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An Analytical Approach on Life Cycle Cost Analysis of a Green Building

Sreeparvathy CM⁽¹⁾, Chitturi Sravanti⁽²⁾

Assistant Professor, Department of Civil Engineering, Mahatma Gandhi Institute of Technology,
Hyderabad, India

ABSTRACT: Cost effectiveness plays a very significant role in any construction sector. Life cycle cost analysis is the most cost effective option among different competing alternatives in the construction industry to consider future running costs associated with a building. Improper understanding of application of life cycle costing is considered one of the hindrances to construction industry. This research demonstrates to develop a life cycle budget for the whole life of a green building for 80 years by using life cycle costing technique. It is shown that future costs are 5.7% higher than the design and construction cost. Among total life cycle budget 67% constitutes the energy cost. Comparison between the existing condition of solar panels and the suggested solar panels are studied. And it is found that implementing monocrystalline solar panels of 370wp reduces its total life cycle cost by 5%.

KEYWORDS: Construction sector, Life cycle costing, Green buildings, Net present value, Solar panels.

1. INTRODUCTION

Now a days, construction industry is mainly focusing on the initial construction costs rather than future running costs. Engineers and contractors are under pressure to decrease the initial cost in order to satisfy the clients. This leads to the increase in operational and maintenance costs. Improper understanding of life cycle costing technique and its application is also considered as the key barriers in construction industry. Life cycle costing technique is a useful tool for projecting future costs using present data.

Life cycle cost (LCC) analysis was originally conducted by the U.S Department of Defense in the mid-1960s for investment purposes. LCC conducted for the U.S Department of defense was shown by the fact that the operational costs regarding the weapon systems, was 75% of the total life cycle costs. Life cycle cost analysis is the total cost associated with initial cost, operational cost, maintenance cost and disposal cost. Where, initial cost refers to land acquisition, design and construction cost. Operational cost refers to the building energy, water, sewerage costs. Maintenance cost refers to the management team, lighting, air-conditioning, cleaning etc. LCC was later applied in automobile and engineering sector.

From the previous studies N. Kale et.al (2015) discussed different economic evaluation methods to calculate LCC and comparison of these methods had been carried out. He concluded that Net Present value method is the most appropriate method. David Elmakiset.al (2006) in his study analyzed the reasons behind the contradiction between the great theoretical achievements and their relatively rare applications in practice. Byron A. Ellis (2019) in his research analyzed the LCC technique for evaluating the total cost of ownership between mutually exclusive alternatives. Schade (2014) in his study discussed structural overview of theoretical economic methods for LCC analysis.

In this research process to develop life cycle cost budget for whole life of a green building by using life cycle costing technique as per Indian standards is discussed. Comparison of the existing condition and the suggested alternatives after developing life cycle cost budget is evaluated. Inflation/deflation rate is defined as the rise/fall in the general prices of goods and services. According to the World Bank data, the average inflation rate as per consumer price index is 4.9% is used for estimating future life cycle cost.

1.1 Case study description

The case study analyzed in this paper is one of the educational buildings in KoneruLakshmaiah Education Foundation (KLEF) in Andhra Pradesh. This educational building is a seven-storey green building with a gross area of 18,395 m². The built-up area of the building is 17,399 m². Green technologies adopted in this building are Radiant cooling system, Heating Ventilating and Air conditioning (HVAC), solar panels of 0.3kwp capacity, wind mills, ground water technique, double-glazed glass. Construction of this building is started in year 2010 and completed in year 2015. Building is commenced from 2016.



II. METHODOLOGY

2.1 Life Cycle Costing Technique:

Life cycle cost analysis (LCCA) is a economic method which is used to evaluate the total cost associated with the building design and construction, building operation, building operation and building deconstruction cost. LCCA is done to project future costs over time with the long-term investment of ownership by using present value. The average inflation rate in India according to world bank data is 4.9%. Change in cost by using inflation rate can be calculated by using the below equation:

$$FV = PV * (1+i)^n$$

Where, FV = Future value
 PV = Present value
 i = inflation rate
 n = number of years

The analysis for the case study covers a period of 80 years starting from construction date 2010 to building disposal 2089.

2.2 Building initial cost:

Initial cost includes building design and construction cost. The building construction was started in the year 2010 and completed in 2015 and building commenced in the year 2016. Since we want to develop total life cycle cost budget in our analysis we have to consider building design and construction cost. The estimated construction cost for the building was INR2,450/square feet and the design cost estimated by our design team was Rs.4/square feet for structural and Rs.3/square feet for architectural. Hence the total design and construction cost was INR46,01,49,417.

2.3 Building operating cost:

Building operating cost includes energy, water consumption and sewerage costs for the case study considered. Implementing life cycle costing technique for the above costs determines the future operating costs for the total life cycle of building.

2.3.1 Energy cost:

The total estimated energy consumption during the operating year 2016 is 1198480 kwh/year based on 72 working hours in a week. According to Andhra Pradesh electricity regulatory commission (APEREC) the electricity price tariff INR6.90/kwh.

Total annual energy cost in 2016 = INR82.69512 lakhs/year (base year)
 Annual energy cost for each year can be determined by using equation (1)

Table 2.1 Estimated life cycle energy cost:

Year	Annual energy cost	Year	Annual energy cost	Year	Annual energy cost	Year	Annual energy cost
2016	82.691	2035	205.217	2054	509.270	2073	1263.813
2017	86.747	2036	215.273	2055	534.224	2074	1325.740
2018	90.997	2037	225.821	2056	560.401	2075	1390.701
2019	95.456	2038	236.886	2057	587.861	2076	1458.845
2020	100.134	2039	248.494	2058	616.666	2077	1530.328
2021	105.040	2040	260.670	2059	646.883	2078	1605.315
2022	110.187	2041	273.443	2060	678.580	2079	1683.975
2023	115.586	2042	286.841	2061	711.830	2080	1766.490
2024	121.250	2043	300.897	2062	746.710	2081	1853.048
2025	127.191	2044	315.641	2063	783.299	2082	1943.847
2026	133.424	2045	331.107	2064	821.681	2083	2039.096
2027	139.962	2046	347.331	2065	861.943	2084	2139.011
2028	146.820	2047	364.351	2066	904.178	2085	2243.823



2029	154.014	2048	382.204	2067	948.483	2086	2353.770
2030	161.561	2049	400.932	2068	994.959	2087	2469.105
2031	169.477	2050	420.577	2069	1043.71	2088	2590.091
2032	177.782	2051	441.186	2070	1094.85	2089	2717.006
2033	186.493	2052	462.804	2071	1148.50		
2034	195.631	2053	485.481	2072	1204.77		

Total energy life cycle cost = INR56478.44 lakhs.

2.3.2 Water cost:

The total water consumption in the building is 10,800m³/year. The water cost in this analysis is negligible as the entire water consumption of the building is based on ground water and there will be no charge collected for the ground water. Hence water cost in this analysis is not considered as it does not affect the life cycle budget.

2.3.3 Sewerage cost:

All the sewage collected from the building is treated in their own Sewage treatment plant (STP) established in the University as the STP is constructed for the entire university. Hence sewerage cost is also neglected as it does not effect the life cycle budget of the case study.

2.4 Building maintenance cost:

Building maintenance cost includes air conditioning, maintenance service budget, fire fighting, lighting, management, cleaning and security. Building maintenance cost is limited to building management, cleaning and security costs for the base year as there will be no other maintenance charges during commissioned year 2016.

Maintenance service budget = INR 5 lakhs/year

Air conditioning = INR 9.44 lakhs/year

Fire fighting = INR4.28 lakhs/year

Lighting = INR 1.2 lakhs/year

Management team = INR2.88 lakhs/year

Cleaning and security = INR4 lakhs/year

Total annual maintenance cost = INR 26.8 lakhs/year

By implementing life cycle costing technique future costs are determined by using equation (1)

Table 2.2: Estimated life cycle maintenance cost:

Year	Annual maintenance cost	Year	Annual maintenance cost	Year	Annual maintenance cost	Year	Annual maintenance cost
2016	6.880	2035	66.507	2054	165.045	2073	409.578
2017	28.113	2036	69.766	2055	173.132	2074	429.648
2018	29.490	2037	73.184	2056	181.616	2075	450.701
2019	30.935	2038	76.770	2057	190.515	2076	472.785
2020	32.451	2039	80.532	2058	199.850	2077	495.951
2021	34.041	2040	84.478	2059	209.643	2078	520.253
2022	35.709	2041	88.618	2060	219.915	2079	545.746
2023	37.459	2042	92.960	2061	230.691	2080	572.487
2024	39.295	2043	97.515	2062	241.995	2081	600.539
2025	41.220	2044	102.293	2063	253.853	2082	629.965
2026	43.240	2045	107.306	2064	266.292	2083	660.539
2027	45.359	2046	112.564	2065	279.340	2084	693.215
2028	47.581	2047	118.079	2066	293.028	2085	727.182
2029	49.913	2048	123.865	2067	307.386	2086	762.814
2030	52.359	2049	129.934	2068	322.448	2087	800.192
2031	54.924	2050	136.301	2069	338.248	2088	839.401



2032	57.615	2051	142.980	2070	354.822	2089	880.532
2033	60.439	2052	149.986	2071	372.208		
2034	63.400	2053	157.335	2072	390.447		

Total maintenance life cycle cost = INR18283.73 lakhs

2.5 Building deconstruction cost:

Building deconstruction cost is the cost associated with the building at the end of its service life. It also includes the disposal of waste generated by the building, labor charges, equipment or machinery charges.

The present case study is expected to generate waste approximately of volume 22,055m³. The gross area of the case study is 17,399m². Solis-Guzman et.al in his research proposed a factor of 1.2676m³ waste generated per square meter to estimate the total waste generated by building deconstruction. The total waste is transported to nearby landfills in Vijayawada and the unit cost of the waste transported is INR600. The total estimated site clearing and waste transport cost is INR1,32,33, 000. According to Guy the required unit rate of labor is around 0.06hour/m². Based on this factor 1044 hours (130.5 day) of labor are required for the deconstruction. According to directorate of economics and statistics government of Andhra Pradesh the average labor rate in construction industry is INR488 per day. The total estimated labor cost is INR 63,684. Of the total cost 10% is taken as the indirect costs such as inspections and supervisions.

Table 2.3 Building deconstruction cost

Description	Area	Unit rate	Quantity	Unit cost	Total cost (INR)
Site clearing and waste transport	17,399m ²	1.2676 m ³ /m ²	22,055m ³	INR 600	1,32,33,000
Labor cost	17,399m ²	0.06 hour/m ²	1044 hours (130.5 days)	INR 488	63,684
Indirect cost 10%					13,29,688
Total cost (based on 2016)					1,46,26,352
Total cost in 2089					4805.474 lakhs

The total estimated building deconstruction cost = INR 4805.474 lakhs

III. RESULTS AND DISCUSSIONS

3.1 Life cycle budget:

Table 3.1 Total Life cycle budget

Description	Total life cycle cost (lakhs)	Weight (%)
Design and construction cost	4601.495	6
Building energy cost	56478.44	67
Building maintenance cost	18283.73	22
Building deconstruction cost	4805.474	6
Total life cycle budget	84169.138	100

The total estimated life cycle budget for the case study is 84,169 lakhs. Of which energy cost constitutes 67% of the total life cycle budget and is also higher than initial cost. Building maintenance cost is 22% of the total life cycle budget. Building deconstruction cost is 6% of total life cycle budget. Hence reducing energy cost will be essential in order to reduce the total life cycle budget.

In the present case study 134 polycrystalline solar panels of each capacity 305wp are installed. The area of each panel is 2 square meter. The average sunlight hours in India is around 1500-2000 hours/year (5.47hrs/day). It generates a total energy of 608.82 kwh in a year/panel (305*5.47) which is around 81582 kwh/year for 134 panels. The



energy efficiency of 305wp polycrystalline solar panels is around 16% which is obtained by dividing panel capacity to amount of sunlight that hits earth surface and area of panel. The amount of sunlight that hits earth's surface is 1000watt/square meter.

To generate solar cells for monocrystalline solar panels, silicon is formed into bars and the silicon used in this are single crystalline and hence these type of panels are called monocrystalline. As the cell is composed of a single crystal, the electron generates a flow of electricity which have more room to move. As a result, monocrystalline panels are more efficient than their polycrystalline counterparts. By installing monocrystalline solar panels each of capacity 370 watt peak reduces energy cost by 2%. The area of each monocrystalline panel is 1.98 square meter. It generates a total energy of 737.3 kWh in a year/panel (370*5.47) which is around 88476 kwh/year for 120 panels. The efficiency of the adopted monocrystalline solar panel is around 18%. The total energy consumption after installing 370wp monocrystalline solar panel is 1110004 kwh/year. By applying life cycle costing technique to the adopted technology and recalculating the energy life cycle cost gives the total life cycle cost budget of INR 80024.434 lakhs. Though the initial cost of monocrystalline solar panels is more it presents the total life cycle cost savings of INR 4145 lakhs.

IV. CONCLUSION

It is necessary to understand the concept of life cycle cost analysis in order to reduce the future costs associated with any of the construction project. By comparing the different alternative options cost savings can be achieved. Life cycle costing technique is one of the effective tool which is used to identify the best cost effective option among different alternatives in the construction sector.

In this paper the concept of life cycle costing technique and its application to a green building to develop a life cycle cost budget for a period of 80 years has been analyzed and estimated. It is found that building operational, maintenance and disposal costs are higher than the initial cost (design and construction). Of which, energy cost constitutes 67% of the total life cycle cost. Hence reducing energy consumption is important in order to reduce building life cycle cost. Energy efficiency of installing 370wp monocrystalline solar panels is more than the existing polycrystalline solar panels. As energy efficiency is more less number of panels generates more energy. After installing 370wp monocrystalline solar panel building energy cost is reduced by 2%. And hence life cycle cost budget is reduced by INR 4145 lakhs.

This developed life cycle cost budget can be used as a baseline to update the future life cycle cost of a building with the changing requirements like inflation/deflation rate, climatic conditions with the course of time.

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