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

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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

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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 thatfifteen 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 LCCanalysis 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 out flow. 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.

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

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)
Ft = 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	Land-scaping	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).

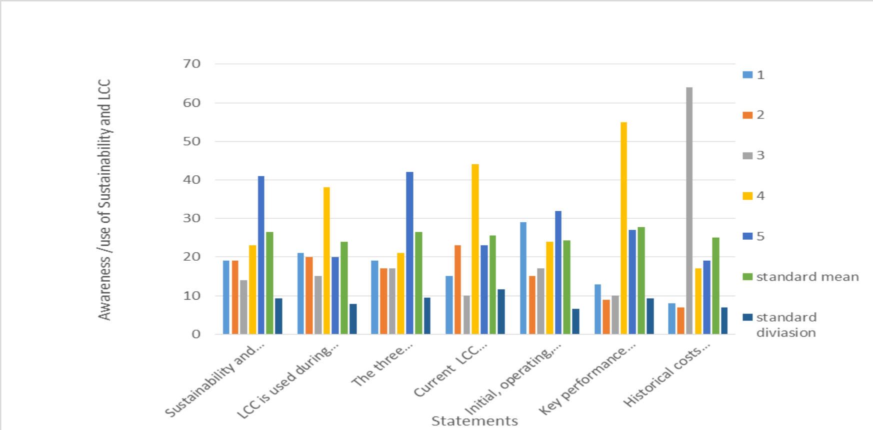

Figure 1 Awareness and use of Sustainability and Life Cycle Costing

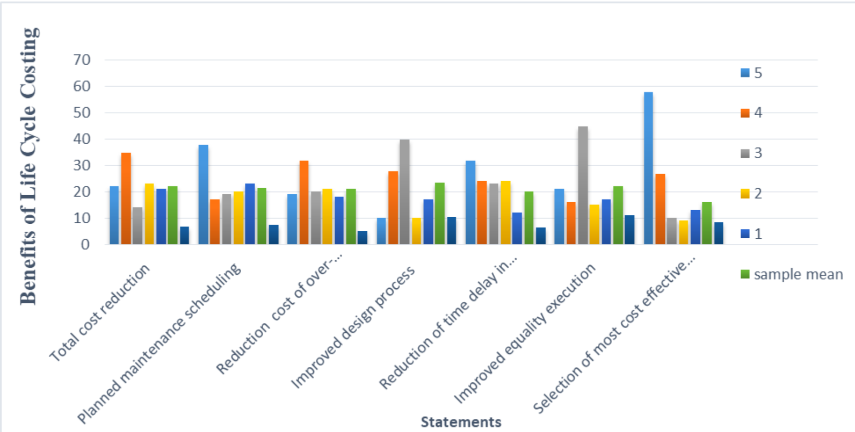

Figure 2 Benefits of Life Cycle Costing

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

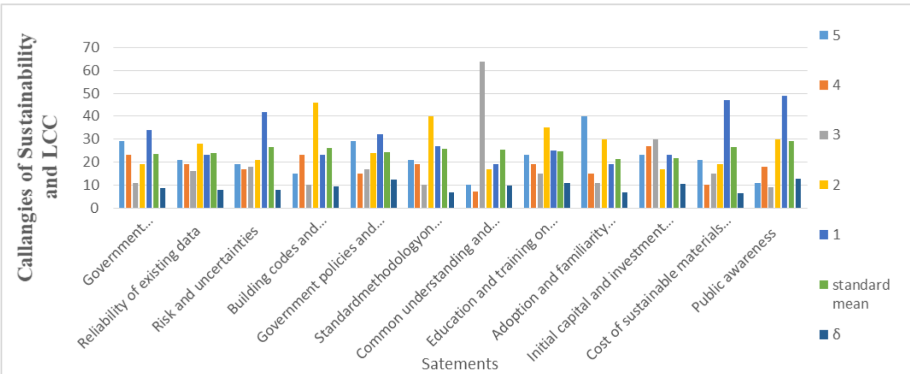

Figure 3 Challenges on the use of Sustainability and LCC

The results for recommendation toward advancement of sustainability and LCC concept are shown in figure 4.

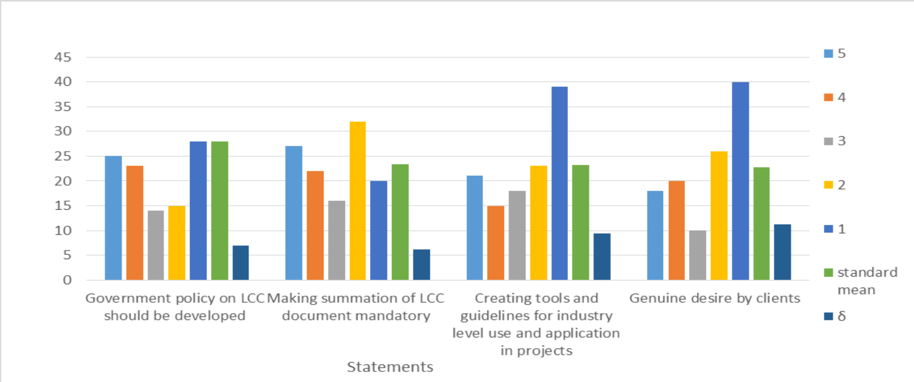

Figure 4 Recommendation Toward Advancement of Sustainability and LCC Concept.

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.

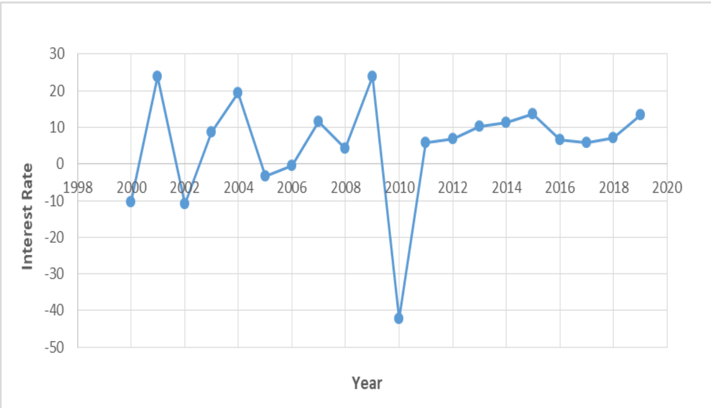

Figure 5 Interest Rate

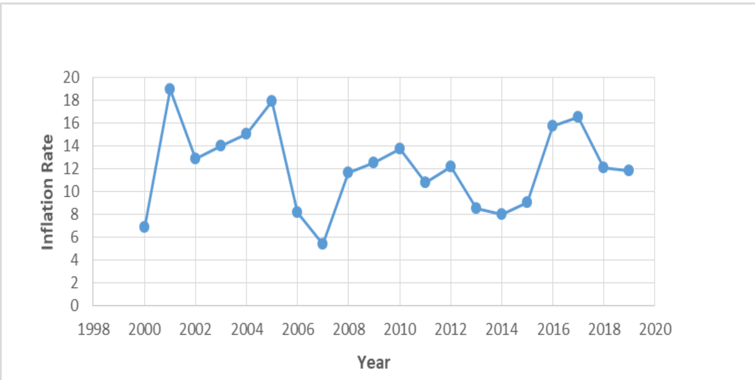

Figure 6 Inflation rate

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

		Discount Rate 4%							
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						
2016	1	3348600	0.961538	3219807.7	2041	26	34944275.02	0.360689	12604024
2017	2	3640000	0.924556	3365384.6	2042	27	36062822.09	0.346817	12507184
2018	3	3847060	0.961538	3420022.3	2043	28	37313975.68	0.333477	12443370
2019	4	3026000	0.854804	2586637.5	2044	29	38257237.63	0.961538	11964779
2020	5	12720050	0.821927	10454954	2045	30	39660000.16	0.308319	11795421
2021	6	11651476	0.790315	9208330.7	2046	31	40560029.59	0.29646	11757614
2022	7	13066616.29	0.759918	9929554.5	2047	32	41999428.07	0.285058	11561958
2023	8	14673756.57	0.73069	10721970	2048	33	43175672.26	0.274094	11511799
2024	9	18993341.3	0.702587	13344470	2049	34	44370600.89	0.263552	11693965
2025	10	10389272.06	0.675564	7018619.9	2050	35	45556721.14	0.253415	11244197
2026	11	14517669.52	0.649581	9430401.3	2051	36	46742841.39	0.243669	11100748
2027	12	16355050.88	0.624597	10215317	2052	37	47921203.62	0.234297	10951700
2028	13	31882417.3	0.600574	19147754	2053	38	49114265.25	0.225285	10795949
2029	14	22927432.07	0.577475	13240021	2054	39	50300354.09	0.216621	10639162
2030	15	18972446.83	0.555265	10534726	2055	40	51486442.93	0.208289	10477013
2031	16	20017461.6	0.533908	10687486	2056	41	53765790.75	0.200278	10311598
2032	17	21612476.37	0.513373	11095267	2057	42	53962740.52	0.192575	10353943
2033	18	22851568.52	0.493628	11280177	2058	43	55152461.45	0.185168	9992183.7
2034	19	26925820.44	0.474642	12780137	2059	44	56342182.38	0.178046	9819694.4
2035	20	27804571.51	0.456387	12689643	2060	45	57531903.31	0.171198	9645692.1
2036	21	28994522.1	0.438834	12723771	2061	46	58721624.24	0.164614	9470548.5
2037	22	30184472.68	0.421955	12736501	2062	47	76623022.82	0.158283	9294608.7
2038	23	31374423.26	0.405726	12729430	2063	48	62493705.9	0.152195	11661623
2039	24	32564373.85	0.390121	12704062	2064	49	63726058.66	0.146341	9145398.9
2040	25	33754324.43	0.375117	12661814	2065	50	64958411.42	0.140713	9140468
Salvage Value =145707728.80, Initial Cost = 5719455950.50, LCC = 899940966.50									

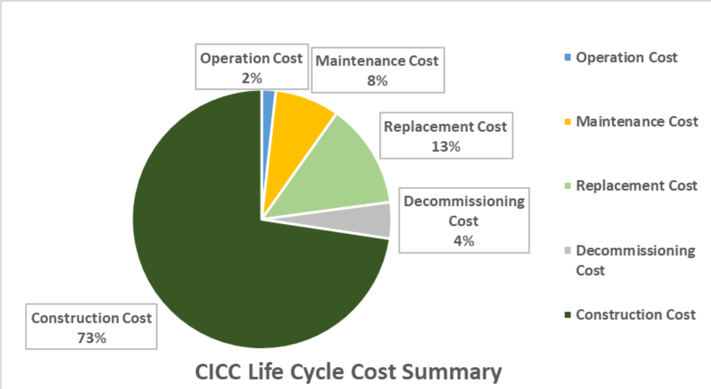

Figure 7 Forecast Cost Summary of CICC Building Project

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	$3391m^3$	$1.269m^2$	15000	320,000,000
2	Cost of labour	2658hr	$0.06hr/m^2$	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

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Disclosure of conflict of interest

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

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