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Research Article

Green Building and Cost Efficiency: Life Cycle Cost Study at ITSB Campus

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Abstract.
This study examines the implementation of the green building concept at ITSB campus using life cycle cost (LCC) analysis. The focus of the research is to determine cost efficiency in the use of energy and water, as well as to identify the proportion of costs incurred throughout the building's operational period. The results indicate that the initial investment dominates the total project cost, accounting for 92%. Despite the high initial investment, the application of environmentally friendly technologies in the building successfully reduced operational costs, particularly energy usage, resulting in savings of Rp 678,890,260. This study provides important insights for project planning in Indonesia, especially regarding sustainability, cost efficiency, and environmental impact.

Keywords: green building, life cycle cost, cost efficiency, sustainability, ITSB, energy savings

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1. Introduction

The growing awareness of environmental issues and the depletion of natural resources has become a driving force for innovation in the construction industry, emphasising the importance of sustainability. Awareness of the condition of resources and the environment as a source of primary construction materials has made the development of innovation in the construction sector pay more attention to the environment. The UN Commission on Environment and Development in 1987, under the leadership of Gro Harlem Brundtland, agreed on the relationship between the concept of development and environmental management, which was later known as the concept of sustainable development, namely a development that is able to meet the needs of today's society without ignoring the ability of future generations to meet their needs (1).

This approach not only highlights the ecological balance but also stresses the social and economic pillars essential for long-term viability. A simple understanding from an economic perspective, especially the neo-classical economic view, sustainability can be interpreted as maximising welfare over time (2). Sustainability is a fundamental attribute in economic activities, encompassing not only productivity (3), but also the quality of consumption and capital investment attributes. Munasinghe identified that sustainable development has three main objectives, namely economic objectives, ecological objectives, and social objectives (4).

In recent years, the concept of green building has gained global attention as part of sustainable development efforts. One of the constructions that pays more attention to the environment is green building. Green buildings use resources such as energy, water, building materials, and land more efficiently than conventional buildings. By minimising resource consumption and reducing environmental impact, these buildings contribute significantly to sustainability objectives. Sustainable development emphasises economic, environmental, and socio-cultural aspects (5). Danusastro further emphasised that sustainable development is a meeting point between the environmental, social, and economic spheres, explaining that sustainable development requires three equally potent and mutually supportive sectors, namely economic growth, environmental protection from the harmful effects of development, and improving the quality of life of the community (6). The three elements of sustainable development can be seen in Figure 1.

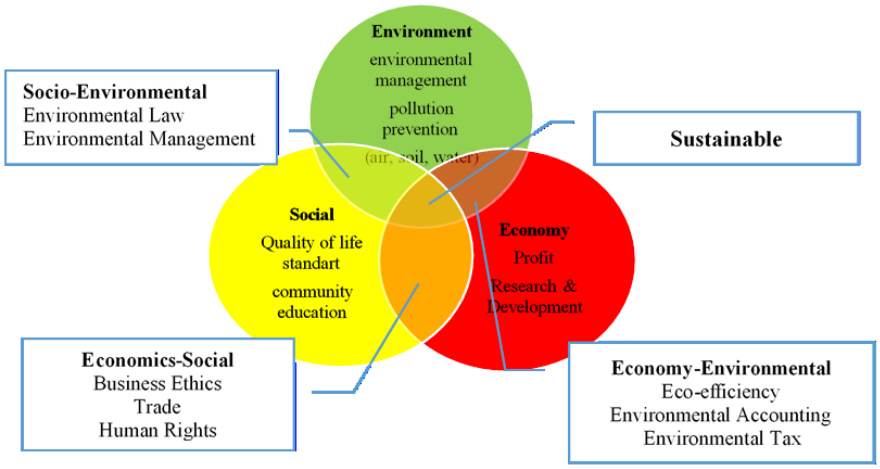

Figure 1: Three elements of sustainable development. Source: Danusastro (2010) in Rachman (2011).

While green building practices have become more prevalent worldwide, their adoption and evaluation in Indonesia remain limited. Many studies on green buildings have been conducted. Still, most green building studies in Indonesia only analyse the technical impact of green buildings, while assessments related to the effects of green building implementation in terms of sustainability are still few. This is in contrast to research that has been conducted outside Indonesia regarding the sustainability value of green buildings. Based on this, research is needed to assess the impact of green building implementation in terms of sustainability in Indonesia. Research related to building costs includes life cycle cost (LCC), as conducted by Firsani et al. (2012) and Kamagi et al. (2013).

2. Methods

Life Cycle Cost (LCC) analysis is used to calculate the economic aspects of construction projects, including energy and water conservation. LCC considers initial investments and the time required to recover those investments during the project period. It also accounts for other expenses such as material costs, professional labour, operational costs, and maintenance expenses. This analysis helps in understanding the total cost over a building's life cycle, including the comparison between green and conventional buildings. Life cycle cost (LCC) analysis is a widely used method of the analysis tools and techniques used to calculate economic aspects in the construction sector, technology value, and technology costs. In addition, LCC analysis is helpful and instrumental in evaluating the economic value of energy use and water conservation (7). The LCC analysis tool considers the initial investment and can conclude the estimated time required to return all investment costs during the construction project period. Another consideration is that LCC also includes other types of expenses such as construction material costs such as bricks and wood or materials to make buildings and professional worker costs (8).

LCC analysis also takes into account the costs required by a building during its operational phase, such as planning and construction costs, maintenance costs, and the costs of demolishing and recycling unused materials, which are carried out when the building is no longer functioning (9). LCC can be described from several sources. Namely, LCC is the simple total cost of something purchased, calculated during its use, and defined as a tool for selecting and evaluating the components and systems used in a building (8).

The assessment of economic criteria is based on Firsani et al. (2012). Energy costs are seen from the cost of electricity and water usage. Operational and maintenance costs are seen from operational costs, building maintenance costs, and building facility maintenance costs. The complete criteria can be seen in Figure 2. The values obtained from these criteria are then calculated to produce the total value of the green building cost cycle. The total cycle value is then compared with the total standard value. The total standard value is obtained from the average electricity and water usage costs of conventional building users based on the literature obtained. Then, the two calculation results are compared to see the difference in the operating costs of buildings that implement green buildings compared to conventional buildings.

Life Cycle Cost (LCC)is the cost required by a building during its technical life through the calculation of the planning and construction cost approach, maintenance costs, and the cost of demolition and recycling of unused materials carried out when the building has reached its technical age (9). Firsani et al.'s (2012) research is an LCC analysis study to see how much cost is incurred by a building with a green building concept during a specified period. In conducting an LCC analysis, relevant costs are needed, including initial costs, operational and maintenance costs, energy costs, replacement costs, and residual value. The results of the total value calculation carried out with the LCC analysis are then compared with the estimated value of the benchmark LCC calculated using energy and water usage indicators.

3. Result and Discussions

The location of building construction based on the Regulation of the Minister of Public Works and Public Housing Number 2 of 2015 concerning Green Buildings is to pay attention to the environmental conditions of building construction. Good building architecture is able to support climate change that occurs in the environment on campus. The design of a building, in addition to providing aesthetic value, can also increase the efficiency of energy use in the building. Such as the use of transparent glass that dominates the walls of the building to become natural lighting so as to be able to use electricity efficiently. The cleanliness of the building area can be seen from the presence of trash bins and the time of cleaning or disposing of trash.

The economic aspect analysis is calculated using the Life Cycle Cost (LCC) method to obtain the total value of the building's life cycle cost. The calculation is done by looking at the amount of costs incurred in 2016. The calculation of the amount of LCC of the

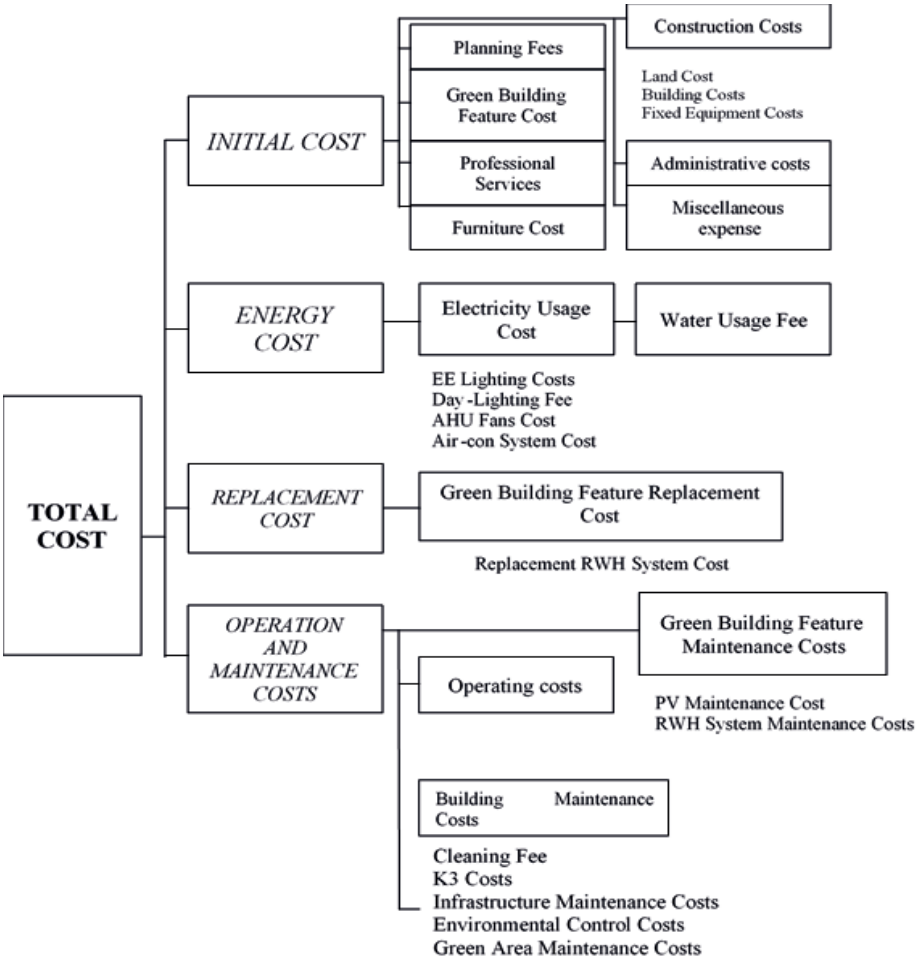

Figure 2: Company cost structure. Source: Firsani et al. (2012).

ITSB campus building is carried out using the research reference of Firsani et al. (2012), which is adjusted to this study. The cost calculation is divided into four categories, namely initial costs, energy costs, replacement costs, and operational and maintenance costs. Initial costs are not affected by the time value of money because they occur at the beginning. The estimated residual value of the building is not calculated because it only looks at the costs incurred in 2016, but ITSB is still in use. The construction of the campus building, which was ongoing at the time of the study, made the value of replacement and maintenance costs carried out in total.

3.1. Initial cost

The initial cost consists of planning costs, construction, features, professional services, moving equipment (furniture), and administration (10). The initial cost was obtained from the building manager, amounting to Rp. 17,264,129,534.

3.2. Energy costs

Managing the efficiency of resource use, especially electricity and water, is one of the crucial elements in maintaining project sustainability. Electricity and water costs will then be combined and referred to as energy costs. Based on Subkhania and Rasyid (2024), the calculation of energy cost efficiency can be seen in Table 1 as follows.

Table 1: Calculation of total electricity and water efficiency.

Efficiency	Amount (Rp)
electricity	34 228 740
water	647 921 400
Total	678 890 260

Source: Subkhania and Rasyid (2024)

3.3. Replacement, Operational, and Maintenance Costs

The ITSB building has been effectively used for eight years and has experienced minor damage several times. During this period, several lamps were replaced due to malfunction. At the time of the study, ITSB was carrying out minor maintenance on the building, such as roof repairs and repainting. Based on this, the replacement cost, operational, and maintenance costs were added together and obtained at Rp 800,000,000.

These costs are then accumulated to determine the expenses incurred by ITSB building management during 2016. Based on the data accumulated, the total LCC value of the use of the ITSB campus building is obtained from the percentage of costs per section. More complete information can be seen in Table 2.

Table 2: Total LCC value and percentage of each category in 2016.

Cost Category	LCC Value (Rp)	Percentage (%)
Initial costs	17 264 129 534	92%
Energy costs	678 890 260	4%
Operational, maintenance and replacement costs	800 000 000	4%
Total	18 743 019 794	100.00%

Source: Processed primary data (2024)

Based on the analysis results of Table 2 regarding the Life Cycle Cost (LCC) estimate, the total projected cost for the entire project life cycle reaches IDR 18,743,019,794.

Of the total cost, the most significant portion is allocated for the initial cost of IDR 17,264,129,534, which covers 92% of the total budget. This demonstrates that the initial investment dominates the project life cycle cost component, which is a crucial factor in long-term project financial planning. In addition, energy costs are recorded at IDR 678,890,260 or around 4% of the total cost, indicating that energy expenditure during the project's operational period is relatively low compared to the initial investment cost. Operational, maintenance, and replacement costs also take the same portion, which is 4% of the total cost, with a value of IDR 800,000,000. Although the proportion of operational and maintenance costs is not significant in percentage terms, this component remains crucial to maintaining the sustainability and operational efficiency of the project.

Overall, this LCC analysis shows that initial costs dominate the project cost structure while operating and energy costs are a smaller portion. This provides essential insights for project planners and managers in determining effective resource allocation strategies to achieve cost efficiency throughout the project life cycle.

4. Conclusions

Based on the *Life Cycle Cost* (LCC) analysis of ITSB campus buildings that implement the *green building* concept, it can be concluded that the initial cost dominates the project cost structure, accounting for 92% of the total expenses. Although a high initial investment is required, the application of environmentally friendly technologies in these buildings has successfully reduced energy and operational costs. Energy efficiency, particularly in electricity and water usage, reached Rp 678,890,260, reflecting significant savings compared to conventional buildings. These operational cost savings demonstrate that, despite the high initial costs, the long-term benefits of reduced operational expenses contribute to the sustainability of the project. This study underscores the importance of implementing *green building* concepts in Indonesia to support sustainable development, taking into account not only technical aspects but also economic and environmental impacts.

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