Study of Sustainable Building Based On Life Cycle Cost

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Abstract—*With the economic development, energy consumption is increasingly serious, land resources becoming scarcer and scarcer. Sustainable building can effectively solve the problem of resource shortage; however, the development of green buildings in India is very slow because of its higher cost, compared with conventional buildings. In this paper, the construction cost of sustainable building and traditional building based on life-cycle cost method is analyzed. Considering the cash flows the key factors that affect the cost are determined. The results indicate that there are three main factors which influence the cost of green building, such as construction technology, building materials prices and local conditions.*

Index Terms—Construction cost; sustainable or green building; life cycle cost analysis.

1. INTRODUCTION

What is a sustainable design?
It refers to structure and processes that are environmentally responsible and resource efficient throughout building's life cycle: from sitting to design, construction, operation, maintenance, renovation and demolition. This requires close operation of design team, the architects, the engineers and clients at all project stages. The sustainable or green building practice expands and compliments the classical building design concerns of economy, utility, durability and comfort [1].
What is LCCA?
Life Cycle Cost Analysis (LCCA) is an economic methodology for selecting the most cost-effective design alternative over a particular time frame. The methodology is beneficial as it addresses not only typical owner concerns of design effectiveness and construction cost, but also reflects future costs associated with maintenance, operation and replacement. LCCA looks at the value of a building or capital project over time, overcoming "first cost" limitations [2].

2. LITERATURE SURVEY

According to The Energy and Resources Institute,India is the seventh largest country in the world, is a leading economy. Construction plays a very important role in its economy contributing on an average 6.5% of the GDP. Commercial and residential sectors continue to be a major market for the construction industry. The sectors consume a lot of energy throughout the life cycle of buildings thus becoming a major contributor to greenhouse gas emissions.
An attempt shall be made to arrive at indicative costs of implementing various measures to assist in achieving:
(a) Zero-net emissions in new buildings by 2020 and 2030
(b) 30-80% reduction in emissions from existing buildings by 2020 and 2030
Melissa O'Mara while answering to the question why to invest in sustainable buildings mentioned that, The benefits of building green can be significant, but only if best practices are followed—not just at the design/build stage, but throughout the entire building life cycle. Owners can expect their sustainable buildings to enable better business outcomes, such as improved stock performance, increased asset value, and higher rental, occupancy, and tenant retention rates. Occupants can expect improved employee productivity and well-being, lower operating costs, reduced environmental impacts, improved public image, and fulfilment of corporate social responsibility goals [3].
According to Lisa Matthiessen, LCCA is not well understood by design professionals, as is a financial modelling tool. The financial sector is comfortable with uncertainty and the weaknesses of long-term estimates; it just needs a

transparent and honest process. Most design teams want a hard and fast answer, and as a result, many teams hesitate to use LCCA, or try to make the results seem more concrete than they really are [4].

3. OBJECTIVE

Objective of study is to perform life cycle cost analysisfor both sustainable buildings and traditional buildings, hence to suggest whether the investor should go for sustainable buildings or not.

4. METHODOLOGY

For project work, two buildings were selected from Dreams Elena, Solapur. This project is planned for four buildings and divided in two phases. Two buildings from first phase were selected out of one is planned as traditional building and another is sustainable building.

1. Literature review is performed for listing out data required for project work.
2. Data required like plans, sections, rate analysis, etc. were collected from site office.
3. Alternatives for waste water treatment, construction materials, energy efficiency, etc. selected.
4. Detailed analysis is performed for capital cost, operational and maintenance cost, etc.
5. By referring literature, collected data is used for life cycle cost analysis for various systems.
6. Based on life cycle cost calculated various systems are compared and best suitable option is selected for the project.

5. DATA COLLECTION

Data collected from both the sites is as given below:

1. Plan, Section of building
2. Rate analysis sheets.
3. Quantity estimates of material (Steel, Concrete, etc.)
4. Technical details of various systems used for sustainable building.

6. THEORETICAL CONTENT

Steps to an Effective LCCA:

Getting Started

The most important aspect in LCCA is identifying appropriate alternatives and establishing good cost data. The next task is comparing all the results and weighing them against available construction capital to make the most cost effective choice. Use the following steps to generate an effective LCCA. The earlier LCCA is used in the design process, the greater the potential net savings.

Step 1: Identify Alternatives

The types of alternatives considered depend on the creativity of the design and management teams. The alternatives should represent a wide range of solutions to the identified objectives. It is often helpful to use an interdisciplinary team during this stage to draw from a wide range of backgrounds, perspectives, and past experiences.

These alternatives can be single components or combination of components. Try and define at least three viable project alternatives for further study.

Step 2: Define Constant Parameters

The time period of the LCCA study is based on theinvestor's interests, preferences or organizational policy.

The base date of analysis is the year the analysis is carried out and all time periods start from this base date. Frequently used periods of analyses are 10-25 years for private sector; public sector owners may use as long as 50 years for their studies.

The project manager must also identify a discount rate for the studies that is held constant for all alternates.

Step 3: Identify Costs and Savings

There are typically two types of costs that must be estimated: non-recurring and recurring. Non-recurring costs appear as a lump sum cost in the present or at a fixed point in the future. An example of a non-recurring cost is the capital expenditure for a new high-efficiency chiller unit.

Recurring costs are paid out periodically over the lifetime of the facility. An example of a recurring cost is a capital cost that is spread out over periodic payments. Repair or maintenance costs that occur on a regular basis are also considered to be recurring costs. All costs are identified as negative cash flow.

Savings are expressed as positive cash flow, regardless of whether they occur one time only (e.g. a utility rebate), or if they occur on a regular recurring basis (e.g. a reduced annual energy bill).

Step 4: Generate LCCs for Each Alternative

Evaluate all project alternatives in a given category, using the same time period and the same discount rate.

Step 5: Perform a LCCA Comparison

Compare the net present value of each alternative and select the alternative or alternatives with the highest net present value. Compare the benefit to cost ratio of the best alternatives in each category to select the most cost-effective options that will fit into the project budget.

7. CASE STUDY

For the study two different buildings from the same project were studied, Dreams Elena, Solapur. In this project out of four wings two wings are selected out of which one is traditional building and another is planned as a sustainable building.

Table – 1: Life Cycle Cost Analysis of Different Alternatives

Sr. No.	Details	Case study I	Case study II
1	**Name of firm**	CCPL Solapur.	CCPL Solapur.
2	**Name of project**	Dreams Elena Wing-A	Dreams Elena Wing-B
3	**Type of project**	Residential	Residential

4	**Type of building**	Traditional	Sustainable
5	**Data collection for**	Wing A	Wing B
6	**Consultant hired**	CCPL Solapur.	CCPL Solapur.

8. DATA ANALYSIS AND FINDINGS FROM STUDY

For data analysis, total costs of two different buildings i.e. sustainable and traditional buildings were calculated.Also systems like roof mounted solar energy power plant, different sewage treatment plants are taken into consideration for their life cycle cost analysis. Some comparison made between various sewage treatment plants with considering their life cycle cost is shown below.

SBR - Sequencing batch reactors
UASB - Up-flow Anaerobic Sludge Bed
MBBR - Moving Bed Biofilm Reactor
ecoSTP - Eco Sewage Treatment Plant

Table – 2: Comparison of STP Based on Life Cycle Cost

Parameter	Unit	SBR	UASB	MBBR	EcoSTP
Average Area Required	acres/ MLD	0.13	0.26	0.13	0.13
Capital Cost	cr/ MLD	0.7	0.26	0.21	1.00
Biogas Generation	m3/d	-	312	-	-
Bio energy Generation*	kWh	-	187	-	-
Annual Power Cost	cr/ MLD	0.0312	0.0052	0.019	0.00
Annual O&M cost	cr/ MLD	0.6	0.203	0.6	0.05
Total Annual O&M cost	cr/ MLD	0.63	0.208	0.6	0.05
Average Land cost	Cr/ Acre	11	11	11	11
Cost of Land	cr/ MLD	1.43	2.86	1.43	1.43
Unit Capital Cost including land	cr/ MLD	2.13	3.12	1.64	2.43
Annual Interest	Percent	12	12	12	12
Economic Life	years	30	30	30	30
Capital Recovery Factor (CRF)		0.124	0.124	0.124	0.124
Total Annual cost	cr/ MLD	0.89	0.59	0.8	0.35
Present Discount Factor		8.06	8.06	8.06	8.06
Net Present Worth	cr/ MLD	7.17	4.75	6.44	0.5586
LCC for 30 years	cr/ MLD	214	142	193	16.76

In above table, life cycle cost analysis is performed for four different STP systems. While performing analysis all the costs i.e. capital cost, operational cost, maintenance cost, etc. taken into consideration. The results indicate that capital cost wise ecoSTP is a highest capital amongst all but in long run; here 30 years it is the cheapest technology to adopt.

In below table a sample example is given how above treatment costs can affect decision making while selecting any added facility for sustainable building.

Table – 3: Comparison of Alternatives

	Sewage Treatment Options (For per MLD)	STP Cost INR	Capital Cost of Traditi-onal Building INR	Capital cost (Building + STP) INR	LCC (STP) INR (30 yr)	(Buildig Cost +STP LCC) @ 30 yr INR
1	SBR	0.7 Cr	10 Cr	10.70 Cr	214 Cr	215.07 Cr
2	UASB	0.26 Cr	10 Cr	10.26 Cr	142 Cr	143.026 Cr
3	MBBR	0.21 Cr	10 Cr	10.21 Cr	193 Cr	194.021 Cr
4	Eco STP	1.0 Cr	10 Cr	11.00 Cr	16.76 Cr	26.76 Cr

In above table, the capital cost of building is the cost of traditional building and is considered as a base case. Then addition of capital cost of building and capital cost of STP is performed. Calculations show that MBBR system requires lowest capital cost. After that addition of capital cost of building and life cycle cost of STP is performed. These calculations indicate that at the end of 30 years ecoSTP is cheapest. Above calculations indicate that, life cycle cost analysis helps in decision making during investing in any technology.

When comparison of traditional building and building with such system which is necessary for sustainable building is done, traditional buildings may require comparatively lesser capital cost. But when such building is taken into consideration, it seems it require a bit higher capital cost but it has other environmental benefits, saving of cost required for disposal of waste through municipal systems, etc. Such increased cost is worth considering environmental benefits.

9. Conclusion

The benefits of sustainable building can be significant, but only if best practices are followed not just at the design/build stage, but throughout the entire building life cycle. Owners

can expect their sustainable buildings to enable better business outcomes, such as improved increased asset value, and higher rental and occupancy. Occupants can expect improved productivity and well-being, lower operating costs, reduced environmental impacts, improved public image.
Building owners, operators, and occupants who invest in high-performance sustainable buildings can realize triple bottom line benefits when they partner with innovative, collaborative companies that look at buildings holistically, are willing and eager to engage with all stakeholders early in the process, and employ design-for-performance principles.

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