APPLICATION OF MONTE CARLO SIMULATION IN EVALUATION OF COST ASSOCIATED WITH GREEN BUILDING PROJECTS IN NIGERIA

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ABSTRACT

Application of Monte Carlo Simulation in evaluating the cost associated with developing green building projects was carried out through distribution and collection of questionnaires from constructions workers in Owerri Metropolis. Relative Importance Index was deployed to determine relative importance of the numerous reasons why delay happens in the construction of green building which is associated with time and cost overrun. Cost of development of green buildings was evaluated to encourage building developers to adopt green building development projects because of their energy friendly nature that helps to preserve the Ecosystem via low level emissions that leads to enhanced energy efficiency and also limit harmful effects of buildings in ecosystems. However, engaging in this sort of project is not without risks attached especially in a country like Nigeria where the green building projects are not yet very common Thus evaluating cost of developing green building projects in Nigeria using Monte Carlo Simulation which was assessed through Microsoft Excel (version 2018) . The study also adopted the survey research design for and also adopted Owerri as the research area for the simulation. Descriptive statistics were adopted for the study in their order of prevalence through the Relative Important Index (RII) rating. Several risks were computed and the results show that non availability of labour was the most prevalent issue since the workers were not used to green building while the other factors such as cost factors, material availability, administrative skills, policies and codes as well as the limitations in communications. Monte Carlo Simulation was used to give several predictions which helped in forecasting Cost of foundation, Material Cost, Labour Cost, Equipment Cost, Wall facility Cost, Widow design Cost, Cost of green building development as well as Cost of Interior.

Keywords: Risk Factors, Relative Important Index, Monte Carlo Simulation, Sustainable Buildings.

INTRODUCTION

The act of building is full of several risks. In fact, according to Kang et al., sited in (Okoye et al., 2022). The industry is compounded with several complicated and time exhausting qualities, yet is filled very high levels of risk magnitude (Mohamed, 2017). This hence attaches so many protocols to construction economically, socially and environmentally Xiahuo, 2018 as these also have a direct relationship with the construction industry. This makes the construction industry to have more effects in terms of sustainability than other industries of the world Willar

et al., 2020). For instance, the industry has been observed to affect up to 50% of the energy consumption of the whole world, 50% of solid waste products among people, 50% of the carbon emissions into the environment as well as a substantial amount of the usage of natural resources according to Thomas & Reddy, 2016, sited in (Okoye et al., 2022). There are also evidence that the building industry directly consume up to 40% of the world's raw materials according to Bribian (Okoye et al., 2022). The building industry leads to an increase in pollution, result in the removal of several green plants as well as improper water or energy usages and even often prove to be harmful to the environment (Pearce & Ahn, 2013). The rise in global population and the growing urbanization needs resulted to the green building construction concept with the goal of providing an energy-efficient sustainable construction method that will prove less harmful to the environment as well as result to a massive energy efficiency and building sustainability (Okoye, et al., 2022). According to the United States Green Building Council (USGBC) in 2012, green building is a sustainable way of curbing the menace of global environmental damage. (Mohamed, 2017). The USGBC further stated that there is more efficiency in the use of eater resources, enhances energy efficiency, generates lesser waste products, and limits the negative impacts of construction in the environment where there is sustainability in the building.

Hence a green building is one which uses efficient resources and environmentally friendly materials in the lifespan of a building, from the design, building up, management, demolition as well as renovation according to Vyas, et al., sited in (Çiner et al., 2019). The building also minimize the effects of pollution, protect the ecosystem from substances such as carbon emissions and also has an enhanced level of comfort from the inside (Akreim & Suzer, 2018).

But in lower once economy such as Nigeria, it is very difficult to actuate sustainable green buildings since majority of construction works are centered on traditional construction idea according to Kibert 2016, sited in (Okoye et al., 2022). This is because this sustainable construction takes a lot of high level approaches, costly materials and complicated designs to complete, with higher level of communication required among the professionals of the project.

The high level of tasks required for implementation is without its own associated risk. The risks involved make the construction to be full of uncertain circumstances. The various risks in green building makes it capital intensive to implement as well as time wasting. Extreme risks in the industry can as well lead to damages or losses for all the actors involved in the green building project. The various risks involved in sustainable green building in Nigeria is very unique since they do not display the normal known risks involved in other unsustainable buildings. The risks are usually affiliated with several uncertainties because of the diverse nature of these risks and these risks become even more diverse due to the activities of several stakeholders, demands in the building activities. Apine and Valdés noted that risks in green building construction increases when new materials and processes are adopted even to the point that there was need for the integration of safety measures which even increased the risk propensity of the project. These several risks resulted to the limitations of using sustainable green building models in Nigeria. Some research specialists have noted that risk identification and risk analysis are the most crucial aspects of risk management. This assessment in the building sector can minimize time wastages as well as cost while also enhancing quality and safety of the workers and the project. This study thus achieved the following objectives (Lu et al., 2016).

i.   Identify the various risks associated with green building construction risk in Nigeria

ii.   Make a quantitative assessment of the financial risks involved in a green building project for a Bungalow in Owerri following the Monte Carlo Simulation technique.

LITERATURE REVIEW

These days, people know of the importance of incorporating sustainable construction algorithms in all aspects of building projects. Although there are several categories of risks involved in sustainable green building today. If these risks are not properly managed, they could result to failed projects. As identified by Hwang these risks are not very similar to those of the conventional buildings which led to the discovery of several types of risks.

Apine thus identified more cost, excessive job requirements, inability to meet up with the codes and certifications associated with green building, schedule, and immediate effects on the environment, professionalism, material availability and management as well as performance.

The studies of El-Sayegh, classified the risks they identified into five categories which include administration, technical, green team, green equipment as well as the policies and still identified cost related risk as the most prevalent.

More studies such as the one done by Ismael identified improper awareness as the most prevalent risk facto involved in the sustainable green building, with poor level of expertise from designers and contractors the major factors that hindered the sustainable green building in Kuwaiti building sector. Though the study also identified expenses in purchasing the sustainable materials as well as equipment, increased level of initial cost, poor awareness and poor experience from the contractors are the major risk factors affiliated with the construction of sustainable green building.

These risks are even worse in developing countries such as Nigeria where the concept is not too common. This is because majority of the construction firms and employees are not ready to yield in, considering the high level of risk involved. For instance, Agbimien & Susanti identified the cost related factor and poor expertise as well as limitation in competent personnel and inadequate communication as the limitation in the effective implementation of sustainable green building in places such as Nigeria.

These complications associated with sustainable green building in developing countries have thus resulted to the need to actuate effective management measures to contain the potential risks. These measures also involve the adoption of certain models. This became apparent since researchers such as Wu et al. (2019) claimed that the various risks have been assessed to improve performance in the aspects of cost, time as well as quality.

Nemuth in 2008 made an assessment of risk management in the German building sector through the use of a certain tool. The exact project was managed on the basis of Monte Carlo Simulation which helps the management to analyze project risks and understand how to tackle them. The model helped to sieve highly risky projects in a separate position and place special evaluations on them.

Peleskei determined the challenging arena of finding and quantifying the risks related to construction as well as their expenses. The study adopted the Monte Carlo Simulation (MCS) which provided clues on how to handle the project costs.

Arunmohan, researched on the analysis of modern building projects using the MCS. The study focused on how the model would affect schedule as well as time, although the study was still prevalent in India.

Rajgor, 2016 researched on the factors resulting to delays of sustainable green building and thus determined them as well as tackling them using the Relative Importance Index (RII) technique.

Hence there are no clear studies on the application of the Monte Carlo Simulation technique in the Nigeria construction industry to minimize risks associated with sustainable green building construction which calls for this study. This study will focus exactly on bungalow, which is one of the smallest units of housing found in Owerri.

THEORITICAL REVIEW

Green Building Concept establishes that. Green building is a kind of high-quality building. Based on the relationship between man and nature. This concept is developed to protect the environment to a maximal extent, Green buildings save resources to the greatest extent in their lifecycle, so as to protect the environment and reduce pollution. Ecological architecture is the architectural system of group and single buildings and their surrounding environment based on the principle of ecology. Sustainable architecture is an environmental protection living architectural culture that needs to be completely shaped from the Earth scale such as ozone layer destruction, global warming, and biodiversity. Sustainable buildings, ecological buildings, and green buildings are energy-saving buildings.

Cost of Green construction project can be linked to Market development environment which shows characters of relevant stakeholders. This market development environment basically refers to the structure of major green building market, the quality of the market, correlation between demand and supply within the market, the status of technically sound green construction project market environment. The sustainability of green construction project market can be achieving through drivers that support the market development environment (Jiaying et al., 2019).They also noted that attitudes and positive trends of behaviour of stakeholders, helps the sustainability of construction technology.

The concept of Ecological value of green construction projects refers to the ecological benefits of high energy savings, water savings, land savings, material conservation, solid waste reduction, and indoor human health support (Jiaying et al., 2019).They also identified the concept of economic value of green construction project which refers to the economic benefits brought by green construction Projects that supports the green construction project sustainability. They did not fail to identify the degree of social participation which supports the effective implementation and sustainable development of green construction projects emanating from green building education for the immediate population, training, and opinion of the public, green construction project reputation, government regulations, and standards.

Fenesta (2019) specified that one of the largest wind turbine suppliers in the world, (Suzlon Generators in Pune) has implemented the green building theory such that, more than 70% of the materials they used in its interiors shows reduced carbon footprint. It also installed jet fans in its basement, with savings of about 50% energy as comparism with ducted base ventilation systems.

Figure 1 below shows the components of green building construction projects that is environmentally friendly and gives it the capacity to sustain human life through human health hazard reduction.
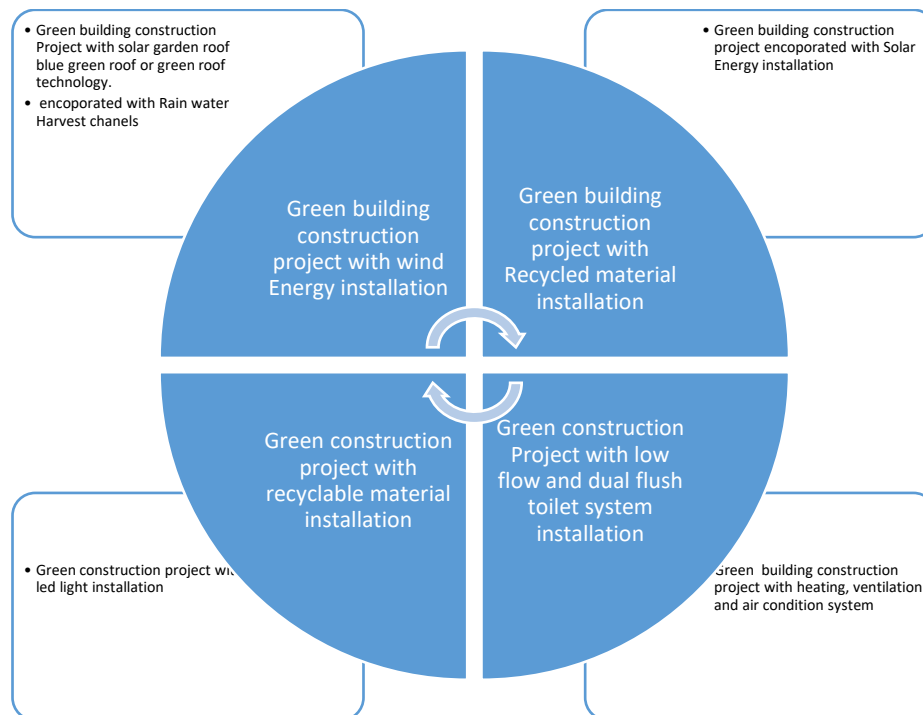
FIGURE 1
COMPONENTS OF GREEN BUILDING THAT ENHANCES HUMAN LIFE AND ENVIRONMENT

Another possible way to help the achievement of evaluating cost involved in construction of green construction project is through Green Building Information Management (GBIM). This concept of GBIM tools will support the construction industry to function efficiently and sustainably with achievement of improved green building performance objectives. Wu et al. (2015) in Alix et al 2020. The construction sector can use GBIM to help facilitate cost evaluation processes by helping in documentation all planned budget for cost estimation purposes.

METHODOLOGY

This study adopted the survey research design. This will thus involve the distribution and collection of questionnaires from constructions workers in Owerri metropolitan region. Owerri was adopted due to the pace of construction green building works going on in the area. Thus the need to ensure that construction activities are geared towards sustainability. Relative Importance Index (RII) was used to determine mean, weighted mean, Percentage and Standard Deviation (S.D.). The RII is deployed when there is need to determine relative importance of the numerous reasons why delay relating cost overrun (Oluwunmi et al., 2019).

The RII = ∑w / (A × N)

The RII and the mean scores were recorded from a 5-point Likert scale in a chronological order of 5- Strongly Agree, 4-Agree, 3- Undecided, 2- Disagree and 1- Strongly Disagree. The data obtained were run through Statistical Package for Service Solutions (IBM SPSS version 21).

Various risks were noted, giving room for a quantitative analysis of risk through the use of the Monte Carlo Simulation (MCS) through Microsoft Excel (version 2018). Special functions such as the mean, standard deviation and probability were all used. Special emphases were made on the financial risks since it negatively influence projects especially in green building.

RESULTS AND DISCUSSION

Table 1 FACTORS OF RISK ANALYSIS USING RII		
Rank	Factors	RII
1	Labour availability	0.921
2	Cost related factors	0.903
3	Materials availability	0.822
4	Administrative skills	0.799
5	Green building Policies and codes	0.774
6	Communication limitations	0.765

Results as displayed in the Table 1 above shows that the required labour to engage in greenhouse building is the most prevalent factors with RII of 0.921 and followed closely by cost related factors with 0.903. In the chronological list, material availability with 0.822, administrative skills with 0.799, green building policies and codes with 0.774 and communication limitations with 0.765 are the other limitations.

Monte Carlo Simulation

This technique is adopted to determine and forecast uncertainties associated with financial risks. In the model, several assumptions are made, mainly on the several categories of cost associated with sustainable green building construction of bungalows in Nigeria.

The assumptions are made based on what is obtainable, considering similar past projects. Hence that is why range of values are adopted which, in this study involves minimum attainable cost, the probable cost and the possible maximum cost of the project. The mean and standard deviation are thus used to estimate the simulation values. This means that the final estimates will also be varying as it starts from a constant point.

More quantitative analysis is adopted to categorize the risk based on in their order of prevalence. After the assumptions are made in the Monte Carlo Simulation, the following table 2 is produced:

/N	Variables	Minimum Cost Forecast (N)	Expected Cost (N)	Maximum Cost Forecast (N)	Mean	Standard Deviation	Simulated Cost (N)
	Cost of foundation	7,000,000	7,540,000	8,500,000	7,680,000	620,322.5	7,693,404
	Material Cost	10,000,000	13,000,000	16,000,000	9,100,000	6,034,899	11,227,722
	Labour Cost	1,200,000	1,500,000	1,900,000	1,533,333	286,744.2	1,700,836
	Equipment Cost	5,000,000	5,010,000	5,600,000	5,203,333	280,515.4	5,297,931
	Wall facility cost	3,000,000	3,060,000	4,000,000	3,353,333	457,918	4,202,696
	Window design cost	1,200,000	1,200,000	1,750,000	1,380,333	259,272.5	1,438,085
	Cost of green growth	300,000	500,000	800,000	533,333	205,480.5	744,977.2
	Interior Cost	3,600,000	4,000,000	4,600,000	4,066,667	410,960.9	3,472,941
	Total						**35,778,592**

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Table 2
FORECAST AND SIMULATION OUTPUT

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After the simulation, the overall costs was obtained as N35, 778, 592. A histogram of the distribution after the simulation is displayed below Figure 2.
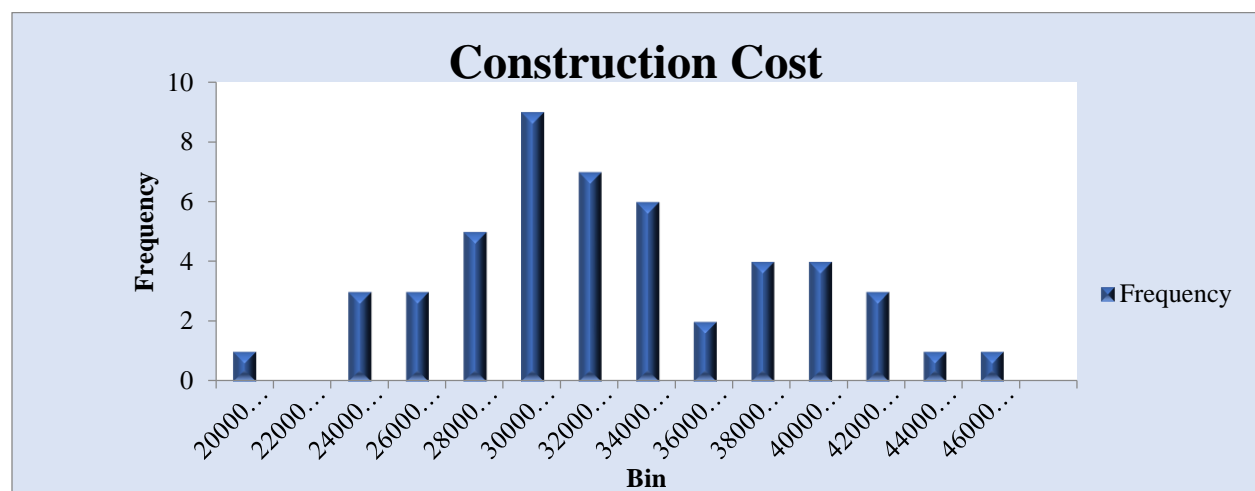
FIGURE 2
HISTOGRAM DISPLAYING REPORT SUMMARY OF COST SIMULATION

This means that in the course of this green building project, the probability of completing the project is highest at approximately N30,000,000.00. This finding is thus in

tandem with the findings of Nemuth assessed risk management in the German building sector through the use of a certain tool. The model assisted in giving clarity of risks associated with some projects in the area. This is also applicable in this situation as the simulation gave a prediction on the overall building cost. This study also aligns with the studies of Peleskei on Monte Carlo Simulation as he used the simulation to predict overall project cost.

CONCLUSIONS

The building industry takes a lot of energy globally. This created the need to engage in sustainable green buildings construction project that will lead to enhanced energy efficiency and also limit the harmful effects of buildings in ecosystems. However, engaging in this sort of sustainability is not without risks attached, like financial risk. Furthermore, Nigeria very low level infrastructural development that is actually insufficient especially in area of green building development. That necessitated the research to evaluate the cost associated with development of green buildings using Monte Carlo Risk Analysis. Several risks associated with cost of green building development in Nigeria was assessed and the financial risks associated green building in Owerri, Imo State was calculated using Monte Carlo Simulation. The result shows that labor availability was the most prevalent issue since the workers are not used to green building. This was followed by other factors such as cost factors, material availability, administrative skills, the policies and codes as well as the limitations in communications. This research dictated that the overall cost of green building development was estimated to be N30, 000, 000 from a range of N2, 000, 000, Thus professionals are expected see this simulated output and ensure they budget accordingly. Though the present Economic situation may not be the same as at the time any further calculation on cost of green building construction project may be done but this would serve as a guide to professionals in the field.

Further Research

Further research can be conducted on development of model support framework for evaluation of cost associated with different green construction project where different green construction projects would be identified and associated cost of each of the projects would be evaluated using the Model support framework.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the author(s) used [AI / SERVICE] in order to [GET SOM INFORMATION ON GREEN BUILDINGS]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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