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# Engineering Economy and Life Cycle Cost Analysis of Concrete Structures

Mohammed Kashif Ali[1], Syed Ashraf Nidal[2],Mujahid Ali Khan[3], Mir Firasath Ali[4]

[1,2,3]*Student, ISL Engineering College, Hyderabad, Telangana*
[4]*Asst Prof, ISL Engineering College, Hyderabad, Telangana.*

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**ABSTRACT**
In any construction project, cost effectiveness plays a crucial role. The Life Cycle Cost (LCC) analysis provides a method of determining entire cost of a structure over its expected life along with operational and maintenance cost. LCC can be improved by adopting alternative modern techniques without much alteration in the building. LCC effectiveness can be calcu- lated at various stages of entire span of the building. Moreover this provides decision makers with the financial information necessary for maintaining, improving, and constructing facili- ties. Financial benefits associated with energy use can also be calculated using LCC analysis.

## I. INTRODUCTION

In this modern era, construction industry is focusing only on aesthetic design of buildings and its functional goal to fulfil the clients' expectation. Also the clients are looking only at its initial construction cost. Instead of merely looking at its structural cost alone, owners have to broaden their perspec- tive to include entire cost of a structure over its expected life along with operational and maintenance cost. Life cycle cost analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over period of time. It can be performed on large and small buildings or on isolated building systems. LCC can be calculated in three stages conceptual stage, acquisition stage, in service stage. LCC considers all cost required for construction, operational, maintenance and end-of-life costs. It includes all associated costs such as delivery, instal- lation, commissioning, insurance, energy and water use, replacement, maintenance, repair and end-of-life costs. India's housing sector alone has assets worth more than Rs 50,000 crore and will require more than Rs 17,000 crore for repair and maintenance every year.[8] Instead of housing owners selling their assets after 12 years and invest in a new property, they should be wise enough to spend on regular maintenance. Also builders must make use of blended cement, steel bars, advanced waterproofing materials and non-conventional energy options in new age housing construction designs.

**Need For Calculating engineering economy and Life Cycle Cost Analysis:**

Investment decisions relating to residential and commercial buildings have based on initial construction cost, with little or no consideration for costs relating to operation and maintenance throughout the life of the building. The construction and operation of buildings has environmental effects. It is important to reduce them by use of modern energy systems. Construction industry is focusing only on aesthetic design of buildings and its functional goal to fulfill the clients' expectation. Also the clients are looking only at its initial construction cost. Instead of merely looking at its structural cost alone, owners have to broaden their perspective to include entire cost of a structure over its expected life along with operational and maintenance cost.

Life cycle cost analysis is a proven economic analysis technique based on well-founded economic principles. LCCA is a cost-based process; its goal is to identify the most costefficient building design and construction strategies over the life of the asset. LCCA includes initial cost such land cost, constructional cost, design cost. It also includes maintenance and repair cost, salvage cost, scrap value or disposal cost or residual cost.

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**LCCA= Cash Inflows – Cash Outflows + Scrap Value/Residual Value /Salvage Value**

LCCA is cost- based process, its goal is to identify the most efficient building design .Usually, while constructing any structure owner and developer mainly focus on preconstructional and constructional cost. But maintenance, repair and operational cost plays vital role in overall life of structure. It includes nearly 30-50 % cost in whole life span of structure. But calculating maintenance, repair and operational cost is very lengthy and tedious process because every component or parts and its replacement and maintenance cost is consider while calculating the LCCA and many examples it consumes lot of time.

Categorization of various costs related to construction, opera-tion and maintenance of building are called terminology .

Following are the terminologies used while calculating LCC of a building. Mainly seven terminologies are used that termi-nologies categorized likewise Initial cost, Operation cost, Maintenance cost, Repair costs,Replacement Costs, Residual Value, and EnergyCost.

**Initial cost:** Initial cost includes land acquisition cost, design cost and construction cost.

**Operation Cost:** Operational cost includes cost required for annual building utilities and services excluding maintenance and repair cost involved in the operations of facility.

**Maintenance cost: Maintenance** cost includes cost required for the maintenance of water pump, maintenance of passenger lift, annual roof inspection etc.

**Repair costs:** Repair cost includes cost required to extend the building life without replacing the system entirely.

**Replacement costs:** Replacement Cost required to Replace-ment of entire component.

**Residual Value:** Residual value is the value of the building at the end of the study period or at the life cycle period.

**Energy costs:** Energy cost includes expenses for energy and other utilities.

There are many methods such as Simple payback (SPP) method ,Discounted payback (DPP) method ,Net present val-ue (NPV) method, Equivalent annual cost (EAC) method ,Internal rate of return (IRR) method ,Net saving (NS) method available for economic evaluation of life cycle cost analysis .The payback period method has some key weakness that are payback method doesn't take into account inflation and thecost of capital, It does not consider the cash flow after the payback period ,it ignore time value money[1]. In discounted payback period cash flow used with the discounted cash flow but it also does not consider cash flow after payback period. Net present value considers time value of money [1] and also takes care of all the cash flows till the end of the life. Internal rate of return does not understand economies of scale and ig-nores dollar valueof the project. It cannot differentiate be-tween two projects with same IRR but huge difference be-tween dollar returns. On the other hand, NPV talks in absolute terms and therefore this point are not missed. IRR assumes discounting and reinvestment of cashflows at same rate. If the IRR of a very good project is say 35%, it is practically not possible to invest money at this rate in the market. Whereas, NPV assumes a rate of borrowing as well as lending near to the market rates and not absolutely impractical .IRR enters the problem ofmultiple IRR when we have more than one nega-tive net cash flow and the equation is then satisfied with two values therefore have multiple IRRs. Such a problem does not exist with NPV.NPV is measured in terms of currency whereasIRR is measured in terms of expected percentage return .From a comparison of NPV and IRR, it can be seen that NPV is ac-tually a better measure than IRR, especially, in long term pro-jects, not only because NPV considers different discount rates but also takes into account the cost of capital .Equivalent an-nual cost gives an average number .It does not indicate the actual cost during each year of the LCC.Net saving can be used if the investment generates an income [1].Therefore most LCC model utilize the NPVmethod .But NPV Should not be usable if the alternatives have different life length.

## II. METHODOLOGY

Investment decisions relating to construction projects have based on initial construction cost, with little or no consideration for costs relating to operation and maintenance throughout the life of the building. Construction industry is focusing only on aesthetic design of buildings and its functional goal to fulfil the clients' expectation. Also the clients are looking only at its initial construction cost. Instead of looking at its structural cost alone, owners have to

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broaden their perspective to include entire cost of a structure over its expected life along with operational and maintenance cost to reduce overall cost of the project over its entire lifespan.

Since Hyderabad being an IT hub of India, two buildings complex have been considered for the present study. LCCA of these buildings has been carried out for the life span of 30 and 25 years respectively. The data relevant to initial costs, maintenance costs, replacement costs and energy used was collected for the selected build- ings, which is required for the LCC computation. Proportion of various cost elements in the maintenance costs of these buildings and the cost of various non-annually occurring maintenance, has been studied for identification of major cost elements. Other important parameters considered as, every year financial variations in electricity cost, interest cost and goods cost such as average inflation rate as per con- sumer price index, Energy index, and average interest rate as per Reserve Bank of India. 'Net Present Value' method has been used for calculation of LCC. The values of various parameters involved were considered as, average inflation rate as per consumer price index: 7.8%, average inflation rate as per energy index: 3% and average interest rate as per Reserve Bank of India: 8%. The sensitivity analysis has been carried out for case study has been done in order to check the variation in LCC due to variation in various parameters.

In order to reduce LCC of building, energy consumption cost has been considered as key component as this being major annual expenditure in commercial buildings. Cost of energy consumption can be reduced by using renewable sources as well as by using modern techniques. India receives solar energy equivalent to more than 5000 trillion kWh per year as it is located in the sunny belt of the world. (Source: India Solar Energy Outlook 2010.) Solar energy technique has been adopted for both the case studies, considering inter- nationally and nationally accepted and proven Photovoltaic (PV) Crystalline Technology. In the first case study, minimum capacity SPP was considered to evaluate the effect on LCC. As it was observed from first case study that considerable savings can be achieved even with minimum capacity SPP, for the second case study, SPP was designed as per the build- ing requirements to enhance the savings in LCC. In first case study, 10 kW capacity monocrystalline solar panel system is considered for installation and for the second case, Polycrys- talline PV technology solar module of 255 Wp is considered. Initial investment for proposed solar system in case study two, has been arrived at by considering cost of the solar system and cost of supporting structure.

| Particular | Before EEA (2020) | After EEA (2021) |
|---|---|---|
| Investment cost | Rs. 66,30,00,000 | Rs. 66,30,00,000+1,50,00,000 |
| Electricity consumption | 16kW-h approx 192 kWh per year | 16kW-h approx 192 kWh per year ( NO COST) |
| Repair & maintenance | 98,000 per month | 1,20,000 per month |
| Water | $5m^3$ per day | $5m^3$ per day |
| Fuel | 110kVa DG set - 330 Liters Diesel/month | 60kVa DG set - 100 Liters Diesel/month |
| Water proofing | Rs 3,37,000 | Rs 3,37,000 |
| Coloring | Rs 492000 | Rs 492000 |
| Plumbing/Piping-fire pipe/drainage | Rs 779500 | Rs 779500 |

**Table 1 - Energy Consumption & Operation & Maintenance Costs of Building**

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**LCCA Applied To Building**

As the building is constructed in year 2019 as it's has been fully in operation & in future at least giving service for 20 more years till 2039. The comparative study of LCCA calculation with & without Energy efficient Approach is given below.

**Table 2 - Lcc For building Without Energy Efficiency Approach**

| No of Year | Year | Capital | Energy | Maintenance | Repair/ Replace | Total Cost |
|---|---|---|---|---|---|---|
| 0 | 2019 | 663000000 | 2867160 | 854400 | 0 | 666721560 |
| 1 | 2020 | 0 | 3053525 | 909936 | 0 | 3963461 |
| 2 | 2021 | 0 | 3252005 | 969082 | 0 | 4221087 |
| 3 | 2022 | 0 | 3463385 | 1032072 | 9945000 | 14440457 |
| 4 | 2023 | 0 | 3688505 | 1099157 | 0 | 4787662 |
| 5 | 2024 | 0 | 3928258 | 1170602 | 0 | 5098860 |
| 6 | 2025 | 0 | 4183594 | 1246691 | 8619000 | 14049285 |
| 7 | 2026 | 0 | 4455528 | 1327726 | 0 | 5783254 |
| 8 | 2027 | 0 | 4745137 | 1414028 | 0 | 6159165 |
| 9 | 2028 | 0 | 5053571 | 1505940 | 7293000 | 13852511 |
| 10 | 2029 | 0 | 5382053 | 1603826 | 0 | 6985879 |
| 11 | 2030 | 0 | 5731887 | 1708075 | 0 | 7439962 |
| 12 | 2031 | 0 | 6104460 | 1819100 | 5967000 | 13890560 |
| 13 | 2032 | 0 | 6501249 | 1937341 | 0 | 8438590 |
| 14 | 2033 | 0 | 6923831 | 2063269 | 0 | 8987100 |
| 15 | 2034 | 0 | 7373880 | 2197381 | 4641000 | 14212261 |
| 16 | 2035 | 0 | 7853182 | 2340211 | 0 | 10193393 |
| 17 | 2036 | 0 | 8363639 | 2492324 | 0 | 10855963 |
| 18 | 2037 | 0 | 8907275 | 2654326 | 3315000 | 14876601 |
| 19 | 2038 | 0 | 9486248 | 2826857 | 0 | 12313105 |
| 20 | 2039 | 0 | 10102854 | 3010602 | 0 | 13113456 |
| 21 | 2040 | 0 | 10759540 | 3206291 | 1989000 | 15954831 |
| Total | | 663000000 | 132180766 | 39389237 | 41769000 | 876339003 |

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**Table 3 - Lcc For building With Energy Efficiency Approach**

| No of Year | Year | Capital | Energy | Maintenance | Repair/ Replace | Total Cost |
|---|---|---|---|---|---|---|
| 0 | 2019 | 663000000 | 116574 | 991037 | 0 | 664107611 |
| 1 | 2020 | 5000000 | 124151 | 1055454 | 0 | 6179605 |
| 2 | 2021 | 5000000 | 132221 | 1124059 | 0 | 6256280 |
| 3 | 2022 | 5000000 | 140816 | 1197123 | 0 | 6337939 |
| 4 | 2023 | 0 | 149969 | 1274936 | 0 | 1424905 |
| 5 | 2024 | 0 | 159716 | 1357807 | 0 | 1517523 |
| 6 | 2025 | 0 | 170098 | 1446064 | 6630000 | 8246162 |
| 7 | 2026 | 0 | 181154 | 1540058 | 0 | 1721212 |
| 8 | 2027 | 0 | 192929 | 1640162 | 0 | 1833091 |
| 9 | 2028 | 0 | 205470 | 1746772 | 0 | 1952242 |
| 10 | 2029 | 0 | 218825 | 1860313 | 0 | 2079138 |
| 11 | 2030 | 0 | 233049 | 1981233 | 4972500 | 7186782 |
| 12 | 2031 | 0 | 248197 | 2110013 | 0 | 2358210 |
| 13 | 2032 | 0 | 264330 | 2247164 | 0 | 2511494 |
| 14 | 2033 | 0 | 281512 | 2393230 | 0 | 2674742 |
| 15 | 2034 | 0 | 299810 | 2548790 | 0 | 2848600 |
| 16 | 2035 | 0 | 319297 | 2714461 | 3315000 | 6348758 |
| 17 | 2036 | 0 | 340052 | 2890901 | 0 | 3230953 |
| 18 | 2037 | 0 | 362155 | 3078809 | 0 | 3440964 |
| 19 | 2038 | 0 | 385695 | 3278932 | 0 | 3664627 |
| 20 | 2039 | 0 | 410765 | 3492063 | 0 | 3902828 |
| 21 | 2040 | 0 | 437465 | 3719047 | 1657500 | 5814012 |
| | Total | 678000000 | 5374250 | 45688428 | 16575000 | 745637678 |

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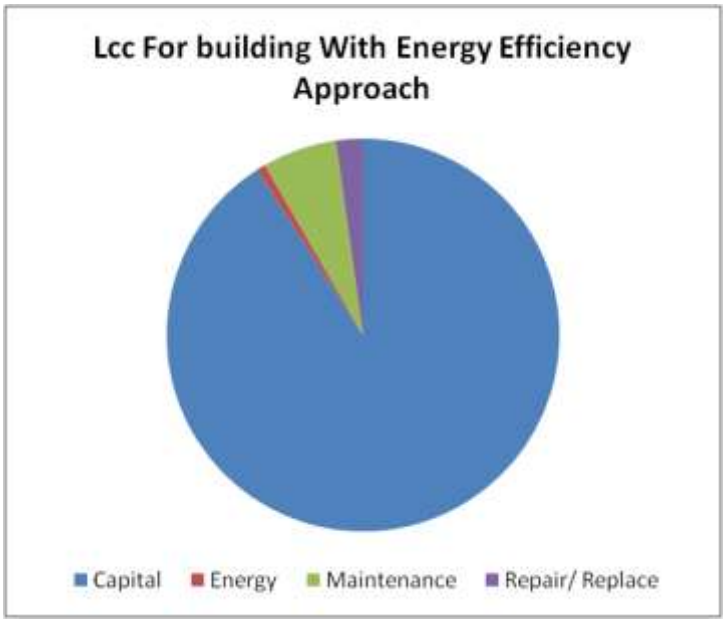


### *A.* LCCA Results for Building

Life cycle cost calculation for building and savings are calculated as follows:

*1)* Capital cost of Energy Efficient Systems = 1,50,00,000 INR
*2)* LCC without EE approach = 87,63,39,003 INR
*3)* LCC O&M Energy-Efficient approach = 74,56,37,678 INR
*4)* Total Cost Saved = 13,07,01,325 INR

**LCC Calculation Results**

Energy efficient approach with above describe system requires initial investment in the range of 2.26 % of the building cost. With this minimum investment the company can save 14.91%of total cost can be saved over span of 20 years.

## III. CONCLUSION:

There has been a lot of attention paid to the EEA as a way to reduce LCC in this study. In this case, we looked at how the building is now and what it would look like if we built it. When you do a case study, you do a sensitivity analysis to see how the LCC changes when different things change. Comparing the LCC between a building that doesn't use energy efficiently and a building that does use energy efficiently has been done. Following are some of the findings from the projectstudy.

The life cycle cost analysis is a good tool. There is an initial investment of 1.3 to 16 percent for an energy efficient solar panel system. When you buy a solar power panel at a low price, you can save 4.3 percent of the total cost over the next 30 years. 54.64 percent of the total cost can be saved over the course of 25 years if the solar power panel is used. Solar power panels can be used to make a building more energy efficient. This can help cut down on the LCC of the old building.

LCCA has talked about how investing in more cost-effective solutions at the start of a building's life can save money over time. Cost savings can be made by looking at other options. The best option will be the one that costs the least over the life of the project. If you apply a Life Cycle Cost Analysis (LCCA) to the O&M costs of a building, you can figure out how the decision you make now will affect your O&M costs in the long term. There is only a small amount of money spent on the capital costs, but over the next 30 years, the savings in energy and maintenance costs are close to 60% to 70%.

Sustainable materials and a smart way to use energy could cut down on the cost of building at an early stage. This could lead to the most benefits over the life of the building. Using a hybrid energy system of a windmill and solar panels can help cut down on the LCC of an old building. Heat-insulating materials that are good for the environment and are used in a smart way could cut the amount of energy needed by a building by a lot. Rainwater harvesting, water use efficiency, and trees that shade from the sun also help cut down on energy costs and the cost of operating and maintaining the building. As a whole, LCC is a very good thing because it makes

the most of natural resources and how they are used to build and run things.

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