous perception is the most important barriers to the dissemination of green construction concepts. Green buildings are thought to be more expensive and have a longer payback period are reasons to not popular this in Sri Lanka(Tathagat and Dod, 2015).

The green building concept is appropriate for Sri Lanka in the current situation due to several factors, including the net present value (NPV) of sense of efficacy and the incremental cost benefit ratio, which are two indexes that measure the benefits of green buildings across their entire life cycle and thus conclude that green buildings are economically feasible through case studies in countries such as China, Sicily, and India (Franzitta *et al.*, 2013; Liu, Guo and Hu, 2014; Tathagat and Dod, 2015). The broader sustainability goals won't be met by green buildings on their own. Local regulations must be met by local building standards. Sustainable real estate must also incorporate town planning, sanitation, and other important social infrastructure in India. As a result, we must expand the green construction concept to include sustainable towns and cities (Tathagat and Dod, 2015**).** Developing countries like China, Sicily, and India are doing this kind of research based on sustainable development. So, it is essential to do such research in a country like Sri Lanka to overcome this economic crisis as well as the energy crisis**.**

The foremost expert in Sri Lanka on green building principles and practices is the Green Building Council of Sri Lanka (GBCSL). The goal of GBCSL is to completely embrace sustainability as an avenue of safeguarding the long-term health of our motherland's nature, financial system, and social fabric through the implementation of green building techniques. The GREENSL Rating System for Current Buildings is a set of performance standards for approving the operation and upkeep of institutional and commercial buildings, as well as residential structures of all sizes, public as well as private (Anon., n.d.). In Sri Lankan practice, if a building is considered a green building, it should be certified according to GBCSL. Then in this study, one would select a university building that has been certified as a green building by GBCSL.

According to the above, there is an energy crisis in Sri Lanka, and the green building concept is a good match for Sri Lanka. To some extent, there is a cost barrier to adopting this green building concept. In this case, a cost-benefit analysis would be performed, considering the initial cost vs. LCC to determine how beneficial green building will be. Then in this research study, we aim to find out the cost analysis between conventional building and sustainable building.

B. Benefits of Green Building Concept

Since green buildings are more energy-efficient, emit fewer greenhouse gas emissions, generate less waste, and enhance tenant efficiency and health, they also guarantee greater tenant satisfaction and lower absenteeism rates. (Simpeh and Smallwood, 2018). Energy consumption can be reduced through energy efficiency and other green building design techniques because it is a large and well-known expense of building operations. (Kats, 2003). Better thermal conditions; increased occupant satisfaction and less new power plants and transmission lines are being built (Waidyasekara and Fernando, 2012). Limiting heat gain is a key component of green architecture, especially when buildings are designed and oriented to make the most of daylight. (Shabrin and Kashem, 2017).

Enhanced tenant health and comfort through lowering Sick Building Syndrome are some of the social advantages associated with green building and in addition to being aesthetically pleasing. (Darko *et al.*, 2013). Sick-building syndrome (SBS) has become more prevalent. Despite the fact that objective physiological abnormalities are uncommon and persistent consequences are uncommon, SBS symptoms can be unpleasant, even crippling, and entire industries can be deemed non-functional (Ross, Ross and Asseiro, 1997). According to some studies, benefits include an increase in the market value of real estate, higher rents, fewer vacancies, and marketing opportunities as a result of social benefits, as well as a decrease in carbon taxes, an increase in energy savings, a decrease in sick days, and an increase in productivity both during and after construction. (Khoshbakht, Gou and Dupre, 2017). Theorize that the social and communal features of green construction create greater potential for local job generation. Because green building is a new industry, there will be plenty of opportunities available, and younger generations will be able to learn about and explore this industry. (Khoshbakht, Gou and Dupre, 2017).

As the number of employees working in green buildings increases, their better levels of satisfaction at work will encourage competitors in the sector to seek out similar environments. (Ashuri and Durmus-Pedini, 2010). These are some benefits that people can get from sustainable construction.

C. The Initial Cost and the Life Cycle Cost (LCC) in Sustainable Construction

Life cycle costing is a technique used in the built environment to calculate a building's predicted economic performance over the course of its whole life cycle, which includes construction, operations, design, maintenance, and disposal. Future building, the cost for operation and maintenance, as well as demolition costs, are approximately 3.6 times greater than structure's construction and design costs. The cost of energy, which is more than twice weight of both the construction and design cost, accounts for 48 percent of the overall life cycle cost of the building. As a result, the most influential aspect in lowering the overall life cycle cost of both the analysed sustainable buildings was determined to be reducing energy use. Construction and design costs, operation costs, maintenance costs, and final costs are the four key categories of building life cycle costs. Concepts and definitions, development and design, manufacture and install, maintenance, and demolish are the five primary phases of a product's or system's life cycle. These successive phases also make up the entirety of a life cycle of a building (Dwaikat and Ali, 2018).

Organizations employ a cost-benefit analysis as a methodical approach to decide which actions to take and which to avoid. The possible benefits of a scenario are added up, and then the overall costs of taking that action are subtracted. Some consultants use models to assign monetary values to crucial elements like the benefits and costs of living in a specific location (Fals-Stewart, Yates and Klostermann, 2005). Especially green buildings have future benefits by saving cost as follows.
It is discovered that while the client must make a higher financial initial investment in contemporary technology, such investment yields monthly benefits in the form of utility bill savings as compared to the conventional building
(Kim, Greene and Kim, 2014).The overall financial advantages of sustainable buildings exceed the average initial investment needed to construct a sustainable construction. Cost saving by energy savings on its own exceeds its average additional costs in sustainable construction, proving that green building is cost-effective and makes financial sense(Kats, 2003).Sustainable construction saves energy, cuts costs and also provides social and environmental advantages throughout the whole construction industry(Abeynayake, 2010).

Recent studies have investigated the effects of green building practices on construction projects. One could compare green and conventional buildings in terms of the variables affecting LCC and construction parameters. The study pertinent to factors influencing LCC of green buildings and cost comparisons of green and conventional buildings is assessed to discover comparable green and conventional buildings.

A shorter payback period due to decreased energy, water, and health costs, as well as a quicker return on investment and improved revenue, are all clear economic advantages of green buildings. Second, there is a decrease in running expenses because of green buildings using less energy, water, and maintaining their structures for less money. Third, because of the potential for higher rents and better occupancy rates, green buildings are more valuable than non-green ones. (Tathagat and Dod, 2015)(Khoshbakht, Gou and Dupre, 2017; MacNaughton *et al.*, 2018).

They claim that lower running costs, the development, growth, and structure of markets for green goods and services, better occupant productivity, and enhanced longterm economic performance are all economic advantages of green construction. (Darko *et al.*, 2013). Due to variations in green cost premiums with different building types (industrial buildings, residential buildings, and commercial buildings), inadequate methods used to assess the green cost premium, and a lack of running cost information for green buildings, the current study evaluates the LCC of a conventional building (a university) with a similar type of green building. (Weerasinghe and Ramachandra, 2018). Green buildings are more expensive to construct than conventional ones by 37%, but they have lower operating, maintenance, and end-of-life expenses, saving 28%, 22%, and 11%, respectively. (Weerasinghe and Ramachandra, 2018).
Green buildings are generally regarded to be much more expensive than traditional buildings, and the increased expense is often not justified when comparing the costs of sustainable architecture to conventional building. The New York Times ran an article with the heading "Not Building Green Is Called a Matter of Economics" in the beginning of 2003.(Kats, 2003).

III. METHODOLOGY

The main objective of this study is to analyses the cost of green building construction and non-green building construction in Sri Lanka. It takes into consideration choosing two university buildings to complete the research. The first one is a green building (X), while the second one is non-green building (Y). To ascertain how advantageous green building will be in this situation, a cost-benefit analysis was carried out, accounting for the initial cost in comparison to LCC. The research is fully assessed through an interview with the concerned authorities and selected site visits. This was a combination of both quantitative and qualitative analysis.

A. Data Collection Methods

Data was gathered from the professional groups in the two buildings that we selected through case studies and interviews. Site visits to the chosen buildings were used for the interviews and for other observations. It interviewed both quantitative and qualitative data during the site visits. The time frame for data collection is three years from the start date to both projects to get them in to common ground.

Initial costs could include capital expenditures for buying land, building it, renovating it, and buying the tools necessary to do the construction work. cost including provisional sum, preambles, prime cost sum, day works and measured works. (Fuller, 2006). In the LCC it considered initial cost and recurring costs in the project.

Recurring cost could include,

- The building operating costs - According to the International Standard ISO 15686-5:2008 (Darko *et al.*, 2013) may consist of electricity costs, taxes, rent, insurance, cyclical regulatory costs, insurance, and other running costs. (Weerasinghe and Ramachandra, 2018)

- Maintenance cost - Building maintenance refers to all tasks necessary to keep the building structure and its components functioning in a way that meets the minimum performance standards. It also includes all tasks necessary to maintain and protect the building structure. The maintenance cost is the total amount of labor, materials, and other costs incurred in connection with certain duties and operations. (MacNaughton *et al.*, 2018; Weerasinghe and Ramachandra, 2018)

- Sewerage service cost - The total of a basic price based on the yearly cost of the commercial property plus an excess charge depending on average water usage above 100 cubic meters is the sewerage service charge. (Rybka, BondarNowakowska and Polonski, 2016).

- Energy cost – Energy expenses are frequently challenging to forecast precisely during the design process. Assumptions must be made regarding use patterns, occupancy rates, and timetables, all of which have an impact on energy usage. During the initial design phase, engineering analysis can provide information on a building's energy use. (Fuller, 2006)

Both quantitative and qualitative analyses were used in this study. And below shows the specific analysis data in both ways. Quantitative data considers project initial cost and building recurring cost data. To collect that data, questionnaires were distributed among occupants and professionals (QS, ENG, and Project Managers). In here it used purposive sampling technique

B. Data Analysis Methods

When analysing qualitative data analysis was done with the use of comprehensive data analysis through interviews. The result was getting by doing a comparison of qualitative data between green building (X) and non-green building (Y). When analysing quantitative data, it considers the initial cost data of the project and the recurring cost of the project. Then do LCC analysis for both projects (projects X and Y). By making comparison between initial cost and LCC for both projects and identify the long-term benefits and do a cost benefit analysis. Tables and charts were used to make the presentation. The Microsoft Office package is used to LCC cost comparison and for the cost benefit analysis.

IV. RESULTS AND DISCUSSION

Here, it considers selecting two university buildings, the first of which is a green building (X), and the second of which is a non-green building (Y). We obtained the information needed on a site visit to the chosen building. Professionals got distributed questionnaires to collect that data (QS, ENG, Project manager, etc.). Purposive sampling was used in this instance. Three years from the start date is the time frame for data gathering. During the site visit, the initial and recurring costs of both projects were collected for the LCC analysis.

Table 1: Cost data of project (X) and (Y) in Rupees

Cost	Green Building (X)	Non-Green Building (Y)
Initial Cost	120,000,000.00	98,187,476.00
Maintenance General Team maintenance	150,000.00 421,000.00	403,819.00 719,000.00

Services Security Telecommunication	550,000.00 175,000.00	679,000.00 348,000.00
Operational Electricity Water Sewerage	270,000.00 75,000.00 58,000.00	1,197,350.00 415,460.00 100,600.00
Other Gardening Cleaning	180,000.00 210,000.00	316,600.00 395,000.00

A. Initial Cost Adjustment

A cost adjustment for the project's initial cost was made to make projects (X) and (Y) in common ground. The time, scale, and location of the projects are taken into consideration for this cost adjustment. Consider time, scope, and location adjustment here. Both projects were completed in 2019. Then there is no need for a time adjustment. Both projects are university buildings with the same scope. Then there was no need for a scope adjustment. When considering location adjustment, project (Y) is in the Matara district, while project (X) is in Colombo. Then it is required to make a location adjustment. In llocation adjustment, it takes labour, plant, and material costs into consideration while adjusting location.

When considering material costs, compared to Colombo, Matara has greater material costs. Because Colombo has better transportation infrastructure and more nearby manufacturing facilities for materials than Matara. Materials are more readily available in Colombo than in Matara, and it costs more to transport materials there as well. Then it increases by 4% of the cost of material in Matara. In comparison to Matara, Colombo has more ongoing construction projects. Then the competition for both skilled and unskilled labor is great in Colombo. So, Colombo has greater labor costs than Matara. Then it decreases by 1% of the cost of labor in Matara. Plants are more readily available in Colombo than Matara due to the city's numerous ongoing construction projects and excellent transportation infrastructure. When compared to Matara, Colombo's plant costs are lower. Then it increases by 4% of the cost of the plant in Matara. The percentages for cost adjustment were taken by referring to the CIDA Bulletin 2022. When considering the above facts, there is an overall 7% cost incensement on the project (Y).

$$\text{Scope adjustment} = \text{Current Initial Cost} \times \text{Cost Increment } \%$$

Equation 1 : Scope Adjustment

98,187,476.00*107/100 = 105,060,600.00

Then it takes the cost of project (Y) as, Rs. 105,060,600.00 after the cost adjustment.

B. Life Cycle Cost Analysis

In contrast to the "Net Percent Value," which is the overall percent day worth of an impending cash flow discounted at a given interest rate, the "Percent Value" refers to the percent day worth of a future cost discounted at a particular interest rate.

$$\text{Percent Value} = \frac{1}{(1+i)^n}$$

Equation 2: Percent value

Annual Equivalent Value – this is used to compare options with a consistent annual spend.

$$\text{Annual Equivalent Value} = \frac{(1+i)^n - 1}{i(1+i)^n}$$

Equation 3: Annual equivalent value The

equations where represents, n = Number of

Years

i = Rate of return

Interest rates were determined by consulting the annual report from Sri Lanka's central bank for 2021. That indicated a 6% interest rate. For both projects we do LCC analysis for 20 years from the completed year.

1) Project (X) – Green Building Project:
Maintenance and other costs are incurred annually for project (X), while services are incurred every 10 years and operating costs every 5 years as per the data gathered by site visits & project document reviews.

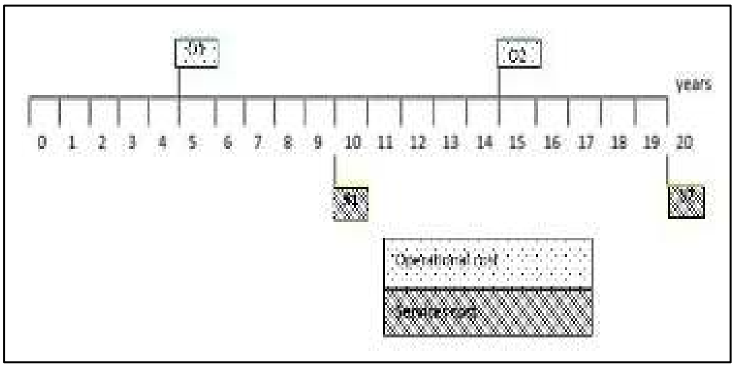

Figure 1: Recurring cost with time duration in project X

Through the interviews with the green building professionals, interviewees said that they were able to reduce their electrical costs due to the solar panels, and even though the initial cost for solar panels was high, the LCC cost was reduced due to the solar system. They said that they used a rainwater harvesting system and used rainwater for non-portable uses, such as gardening, they would receive a lower monthly water expense payment. They said that they utilized natural ventilation, which resulted in a reduction in A/C consumption and lower electricity costs.

Table 2: LCC analysis of project (X)

Cost Items	Period	Rate	Cost	Total Amount
Initial Cost				120,000,000.00
Maintenance	Annual	11.47	571,000.00	6,549,370.00
Services	10 yrs 20 yrs	0.55 0.31	725,000.00	404,550.00 226,200.00
Operational	05 yrs 15 yrs	0.74 0.41	403,000.00	301,041.00 168,051.00
Other	Annual	11.47	390,000.00	4,473,300.00
Total				132,122,512.00

2) Project (Y) – Non-Green Building Project:

In project (Y), services are provided every 5 years, while maintenance and other costs are incurred annually, and operational costs are incurred every 3 years as per the data gathered by site visits & project document reviews.

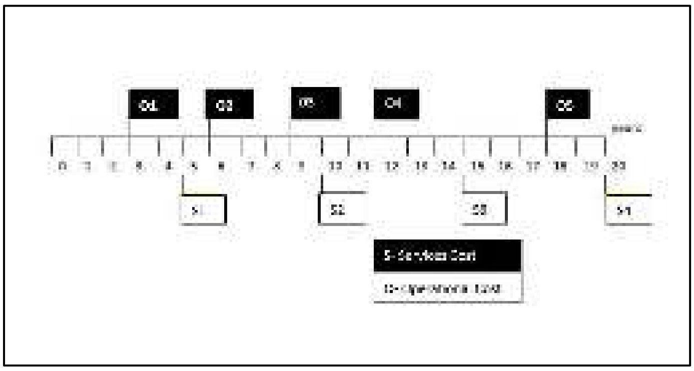

Figure 2: Recurring cost with time duration in project Y

Through the interviews with the non-green building professionals, interviewees said that they did not use the Solar system due to its higher initial cost and that they employed A/C equipment in both the computer laboratories and the classrooms. They then received a large monthly electricity bill. Furthermore, Interviewees said that on the structure, there are cracks and breaks. It therefore requires additional general maintenance, which incurs additional costs.

Table 3: LCC analysis of project (Y)

Cost Items	Period	Rate	Cost	Total Amount
Initial Cost				105,060,600.00
Maintenance	Annual	11.47	1,122,819.00	
Services	5 yrs 10 yrs 15 yrs 20 yrs	0.74 0.55 0.41 0.31	1,027,000.00	767,169.00 573,066.00 428,259.00 320,424.00
Operational	3 yrs 6 yrs 9 yrs 12 yrs 18 yrs	0.83 0.70 0.59 0.49 0.35	1,713,410.00	1,437,550.99 1,206,240.64 1,012,625.31 851,564.77 599,693.50
Other	Annual	11.47	711,600.00	8,162,052.00
Total				133,297,979.00

As a summary, initial cost and life cycle cost of projects can be shown as follows.

Table 4: Summary of initial cost and LCC in project (X) and (Y)

	Green Building (X)	Non-Green Building (Y)
Initial cost	120,000,000.00	105,060,600.00
LCC	132,122,512.00	133,297,979.14

Here, the initial cost of green construction is greater than that of non-green construction. However, using green equipment reduces the long-term cost of green building. Then green construction is cost effective in long run.

IV.CONCLUSION

In here it takes consideration about initial cost and recurring cost of two university buildings. One is green building (X), and other one is non green building(Y). the professional groups within the two buildings were interviewed to gather data. When collecting data, it was difficult to find quantitative data because of their high confidentiality. As well as the two projects were in different locations, and we had to do cost modifications to take the initial costs of projects in a common ground. By comparing the initial costs and LCC for both projects determining the long-term advantages and doing a cost benefit analysis. In here the initial cost of project (X) is higher than the project (Y). But when considering 20 years of LCC, the LCC of project (X) is lower than project (Y). Then as a conclusion, even though the initial cost of green building is greater than the nongreen building, when it considering LCC including recurring costs in long time, green building is more profitable than non-green building. According to these points there are several advantages to green buildings over their whole life cycle. Therefore, Sri Lanka could apply the green construction concept to eventually get out of its current energy and economic crisis.

V.RECOMMENDATION

With its present energy and economic crises, Sri Lanka can benefit from the sustainable building concept. Sustainable constructions are more energy-efficient, have a shorter payback time because of fewer utility bills, water, and health expenses, as well as a quicker return upon investment and higher income. Even though green building concept is beneficial, local industry is not use it widely because of lack of knowledge as well as ability of traditional working. Then, it is advised to create educational programs and training workshops regarding the advantages of green building and green building techniques for those who work in the industry. There is more possibility for local employment creation with green building. Due to the growing industry of "Green Building," there will be plenty of jobs accessible. To promote this green building idea, the industry also needs to hire more green professionals. The theory of green building must be explained to clients by building professionals & promote with the potential benefits which can give positive outcomes on economic, social & environment.

VI. FUTURE RESEARCH DIRECTIONS

Future studies can be conducted to determine reasons other than cost why sustainable construction is not widely used in Sri Lanka and to investigate the advantages the Sri Lankan construction industry gains from implementing sustainable construction, even though this research focuses on the costbenefit analysis between sustainable construction and nongreen projects.

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ABBREVIATIONS

LCC – Life Cycle Cost
QS – Quantity Surveyor
ENG – Engineer
SBD – Sick Building Syndrome
GBCSL - Green Building Council of Sri Lanka
WBCSD - World Business Council for Sustainable Development

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