A Literature Review of Methods in Research on Green Building Cost Analysis

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Abstract. Development greatly influences environmental sustainability and quality. The concept of green building is one solution to minimize environmental damage due to construction. The concept of green building requires greater investment than conventional building. Life Cycle Cost (LCC) impacts the cost of planning, building's operational and maintenance cost and residual cost. Recently, research of green building on cost analysis is developing rapidly. There are so many studies of green building on cost analysis with different methods. This research addressed several relevant methods and is expected to set clear which methods to use for the future research under green building topics. This journal is meant to find out research method used in determining green building on cost analysis. The method to be carried out is a literature review of 14 relevant reputable journals from 2013-2020. The most widely used method is the Life Cycle Cost Analysis (LCCA).

1 Introduction
The construction industry in developing countries account for around 30% of total greenhouse gas emissions [1]. CO₂ gas emissions generated by the building sector accounted for 34.8% of the total energy use in the world [2]. The concept of green building is one solution to minimize environmental damage due to construction [1]. Not only maximizes savings in energy, green building also makes an effective use of space. It harmonizes with nature the way it preserves the environment, result in less pollution and a maintained health. The characteristics of green building are environmental improvement and human health, efficiency of natural resources and building materials, and water and energy efficiency [3]. Green building has attracted widespread attention since the early 1990s. Until now, research on green building has been carried out in many different disciplines [4]. Until now there is still debate about the differences used for green building. However, there are some studies mentioning that the application of the concept of green building requires greater investment than conventional building. The high initial cost of construction is a major obstacle in applying the concept of green building.

There are several methods to measure and analyze the effect of applying green building on cost analysis, namely LCC analysis, payback period, Net Present Value (NPV, sensitivity analysis, regression analysis and fuzzy analysis. Some studies applied LCC calculation methods such as in studies [19], [22], [23], [27], [28], [29] and [32] while studies that applied regression analysis are those such as research [20] and [21]. In addition, studies [19], [22] and [25] applied the sensitivity analysis method. This journal is meant to find out research method used in determining green building on cost analysis.
2 Conceptual Background

2.1 Cost Analysis of Green Building
Cost of planning, operational and maintenance cost and residual cost are part of the Life Cycle Cost (LCC). LCC is the total cost of a building over its lifetime and includes the cost of planning, design, operation, maintenance, minus the residual value [5]. At present, most building are only concerned with initial capital cost such as land, projects and construction cost without regard to the operational and maintenance cost of the building. This does not happen if you apply the concept of green building. Emphasis on initial cost by using green building materials has a small operational cost. While conventional building that do not apply the concept of green building result in higher energy use cost and also lower sustainable level (such as higher carbon emissions) [6]. Cost analysis have been carried out in previous studies, such as the Weerasinghe and Ramachandra study [22] who analyzed the cost differences in applying green building and conventional building using survey methods, LCC analysis and sensitivity analysis.

2.2 Methods of Previous Research

2.2.1 Types and Data of Research. In general, the type of research is divided into 2 namely quantitative and qualitative research. Quantitative method is a method that explains the data obtained into statistics, while the qualitative method is a method that explains the data obtained to be descriptive to produce meaning and understanding of a thing [7]. Primary data is original data collected by researchers directly. While secondary data is data that has been collected and analyzed by others [8].

2.2.2 Research Techniques. The following are the methods used by previous researchers regarding the effect of applying green building on cost analysis.

a. Life Cycle Cost Analysis (LCCA) is a method that analyze the total cost in the form of construction, operational cost and the residual value of building [9]. LCC considers all cost including initial cost, such as capital investment cost and construction cost; future cost, such as energy cost, operational and maintenance cost; and depreciation cost. The advantage of LCCA is calculate all cost over the age of the building thereby reducing the risk the failure of investment. Meanwhile, the disadvantage of this method is can’t calculate budget allocation [10].

b. Sensitivity analysis is a method that measures the uncertainty impacts one or more variables. This method is useful to improve the model prediction that will be made. The results of various parameters can be used to evaluate resilience, alternative different outcomes and analyze values with results that can change significantly. Disadvantage of sensitivity analysis is this method based on assumptions [11].

c. Payback period is the time needed to recover investment. This method is to calculate the breakeven point of investment. Payback period only counts how quickly a company will recover cash investment [12]. Disadvantage of payback period is ignored time value of money and too much emphasis on short-term benefits [13].

d. Regression analysis is a quantitative method that measures the effect of dependent variables with an independent variable [14]. In the regression graph there is a sufficiently low-dimensional summary plot. These plots, which do not require a model for their construction, all contain information about the responses available from the predictors. This method is used to visualize dependencies, find unexpected relationships and examine the right model. Disadvantage of regression analysis is easily affected by outlier [15].

e. Fuzzy analysis is a method used to analyze the uncertainty, such as decisions making, planning and production problems [16]. Disadvantage of fuzzy analysis is required a lot of data and expertise to develop this method [17].
f. Net Present Value (NPV) is present value of cash flow at the project rate of return compared to the initial investment. This method is used to calculate the Return on Investment (ROI) for projects or expenses. NPV analyzes cash flow and time value of money [18]. The disadvantage of this method is the inaccurate calculation between projects with different economies [13].

3 Results and Discussion

3.1 Methodology

This research is to analyze the method used in influencing the application of green building in stages of cost analysis. Various sources from reputable journals in this study to be analyzed. There are 14 publication journals published from 2013 - 2020. The following is a list of journals with rank and SJR of each journal listed in table 1.

| Journal Publication                        | SJR  | Quartiles Category                                           | Number of Papers |
|--------------------------------------------|------|-------------------------------------------------------------|------------------|
| Renewable Sustainable Energy Reviews       | 3.632| Q1 in Renewable Energy, Sustainability and the Environment  | 3                |
| Journal of Environmental Economics and Management | 2.393| Q1 in Economics and Econometrics                            | 3                |
| Energy Policy                              | 1.988| Q1 in Energy (miscellaneous)                                | 1                |
| Journal of Cleaner Production              | 1.886| Q1 in Renewable Energy, Sustainability and Environment      | 1                |
| Building and Environment                   | 1.871| Q1 in Building and Environment                              | 2                |
| Cities                                     | 1.606| Q1 in Urban Studies                                         | 1                |
| Regional Science and Urban Economics       | 1.419| Q1 in Urban Studies                                         | 1                |
| Sustainable Cities and Society             | 1.047| Q1 in Civil and Structural Engineering                     | 1                |
| Built Environment Project and Asset Management | 0.515| Q2 in Civil and Structural Engineering                     | 1                |

Based on table 1, information about 14 reputable journals was obtained to measure the effect of the application of green building on cost analysis.

3.2 Result

Based on the literature review, a description of a number of methods used in analyzing the effect of applying green building on cost analysis was obtained. The following is an explanation of the types and research data used in 14 journal publications. There is an explanation Y (Yes) is used to state the use of research types and data that are appropriate and N (No) is used to express the use of research types and data that are not appropriate. The following is an explanation of the theoretical mapping from previous research presented in table 2.
| Cost Analysis of Green Building | Type and Data of Research | Methods                                      | Objectives                                                                 |
|--------------------------------|---------------------------|---------------------------------------------|-----------------------------------------------------------------------------|
|                                | Quantitative | Qualitative | Primary Data | Secondary Data |                                  |                             |
| Li et al [19]                  | Y            | N           | N            | Y              | Literature Review, LCC Analysis and Sensitivity Analysis | Calculate and analyze LCC and sensitivity analysis of green building |
| Chegut et al [20]              | Y            | N           | Y            | N              | Survey and Regression Analysis    | Analyze the difference in marginal cost used between green building and conventional building |
| Devine and McCollum [21]       | Y            | N           | N            | Y              | Literature Review and Regression Analysis Survey, LCC Analysis and Sensitivity Analysis | Analyze the relation between development of finance and green building |
| Weerasinghe and Ramachandra [22]| Y            | N           | Y            | N              | Literature Review and Regression Analysis Survey, LCC Analysis and Sensitivity Analysis | Compare LCC of green building and conventional building |
| Vyas and Jha [23]              | Y            | N           | Y            | N              | Literature Review, Survey and Fuzzy Analysis, Payback Period and NPV | Develop the concept of green building in accordance with the rules of the Government |
| Khoshbakht [24]                | Y            | N           | Y            | N              | Literature Review and Sensitivity Analysis | Developing research systematically with the criteria of green building materials that consider the 3 pillars of sustainability |
| Deng and Wu [25]               | Y            | N           | N            | Y              | Literature Review and Sensitivity Analysis | Evaluate energy efficiency in green building from a developer's perspective |
| Fan et al [26]                 | N            | Y           | Y            | N              | Survey and Descriptive Analysis    | Improve the efficiency of green building with transaction cost analysis |
| Illankoon and Lu [27]          | Y            | N           | N            | Y              | Literature Review                  | Analyze literature review of journals from 2005 to 2018 |
| Cost Analysis of Green Building | Type and Data of Research | Methods | Objectives |
|--------------------------------|---------------------------|---------|------------|
|                                | Quantitative | Qualitative | Primary Data | Secondary Data | and LCC Analysis | on critical success factors for green building |
| Dwaikata and Ali [28]          | Y            | N            | Y            | N              | Survey and LCC Analysis | Analyze and develop LCC of green building that reach 60 years the age of building |
|                                |              |              |              |                | Literature Review, Interview and LCC Analysis | Analyze LCC of green building wood materials to fulfill the requirements of the Green Start rating tools |
|                                |              |              |              |                | Literature Review and LCC Analysis | Evaluate the LCC net-zero energy building design with energy efficient heating, ventilating and air conditioning (HVAC) system and solar power generation system |
| Tam et al [29]                 | Y            | N            | Y            | N              | Literature Review and LCC Analysis | Analyze concept of green building using LCC analysis |
|                                |              |              |              |                | Literature Review and LCC Analysis | Analyze the optimal condition between building energy performance and investment cost using LCC analysis |
| Kim et al [30]                 | Y            | N            | N            | Y              | Literature Review and LCC Analysis | |
| Zuo et al [31]                 | Y            | N            | N            | Y              | Literature Review and LCC Analysis | |
| Annibaldi et al [32]           | Y            | N            | Y            | N              | Survey, Interview, and LCC Analysis | |

The use of questionnaire distribution and expert opinion as data collection tools has been carried out by [20], [22], [23], [24], [26], [28], [29] and [32]. The dominant analysis used is LCC analysis as in the studies of [19], [22], [23], [27], [28], [29], [30], [31] and [32]. Meanwhile sensitivity analysis is used by researchers [19], [22] and [25]. Regression analysis is used by researches [20] and [21]. The only one Fuzzy analysis is used by researcher [24].
3.3 Discussion
Judging from previous research, a mapping diagram is formed. Mapping diagram is a group of previous research based on data sources and types of research. Data sources are on the X axis in the form of primary and secondary data, while the Y-axis in the form of research types is qualitative and quantitative. The mapping diagram can be seen in figure 1.

![Mapping Diagram of Research Type and Data](image)

**Figure 1.** Mapping diagram of type and data research

Based on figure 1, it is found that the most dominant method used is research that uses quantitative types with primary data.

4 Conclusion
The most widely used method is research with quantitative methods with the types of primary data described in journals [20], [22], [23], [24], [28], [29] and [32] with differences in analysis namely regression analysis, LCC analysis, sensitivity analysis, payback period, NPV and fuzzy method. From the explanation above, it is also obtained that the most widely used analysis is the LCC analysis. This paper can help future research on the application of green building to cost analysis by using appropriate methods and analysis.

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