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LIFE CYCLE COST ANALYSIS OF GREEN CONSTRUCTION SITES

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Abstract
Due to the tremendous growth of construction and infrastructure in most of the countries with the high shortage of raw materials, the various stakeholders are compelled to adopt Green technologies and management techniques for the project. Construction industry in India is considered to be one of the largest economic activities which is growing at an average rate of nearly ten percent as compared to the global average of five percent and contributes ten percent of Gross Domestic Product. Life Cycle Cost (LCC) provides a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operation related costs in the short run. Green building is a way of enhancing the environment, which benefits human wellbeing, community, environmental health, and life-cycle costs. It belongs to the concept of "sustainable development," which also serves as the driving force. An attempt has been made to analyze the life cycle cost of building construction site has been carried out in this research. The research outlines the various cost involved at various stages of project construction site and estimates the Savings to Investment Ratio (SIR). The study estimates Adjusted Internal rate of return (AIRR) of the Green project construction site with that of conventional site. The comparative results of this study between green project construction site and conventional site of similar scale highlighted the cost saving and advantages to the stake holder in adopting the green techniques.

Keywords
Life cycle cost, Green construction proejcts, AIRR, SIR

1. Introduction

Life Cycle Cost (LCC) provides a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operation related costs in the short run. Green building is a way of enhancing the environment, which benefits human wellbeing, community, environmental health, and life-cycle costs. It belongs to the concept of "sustainable development," which also serves as the driving force. The study on "Life Cycle Cost Analysis of Green Construction Sites" comprises of collecting information on the various types of costs that are likely to be incurred during the lifecycle of any project, which are then analyzed by suitable software that will enable calculation of the Life Cycle Cost of the projects considered.

LCC is an economic model over the project life span. Usually the cost of operation, maintenance and disposal costs exceed all other first costs many times over (supporting costs are often 2-20 times greater than the initial procurement costs). The best balance among cost elements is achieved when

the total LCC is minimized (Landers 1996). As with most engineering tools, LCC provides best results when both engineering art and science are merged with good judgment to build a sound business case for action.

Actual costs of sustainable building practice are not always as high as perceived (landman 1999).In many cases, initial costs of implementing green design can be lower than traditional practice, such as incorporating natural cooling through shading and ventilation in place of an air conditioning system, or eliminating the need for an irrigation system by planting native landscape (Lee et al, 2000). Additionally, an integrated design team using a whole-systems perspective may specify a combination of increased insulation, efficient lighting, and higher grade windows to allow downsizing the HVAC system, hence offsetting any additional capital costs associated with the upgrades (Schendler and Lane, 2002)

The acquisition cost of goods has historically been the key factor influencing procurement decisions, with future costs sometimes ignored. In reality however, the immediate costs may represent only a small component of the total costs incurred over the entire life of the procurement. In some cases, operating and maintenance costs may comprise the majority of total life cycle costs.

It is common for goods to have differing cost patterns or elements. For example, some goods may have a higher energy consumption rating, require a lower frequency of servicing or have more expensive costs associated with their disposal. LCC analysis identifies the pattern of these anticipated costs, enabling a more effective and informed procurement decision to be made.

Applying the LCC methodology allows procurement practitioners to:

- Forecast future costs
- Understand the factors that drive costs (including hidden costs
- Evaluate competing options when undertaking procurement
- Assess future resource requirements (i.e. Budget implications)
- Assess at which point a good will reach the end of its economic life
- Improve operational support for a good during its economic life

2. Methodology

The methodology adopted in this study involved extensive data collection that included the various components of cost in similar green and conventional construction project that were carried out at identical geographical and socio-economic location.

2.1 Collection of data

As mentioned earlier data collection comprised of two parts.

- Online survey – Questionnaire was uploaded in a website www.kwiksurvery.com and the corresponding link were emailed to various organizations for collection
- Collection of data through Project Management consultants – The printout of the questionnaire was circulated to various project managing consultants to collect relevant data for the analysis.

The questionnaire was divided into three major stages viz.,

- Investment Planning Stage
- Design and Construction Stage
- Commissioning Stage

Cost data for each of the cost elements in these stages were acquired with respect to five different components viz.

- Initial investment costs
- Operation costs
- Maintenance costs
- Repair costs
- Facility costs

Table 1: Cost at various stages of construction (in INR)

Cost activity	Investment Planning				
	1*	**2***	**3***	**4***	**5***
Land Acquisition	250000000	N/A	N/A	N/A	N/A
Financial interest or cost of money and cost management	550000000	N/A	N/A	N/A	N/A
Site investigation	300000000	10000000	N/A	N/A	N/A
Brownfield redevelopment and stabilization	120000000	3000000	1000000	N/A	2200000
Innovative technology & Equipment	10000000	1000000	N/A	500000	1500000
Development of clean vegetation equivalent of building footprint	N/A	N/A	150000	N/A	100000
Provision of shade and open grid pavement system for parking area	N/A	N/A	50000	50000	N/A
Cost activity	**Design and construction Stage**				
Construction management & design to meet standards, ASHRAE & local energy code	10000000	N/A	N/A	N/A	N/A
Innovative architectural design	5000000	N/A	N/A	N/A	N/A
Development of structure	40000000		500000	N/A	N/A
Construction waste management and recycling	3000000	300000	450000	N/A	300000
Local and renewable materials	N/A	N/A	100000	N/A	N/A
Storage of materials	N/A	N/A	100000	N/A	N/A
Transportation facilities	1000000	200000	50000	N/A	300000
Water efficient plumbing fixtures for soft water and sewerage	2700000	400000	100000	N/A	N/A
Solar external lighting	5000000	350000	200000	N/A	N/A
CO2 &airflow measurement equipment	N/A		N/A	N/A	
Fire protection and special electric systems	25000000	500000	200000	N/A	500000
Motors and Pumps	5000000	200000	150000	40000	50000
Communication, electricity and other utility lines	37000000	2100000	150000	N/A	N/A

Labor charges	450000	1000000	N/A	N/A	N/A
Cleaning & House keeping	N/A	200000	N/A	N/A	50000
Interior decoration	40000000	N/A	500000	N/A	N/A
Rainwater harvesting & storm water set up	4000000	250000	100000	N/A	N/A
Cost activity	**Commissioning stage**				
Permits & legal cost for handing over & commissioning	2000000	N/A	N/A	N/A	N/A
Green and clean cost	500000	250000	50000	N/A	100000
Site and land clearance and clean up	2500000	500000	N/A	N/A	N/A

**1, 2, 3, 4, 5 corresponds to Initial investment, Operation, Maintenance, Repair and Facility costs*

A cost matrix presented created based on the questionnaire survey was prepared using the relevant cost components that contributed to each activity.

2.2 Data Analysis

The criteria used for the economic analysis was descriptive methodology. Life Cycle Cost Analysis was used as the evaluation method. Present value (PV) of the base date was used as the discounting approach. The total study period (planning, construction and maintenance) was assumed to be 6 years. Different types of costs were grouped in the following order ant the PV value for each type of costs was calculated.

The various types of costs were grouped as:

- Onetime costs (Non recurring costs) – Costs which will occur only once. E.g.: Initial investment cost, Resale value
- Annually recurring fixed costs – Costs which will occur regularly (annually or monthly) by a specific amount. E.g.: Operation costs, Maintenance costs, Repair costs
- Annually recurring escalating costs – Costs which will occur regularly but with different amounts. E.g.: Facility costs

The factors adopted for the calculation of present value were

- Nominal discount rate (D) which was taken as 16% based on the statistics from the Banking Companies.
- Nominal escalation rate (E) which is taken as 12% based on the statistics from Economic Survey of India, published by Government of India
- Inflation rate (I) $inflation\ rate = \frac{P_0 - P_{-1}}{P_{-1}} X100$ [1]

Where P_0 is the current average price level and P_{-1} is the price level a year ago

Based on the purchasing power of unit Indian Rupee, the inflation rate for analysis was assumed as 9.6% and the real discount rate (d), real escalation rate (e), Single Present Value (SPV), Uniform annually recurring present value factor (UPV), Non uniform annually recurring present value factor (NUPV) were computed based on equations 2 to 7.

$$d = \frac{1+D}{1+I} - 1 \qquad [2]$$

$$e = \frac{1+E}{1+I} - 1 \quad [3]$$

$$SPV = \frac{1}{(1+d)^t} \quad [4]$$

$$UPV = \frac{(1+d)^t - 1}{d(1+d)^t} \quad [5]$$

$$NUPV = \left(\frac{1+e}{d-e}\right)\left(1 - \frac{(1+e)}{1+d}\right)^t \quad [6]$$

Where t = no. of years
Based on the above the PV factors, costs of each type at every year were calculated and the "Present Value of Life Cycle Cost" was calculated for each year.
The cost effectiveness of the project was then calculated by using the Adjusted Internal Rate of Return (AIRR)

$$AIRR = (1 + r)(SIR)^{\frac{1}{n}} - 1 \quad [7]$$

$$SIR = \frac{Savings}{Additional\ Investment} \quad [8]$$

Where,

r = the reinvestment rate
n = Number of years in the study period
SIR = Savings to investment ratio

Based on the equation [7] conclusion was drawn that if the AIRR value is greater than the Discount rate, then the project is cost effective.

2.3 Methodology of Life Cycle Costing

The four key steps involved in the calculation of life cycle costs of a proposed procurement are to:

- Develop a plan
- Identify the cost elements
- Create a cost structure
- Analyze the future costs

Each procurement or project will have its own unique features and the level of complexity of each LCC plan which should be customized to suit the particular circumstances of the procurement. Development of plan in LCC analysis is commensurate with the value and complexity of the goods being procured. This LCC plan will, amongst other considerations.

- Define the expected outputs and outcomes of the proposed LCC analysis
- Delineate the scope of the proposed LCC analysis
- Identify any underlying conditions, assumptions, limitations or constraints.

LCC plan for the green site under consideration must be adopted and be investigated thoroughly. Identification of the cost elements involves five cost categories in any life cycle cost analysis, each comprising individual cost elements viz.

- Acquisition costs
- Lifetime operating costs
- Lifetime maintenance
- Disposal
- Residual

Each cost element was clearly defined, with an estimated value, for defined number of years in which the costs are expected to occur. The amount of time spent on estimating the cost and frequency should be commensurate with the size, risk and complexity of the proposed procurement.

Procurement related costs are generally incurred over the defined life of the project site, which was taken as 7 years based on the planned duration of the project. While the majority of acquisition costs are generally incurred in initial period, operating and maintenance costs were usually extended to future. Discounting future costs to an NPV provided meaningful comparison of competing purchase options with different future cost profiles. Based on the rule of thumb, the discount rate is adopted as combination of the current long-term expected interest rate minus the current long term expected inflation rate. However, it is important that specialist financial advice be sought before a particular discount rate is adopted. The relevant agency assigned Account Manager from the Finance Branch, Department of Treasury and Finance can provide an indication of the appropriate discount rate applicable for the period being considered.

3. Results and Discussions

The cumulative savings and Cumulative additional investment was then calculated to evaluate the cost effectiveness of green construction sites. Based on SIR values the Adjusted Internal Rate of Return (AIRR) values were calculated with rate of re investment(r) as 6%, for a period of 6 years. The results thus obtained are presented in Table 2.

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
AIRR (%)	6.1	-7.2	4.45	12.5	18.9	23.7	28.2

Table 2 – AIRR variation with time

Based on the results it is evident that for the construction duration of 6 years, the AIRR obtained is 28.2 % which is higher than the annual discount rate of 5.85% which was prevailing the country.

Present value of cash flow of conventional site to green construction site for comparing the LCC of the two different projects. The Figure 1 indicates the variation of ratio of fife cycle cost to Initial investment cost of green project to conventional project over the life of the construction site. The figure indicates that LCC to investment cost ratio is higher for Green construction project compared to the convention al projects. The analysis of variation of AIRR with respect to time presented in Figure 2 indicates that for the project the optimum duration for completion is three years.

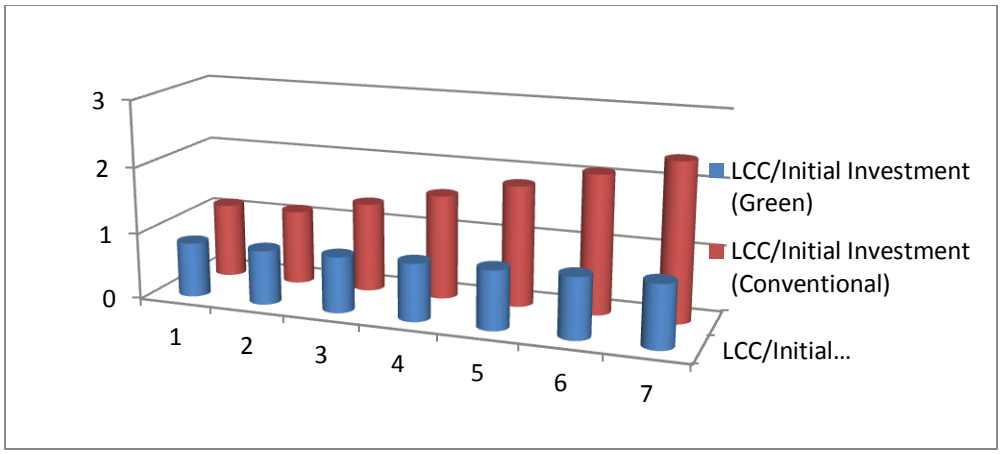

Figure 1 Variation of LCC/ investment cost

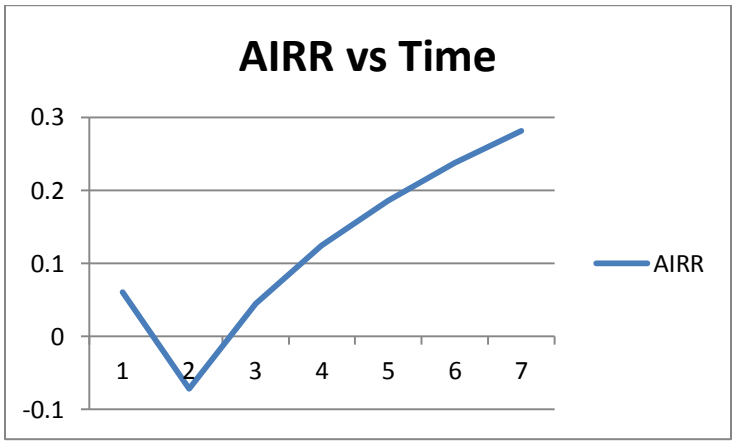

Figure 2 Variation of AIRR with respect to duration of project

4. Conclusion

The study emphasizes the life cycle cost of Green construction sites with emphasis to various stake holders of the project site. The benefits of Adopting "Green concept" can be experienced by all the three parties i.e. client, contractor and customer, although further research is required to state a firm conclusion on the health and safety aspects of "Going Green" concept.

Life Cycle Cost of the project site provided a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on first costs or on operation related costs in the short run. The various components of life cycle cost were analyzed at various stages of construction and a comparative study was carried out with conventional sites to determine the effectiveness of Green construction. This study derived the cost effectiveness and ratio of LCC to Initial Investment cost of green and conventional building site of similar scale and similar socio economic parameters and evaluated the benefit of going green concept to contractors. The real time cost involved at various stages in project construction site was utilized to estimate the Savings to Investment Ratio (SIR). The study estimated Adjusted Internal rate of return of the Green project construction site with that of conventional site. The comparative results of this study between green project construction site and conventional site of similar scale highlighted the cost saving and advantages to the stake holder in adopting the green techniques.

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