Sustainability assessment of building life cycle costing: A case study of Calabar International Conference Center

Godwin Adie Akeke 1, *, Melody Sunday Osok 2 and Clifford Ugochukwu Nwoji 2

1 Department of Civil Engineering, University of Cross River State, Calabar.
2 Department of Civil Engineering, University of Nigeria, Nsukka.

World Journal of Advanced Engineering Technology and Sciences, 2021, 02(01), 101–109
Publication history: Received on 01 March 2021; revised on 16 April 2021; accepted on 18 April 2021
Article DOI: https://doi.org/10.30574/wjaets.2021.2.1.0025

Abstract
This work presents a study of sustainability assessment of building life cycle (LCC). The analysis was conducted, information model developed. The LCC analysis was forecast for 50 years with the following discount rates 4%, 5%, 6%, 8%, 10%, 12% and 13%. The result showed, the lower the discount rates the higher the cost value and via vasa. The product of net present value (NPV) is > 0, indicating a significant benefit at the end of the study period. The construction cost was 73% of the total forecast costs of the building while operation, maintenance/repair, replacement and decommissioning cost ranks 2%, 8%, 13% and 4% respectively of the building costs. The total forecast life cycle costs ranked 30.24% of the construction cost. The energy costs contributed 54.78% of the total forecast cost. The energy costs were the most cost incurring factor, the use of alternative sources of power supply such as solar will serve as the best and more cost friendly alternative source of energy. The decommissioning costs at the end of CICC building life cycle stand at ₦355,807,000. The study explains a practical analysis on how a life cycle costing of Calabar International Conference Center project was analysed and forecast for a period of 50 years using different discount rates.

Keywords: Life Cycle Costing; Sustainability; Building maintenance

1. Introduction
The origin of sustainability is traced back to an ancient practice in forestry, where the benefits of exploring timbers from the forest is more than that it can generate. [8]. Since then, it has become one of the topmost agenda globally. Researchers have been working tirelessly on a universally acceptable definition of sustainability. [1]. The urgency came to limelight in the 1980s when the World Commission on Environmental and Development (WCED) promulgated a universally acceptable definition as “economic and social development that meets the needs of the current generation without undermining the ability of the future generations to meet their own needs”. [10]. The concept of sustainability has been a global phenomenon, driven by three main elements; social, economic and environmental functioning actively throughout the building life cycle without failing as a result of depletion of major resources [7].

[4] asserted that, the concept of building life cycle costing (LCC) was first applied in the procurement of military equipment by the United State Department of Defense in the mid-1960s. Since then, researchers and academia had further developed LCC frameworks used in many sectors including the building industry. Life cycle costing concept is also used in evaluating the total cost of project ownership and how best it can minimize project cost for good return on investment. [6] opined that the conception, acquisition, operation, maintenance, conversion and decommissioning of the building are the most costs oriented stages to be considered. Furthermore, it can be used in evaluating alternative project, as policy tool and as a management tool in analyzing the total cost of a building project acquired in the building whole life. [3]. The life cycle of a building is surrounded with risk and uncertainty during its estimation process because

*Corresponding author: Godwin Adie Akeke
Department of Civil Engineering, University of Cross River State, Calabar.

Copyright © 2021 Author(s) retain the copyright of this article. This article is published under the terms of the Creative Commons Attribution License 4.0.
buildings generally have long life cycle. [5], [2]. The above case, however, becomes a management issue under the umbrella of operating for the lowest long term cost of ownership. Hence, LCC becomes a management decision tool to remediate the underpin issues by focusing on facts, money and time, [6] as earlier mentioned. In the building industry, LCC seeks to evaluate the cost performance of buildings throughout its service life including acquisition, development, operation, management, repair, disposal and decommissioning. It allows among different investment scenarios, design and specification. [2].

In Nigeria the concept of sustainability and life cycle costing, is still in its infancy, since not all stake holders in the industry have awareness of its application during the design and construction stages of building projects [3]. A locally-based building sustainability assessment tool is yet to be developed in Nigeria [9]. Therefore, the integration of sustainability and life cycle costs framework in building projects will serve as the right tool in addressing all unsustainable building and cost related problems in the industry, since only few research works have been conducted on sustainability assessment of building life cycle cost. Most frameworks focus on the running cost of building components failing to incorporate the decommissioning cost. However, this pitfall is paramount to researchers in the building industry, as the process of sustainability assessment of building life cycle cost requires a detail assessment from cradle to grave. Hence, this study chooses to assess sustainability and life cycle cost of building components and forecast the future running cost from operation, maintenance and repair and replacement including decommissioning phase of the building. The study also presents a breakdown of percentage contribution of all cost components as regards to CICC building complex LCC.

2. Methodology and sampling technique

The study incorporates the use of a well-structured questionnaire formulated based on sustainability assessment of building life cycle costs.

The methodology is structured into two approaches; a questionnaire survey adopting a purposive method of sampling and a framework for the development of a life cycle costs model using the Net present value (NPV). Findings from the questions in the questionnaire by respondents are as follows.

2.1. General Awareness and use of Sustainability and Life Cycle Costing

On the awareness and use of sustainability and life cycle cost, it was noticeable that out of 116 participants 19 strongly agree on the awareness and use of sustainability and life cycle cost, 19 agree, 14 neither agree nor disagree, 23 disagree and 41 strongly disagree with mean ± SD (26.4 ± 9.346).

LCC is used during project brief, design and construction, it was observed that 21 respondents strongly agree with the application of LCC during project brief, design and construction, 20 respondents agree, 15 neither agree nor disagree, 38 respondents disagree and 20 respondents strongly disagree with mean ± SD (23.866 ± 7.884).

On the three element of sustainability: social, economic and environmental influence on the performance of a building project, it can be seen that 19 respondents strongly agree, 17 respondents agree 17 respondents neither agree nor disagree, 21 respondents disagree and 42 respondents strongly disagree with mean ± SD (26.533 ± 9.516).

On current LCC techniques are suitable for calculating the costs of buildings, it can be seen that fifteen 15 respondents strongly agree, 23 respondents agree, 10 respondents neither agree nor disagree 44 respondents disagree and 23 respondents strongly disagree, mean ± SD (25.466 ± 11.610)

Initial, operating, maintenance and disposal costs of buildings are useful when conducting LCC analysis 29 respondents strongly agree, 15 respondents agree, 17 respondents neither agree nor disagree, 24 respondents disagree and 32 respondents strongly disagree, mean ± SD (24.4 ± 6.590)

Key performance indicators and economic performance measures need to be incorporated into lifecycle costing, it can be seen that 13 respondents strongly agree, 9 respondents agree, 10 respondents neither agree nor disagree, 55 respondents disagree and 27 respondents strongly disagree mean ± SD (27.733 ± 9.348)

Historical costs data are very accurate shows the responses from respondents. Intuitively, it shows that 8 respondents strongly agree, 19 respondents agree, 64 respondents neither agree nor disagree 17 respondents disagree and 7 respondents strongly disagree, mean ± SD (25.133 ± 7.042)
The net present value (NPV) technique was used in the analysis for all cash inflow and outflow. The parameters for the study was gotten from the CICC project, they include the Initial cost (Construction cost), Operation cost, Maintenance/Repair cost and the Replacement cost, while the salvage value was determined at the end of the study period. The Initial cost of the project is made up of the design cost and construction cost. Since CICC project is a government project the cost of land and taxation was not included. The Operation cost (PC) of the project includes the cost of water bills, electricity bills (independent power source and National power source) cleaning and garbage disposal, wages of staffs and other costs. The Maintenance and Repair cost (M/RC) consist of the maintenance and repair of doors, windows, plaster of Paris (POP), roofs, electrical fittings, plumbing, fire protection system, fumigation and other costs. Replacement cost (RC) includes the cost of doors and windows, appliances, chairs and tables, electrical services, plumbing and other servicing.

This costs drivers were collected for each month and sum up to obtain the yearly costs of the facility for every year for a study period of 5years and extrapolated to a study period of 50 years using NPV as shown in equation 1.

\[ NPV = \sum_{t=0}^{N} \frac{F_t}{(1+r)^t} \]

Where,
- \( t = \) time of the cash flow
- \( N = \) the total time of the cash inflow/out flow in the project
- \( r = \) the discount rate (the rate of return that could be earned on an investment in the financial market with similar risk)
- \( F_t = \) the net cash flow (the amount of cash) at time, \( t \).

The questionnaire was broken into two parts. Part one involves the preliminary data from the respondents while Part two involves a well-structured question from the questionnaire, which investigated, among other things the respondent’s view on the following issues:

- General awareness and use of sustainability and life cycle cost.
- Building sustainability and life cycle cost concept.
- Most important considerations in project design and construction.
- Making life cycle costing and sustainable building a mandatory requirement in Government and public projects. The details in the questionnaire were derived from the research objective and represented in Appendix1.

### 2.2. Questionnaire analysis

The questionnaires were distributed to selected states across Nigeria to assess respondent’s views on the research questions base on their level of awareness and use of sustainability and life cycle costing in project delivery.

#### Table 1 Responses from Professionals.

| S/N | Variables            | Frequency | Percentage |
|-----|----------------------|-----------|------------|
| 1   | Quantity Surveyor   | 8         | 6.7        |
| 2   | Builder              | 30        | 25.0       |
| 3   | Architect            | 6         | 5.0        |
| 4   | Mechanical/Electrical| 21        | 17.5       |
| 5   | Facilities Manager  | 17        | 14.1       |
| 6   | Civil Engineer       | 18        | 31.7       |
Table 2 Professional Qualification of Respondents

| S/N | Variables | Frequency | Percentage |
|-----|-----------|-----------|------------|
| 1   | COREN     | 21        | 17.5       |
| 2   | MNSE      | 7         | 5.8        |
| 3   | PMI       | 18        | 15.0       |
| 4   | MNIA      | 14        | 11.7       |
| 5   | MNIQS     | 19        | 15.8       |
| 6   | MNIOB     | 5         | 4.17       |
| 7   | Other     | 36        | 30         |

Table 3 Operation Cost

| Year | Door/Windows | Ceiling | Roofing System | Wall Painting | Floor finish | Plumbing Fixture/ Sewage | HVAC | Electrical Services | Fumigation |
|------|--------------|---------|----------------|---------------|--------------|--------------------------|------|---------------------|------------|
| 2015 | 0            | 1,000   | 50,000         | 0             | 0            | 50,000                   | 10,000| 1,200,000          | 150,000    |
| 2016 | 0            | 1,600   | 30,000         | 0             | 0            | 10,000                   | 10,000| 1,500,000          | 150,000    |
| 2017 | 0            | 3,000   | 0              | 0             | 0            | 5,000                    | 15,000| 1,820,000          | 150,000    |
| 2018 | 60           | 8000    | 0              | 0             | 0            | 2,000                    | 10,000| 2,000,000          | 180,000    |
| 2019 | 10,000       | 15,000  | 150,000        | 500,000       | 500,000      | 4,000                    | 15,000| 2,000,000          | 185,000    |
| Total| 10,060       | 28,600  | 230,000        | 500,000       | 500,000      | 71,000                   | 60,000| 8,520,000          | 815,000    |

Table 4 Maintenance/Repair Cost

| Year | Doors/Windows | Ceiling | Floor Finishes | Water Devt/Plumbing | HVAC | Landscaping | Special Electrical System |
|------|---------------|---------|----------------|---------------------|------|-------------|--------------------------|
| 2015 | 0             | 0       | 0              | 0                   | 0    | 0           | 0                        |
| 2016 | 0             | 0       | 0              | 0                   | 0    | 0           | 0                        |
| 2017 | 0             | 0       | 0              | 0                   | 0    | 0           | 0                        |
| 2018 | 0             | 0       | 0              | 0                   | 0    | 0           | 0                        |
| 2019 | 5,000,000     | 400,000 | 1,000,000     | 1,500,000           | 800,000 | 99,000     | 500,000                  |
| Total| 5,000,000     | 400,000 | 1,000,000     | 1,500,000           | 800,000 | 99,000     | 500,000                  |

3. Results and discussion

Figure 1. shows results of responses on awareness, sustainability and Life Cycle costing against statements of the CICC project.

The results of the benefits of LCC against total cost reduction, planned maintenance scheduling, reduction of cost over specification, improved design process, reduction of delay in time of design and construction, improvement in quality of execution and selection of most cost effective methods are shown in figure 2. The results show that respondents view
on the total cost reduction, indicates twenty-two (22), respondents who agreed that it is highly beneficial, thirty-five was (35), those who said it is beneficial fourteen (14), those for less beneficial, twenty-three (23), fairly beneficial was (22) and twenty-one (21) respondents said it not beneficial with mean ± SD (22.066 ± 6.782).

Planned maintenance scheduling, thirty-eight (38) respondents said it is highly beneficial, seventeen (17) respondents said it is beneficial, nineteen (19) respondents said it is less beneficial, twenty (20) respondents said it is fairly beneficial and twenty-three (23) respondents said it not beneficial with mean ± SD (21.600 ± 7.552).

The results for challenges in sustainability and LCC against responses (statements) are as shown in figure 3.

The results for recommendation toward advancement of sustainability and LCC concept are shown in figure 4.
Results interest rate per annum showing that interest rate is the amount of interest due per period, as a proportion of the amount lent, deposited or borrowed (call the principle sum) is shown in figure 5 while the results on inflation rate are shown in figure 6.

The total life cycle cost summary represents the total present and future cost of Construction, Operation, Maintenance/repair, Replacement, end of Life cost and the total life cycle cost of the case study. Their percentage contribution highlights the weight of cost incurred at difference stages. Results shows that the construction cost rate weighted 73% of the total life cycle cost while operation, maintenance, replacement and decommissioning cost where ranked 2%, 8%, 13% and 4%. Details of the results for Forecast Costs Summary of CICC project are as shown in figure 7.
Table 5: Sensitivity Analysis on Discount Rate

| Year | t | F=(OC+M/RC+RC) | 1=(1+r)^t | F=(1+r)^t | Year | t | F=(OC+M/RC+RC) | 1=(1+r)^t | F=(1+r)^t |
|------|---|----------------|------------|-----------|------|---|----------------|------------|-----------|
| 2015 | 0 | 2865400        | 1          |           | 2041 | 26| 34944275.02    | 0.360689   | 12604024  |
| 2016 | 1 | 3348600        | 0.961538   | 3219807.7 | 2042 | 27| 36062822.09    | 0.346817   | 12507184  |
| 2017 | 2 | 3640000        | 0.924556   | 3365384.6 | 2043 | 28| 37313975.68    | 0.333477   | 12443370  |
| 2018 | 3 | 3847060        | 0.961538   | 3420022.3 | 2044 | 29| 38257237.63    | 0.961538   | 11964779  |
| 2019 | 4 | 3026000        | 0.854804   | 2586637.5 | 2045 | 30| 39660000.16    | 0.308319   | 11795421  |
| 2020 | 5 | 12720050       | 0.821927   | 10454954  | 2046 | 31| 40560029.59    | 0.29646    | 11757614  |
| 2021 | 6 | 11651476       | 0.790315   | 9208330.7 | 2047 | 32| 41999428.07    | 0.285058   | 11561958  |
| 2022 | 7 | 13066616.29    | 0.759918   | 9929554.5 | 2048 | 33| 43175672.26    | 0.274094   | 11511799  |
| 2023 | 8 | 14673756.57    | 0.73069    | 10721970  | 2049 | 34| 44370600.89    | 0.263552   | 11693965  |
| 2024 | 9 | 18993341.3     | 0.675564   | 7018619.9 | 2050 | 35| 45556721.14    | 0.253415   | 11244197  |
| 2025 | 10| 10389272.06    | 0.649581   | 13240021  | 2051 | 36| 46742841.39    | 0.243669   | 11100748  |
| 2026 | 11| 14517669.52    | 0.624597   | 10215317  | 2052 | 37| 47921203.62    | 0.234297   | 10951700  |
| 2027 | 12| 16355050.88    | 0.600574   | 10687486  | 2053 | 38| 49114265.25    | 0.225285   | 10795949  |
| 2028 | 13| 13882417.3     | 0.577475   | 13240021  | 2054 | 39| 50300354.09    | 0.216621   | 10639162  |
| 2029 | 14| 22927432.07    | 0.555265   | 11095267  | 2055 | 40| 51486442.93    | 0.208289   | 10477013  |
| 2030 | 15| 18972446.83    | 0.533908   | 12704062  | 2056 | 41| 53765790.75    | 0.200278   | 10311598  |
| 2031 | 16| 20017461.6     | 0.513373   | 11095267  | 2057 | 42| 53962740.52    | 0.192575   | 10353943  |
| 2032 | 17| 21612476.37    | 0.493628   | 11280177  | 2058 | 43| 55152461.45    | 0.185168   | 9992183.7 |
| 2033 | 18| 22851568.52    | 0.474642   | 12780137  | 2059 | 44| 56342182.38    | 0.178046   | 9819694.4 |
| 2034 | 19| 26925820.44    | 0.456387   | 12689643  | 2060 | 45| 57531903.31    | 0.171198   | 9645692.1 |
| 2035 | 20| 27804571.51    | 0.438834   | 12737717  | 2061 | 46| 58721624.24    | 0.164614   | 9470548.5 |
| 2036 | 21| 28994522.1     | 0.421955   | 12736501  | 2062 | 47| 76623022.82    | 0.158283   | 9294608.7 |
| 2037 | 22| 30184472.68    | 0.405726   | 12729430  | 2063 | 48| 62493705.9     | 0.152195   | 11661623  |
| 2038 | 23| 31374423.26    | 0.390121   | 12704062  | 2064 | 49| 63726058.66    | 0.146341   | 9145398.9 |
| 2039 | 24| 32564373.85    | 0.375117   | 12661814  | 2065 | 50| 64958441.42    | 0.140713   | 9140468   |

Salvage Value = 145707728.80, Initial Cost = 5719455950.50, LCC = 899940966.50
Figure 7 Forecast Cost Summary of CICC Building Project

The results of Sensitivity Analysis on Discount Rate using sensitivity analysis technique for determination of the impact level of discount rate of 4% on the forecast cost of the building project are shown in table 5.

The results of the decommissioning cost of CICC Expected labour hours for decommissioning of CICC using NPV technique are shown in table 6.

Table 6 CICC building decommissioning estimations

| S/N | Description                              | Quantity | Unit   | Rate(₦) | Amount(₦)   |
|-----|------------------------------------------|----------|--------|---------|-------------|
| 1   | Building waste cleaning & transportation| 3391m³   | 1.269m²| 15000   | 320,000,000 |
| 2   | Cost of labour                           | 2658hr   | 0.06hr/m²| 250     | 3,807,000   |
| 3   | Cost of inspection/supervision 10%       |          |        |         | 32,000,000  |
| 4   | Overall decommissioning cost             |          |        |         | 355,807,000 |
| 5   | End of life cost                         |          |        |         | 144,707,728 |

4. Conclusion

Sustainability assessment of building life cycle cost has avail clients and stake holders of the benefits of sustainable building and the choice to choose between sustainable and conventional buildings construction projects. Findings shows that, sustainable buildings have less operational and maintenance life cycle cost and the best alternative in reducing the running cost of a building. This can only be achieved in the design stage of the building, where sustainability elements and most cost driven components are considered. It will be a great achievement to the Nigeria construction industry, if sustainability and LCC tools are developed and implementing for used during building project design and construction. Furthermore, its implementation in real time is associated with some difficulties in obtaining the required cost data, particularly, if the analysis is conducted to develop life cycle cost in the nominal terms, in which future inflation and interest rates for the different cost elements cannot be disregarded. This research explains a theory in practice and demonstrates how the life cycle cost of a sustainable building was analyzed and estimated for a period of 50 years. Results showed that the energy costs constitute 51.60% of the total forecasted life cycle cost and 16% of the total design and construction cost. Reducing energy consumption was found to be the most influential factor to reduce the total life cycle cost of CICC building complex.

The accuracy of the results, is a function of the accuracy of the used life cycle cost variables.
Compliance with ethical standards

Acknowledgments

We wish to acknowledge the contributions of the Managing Director, Management and technical staff of CICC, Calabar for the arduous work of guiding us through their facility and the various professionals and public who responded to the questionnaires. We thank you all.

Disclosure of conflict of interest

We wish to declare that there is no conflict of interest amongst us.

References

[1] Aussama Khalil. Developing a Strategy for the Implementation of Sustainable Construction Practices in Libya. 2018.
[2] David Langdom management consulting. Life cycle costing (LCC) as a contribution to sustainable construction: a common methodology Literature Review. 2007.
[3] Ebunoluwa Bimbola Akinrata. Life Cycle Costing (LCC) in Nigerian construction industry: Barrier and Drivers facing its Implementation. 2016.
[4] Epstein MJ. Measuring corporate environmental performance. Chicago: Irwin professional publishing. 1996.
[5] Flanagan R, Jewell C. Whole Life Appraisal for construction. Oxford. 2005.
[6] H. Paul Barringer. Life cycle cost Summary. 2003.
[7] Ugwu. Indicators and Framework for Assessment Sustainable Infrastructure. 2005.
[8] Oraegbune, Ojiako Marcel. An Appraisal of Transportation Infrastructure Sustainability in Nigeria. 2015.
[9] Tamaraukuro Tammy Amasumo, Jabril Atandab, George Baird. Development of a Building Performance Assessment and Design Tool for Residential Buildings in Nigeria. 2016.
[10] United Nations Report of the World Commission on Environment and Development: Our Common Future. 1987.