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# Analysis of The Application of The Life Cycle Cost Method of Green Retrofit of Mosque Building Based on Gbci and Edge Benchmarks to Improve Investment Performance

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**ABSTRACT**

This study conducts a comprehensive life cycle cost analysis (LCC) of green retrofitting in mosque buildings, assessing its financial feasibility and performance. The research involves a risk assessment of three crucial stages: pre-, construction, and post-construction. A Likert scale is employed for the validation process based on responses from 51 experts involved in green building retrofit projects. Results indicate that the highest risk occurs during construction, impacting investment performance. Sensitivity analysis reveals the potential longevity of investments, with pre-construction risks affecting the Net Present Value (NPV) in the 18th year and post-construction risks proving feasible by the 17th year. The study introduces benchmarks such as NPV, Internal Rate of Return (IRR), Benefit-Cost Ratio (BCR), and Break Even Point (BEP) for investment evaluation. The financial feasibility of green retrofit items, including solar panels and energy-efficient utilities, is confirmed with an NPV of IDR 140,797,698, IRR of 10.26%, and BCR of 2.21, with feasibility realized in the 17th year. Risk visualization through a Tornado Chart emphasizes the significance of each risk stage on NPV values. In conclusion, the study recommends broader case studies involving multiple certified green mosques for more accurate risk identification. This research provides valuable insights for informed investment decisions in mosque building green items, emphasizing the importance of risk management for long-term sustainability.



## Introduction

Green retrofit is an effort to convert an existing building into a green building where one of the applications of the building is a building that applies energy and water efficiency. New buildings still dominate the application of the green building concept in the world. This is inversely proportional to the number of existing buildings that are more than new buildings (Hidayah & Husin, 2022). Many studies have been related to applying the green building concept to new buildings, but not many have taken the object of existing buildings. In fact, in developing countries, the number of new buildings is only 2% of the total existing buildings, and the remaining 98% are existing buildings (Abdallah, 2023).

In previous studies, green retrofit research predominantly focused on buildings such as schools, offices, housing, etc. However, there is currently no research examining the application of green retrofits to mosque buildings as a case study object. The selected mosque for this case study boasts an area of approximately 24,200 square meters, complying with building requirements. This worship building is required to adhere to green building standards. Notably, the mosque has been awarded a green certificate from EDGE (Excellence in Design for Greater Efficiencies) and is currently undergoing assessment by the Green Building Council Indonesia (GBCI)

A mosque has always been considered 'green' as it upholds the true meaning of Islam. Meeting current requirements without compromising the ability of future generations to fulfill their own environmental, social, and economic needs forms the foundation of the 'green' or 'sustainable' concepts. This concept instills in us the idea that every human being must maintain and manage, not only for ourselves but also for everyone else—not just for the present but also for the future (Omar, Ilias, Teh, & Borhan, 2018).

The most significant energy consumption in mosque buildings occurs during their operation and is primarily related to the energy and water usage in the various rooms. The peak energy consumption is during prayer times and other activities such as lectures, weddings, and events that demand prolonged energy and water use throughout the day and even multiple days. This is particularly evident during daylight hours when hot climatic conditions necessitate higher electrical energy usage, such as the operation of air conditioning systems in the rooms. Therefore, a solution to reduce energy costs associated with electricity and water bills in mosque buildings is implementing green retrofits (Huo, Xue, & Jiao, 2023).

The concept of energy-efficient buildings is evolving in the face of global sustainability challenges. Innovations in international challenges, such as using green construction materials, energy sources, energy-efficient storage, and green technology, have been instrumental (Moletsane, Motlhamme, Malekian, & Bogatmoska, 2018). A bright mosque aims to use less energy and water while providing the highest possible degree of comfort, silence, and ambiance for worship. This involves controlling the temperature, lighting, and air quality at different times of the day.

For the application of energy savings in the mosque building, which is the object of the case study, 504 PV solar panels and 588 ablution taps, flush toilets, and other toilet equipment with green features are utilized. The consideration for existing renewable energy primarily focuses on photovoltaic (PV) systems. For example, Liu et al. [14] used a solar PV system to achieve energy savings, resulting in zero carbon emissions in buildings, albeit with high investment costs. Similarly, Salameh et al. employed a PV system for energy-saving transformations in buildings, reducing energy consumption by 27.69%.

In addition, based on previous research on other buildings, such as the CIMB NIAGA building in Jakarta, which already holds a green platinum certification from BCAI Singapore, there is an energy conservation efficiency of 10% and a water conservation efficiency of 10% for green retrofit buildings (Purnomo & Tenriajeng, 2022).

Life cycle costing is technically based on the principles of engineering economics, and it considers the time value of money at each stage of the life cycle to calculate costs and benefits. The calculations take into account various cost aspects, including initial investment costs (initial costs for both design and installation), energy costs (electricity and water costs), and operation and maintenance costs (Dwaikat & Ali, 2014).

Several cost components are used to conduct a life cycle cost (LCC) analysis to compare different retrofit strategies that address relevant costs. These costs include construction site preparation and preliminary works, construction (retrofit), maintenance, repair, replacement, and operational energy costs. The overall life cycle cost breakdown consists of dismantling original parts, developing each retrofit strategy, replacing material for maintenance, and using operational energy (Rodrigues & Freire, 2017).

Based on (Kamaralo, Alhilman, & Atmaji, 2020), the journal Life Cycle Cost is classified into several parts, including Sustaining and Acquisition costs. Sustaining costs are annual energy or operational costs, maintenance, and replacement costs. Acquisition Cost is the sum of initial yearly costs, including construction costs, initial costs of green building features, and administrative costs.

This study examines how a cost-benefit analysis could be used to evaluate sustainability, with a particular emphasis on the economic aspect of sustainability and the use of LCC as a tool (Tushar et al., 2022). Results of cost simulations generated from the LCC process include investment performance indicators such as Net Present Value (NPV), Benefit-Cost Ratio (BCR), Internal Rate Of Return (IRR), and break-even point (BEP), along with additional indicators for starry designs (Huo et al., 2023).

A project risk index system for the retrofit project in the Old Housing Area (ORA) was constructed throughout the project life cycle. Participants' opinions on possible risk factors and the degree of impact on the project were collected through a questionnaire survey. Based on C-OWA and grey cluster analysis, a risk assessment model was developed to evaluate risks, and risk management and control were proposed based on different risk levels. Risks involve decision-making, design, construction, operation, and maintenance stages (Lee, Mohamed, Masrom, Abas, & Wee, 2020).

The risks throughout the project cycle will affect the overall value of the entire project. According to (Wen, Lau, Leng, & Liu, 2023), risk is a factor causing unexpected conditions that can cause loss, damage, or loss. Therefore, based on previous research, an evaluation of the risks avoided in the green retrofit of buildings in the preliminary study on energy efficiency is conducted to overcome the risks of using green building items, considering the decision to apply green items to buildings (You, Wu, Yang, Liu, & Li, 2021).

Risk uncertainty simulation can be anticipated in several ways. According to (Gierens et al., 2020), one is sensitivity analysis. The parameters that will make significant changes to the analysis output and how much these parameters can change will be known by sensitivity analysis. Risk uncertainty simulation can be anticipated in several ways. According to (Gierens et al., 2020), one is sensitivity analysis. Sensitivity analysis helps identify parameters that will make significant changes to the analysis output and how much these parameters can change.

This research will discuss the influence of risks occurring in green retrofit work, considering the value of the dominant risk factor on investment performance. It focuses on a case study of mosque buildings implementing green items based on Indonesia's GBCI and EDGE assessment benchmarks.

## Research Methods

The method employed in this research aligns with the flow chart presented in Figure 1. Data collection involves archival analysis and case studies on mosque buildings that have received green certification. Subsequently, the results of the archival analysis for each research component will be scrutinized concerning the life cycle cost and the risks associated with green retrofit work, which includes solar PV work and the implementation of energy-efficient ablution faucets/flush toilets. This analysis uses questionnaire instruments distributed to 5 experts and 51 respondents. These respondents primarily consist of building construction workers from various agencies. The risk analysis process is detailed in the flow chart below.

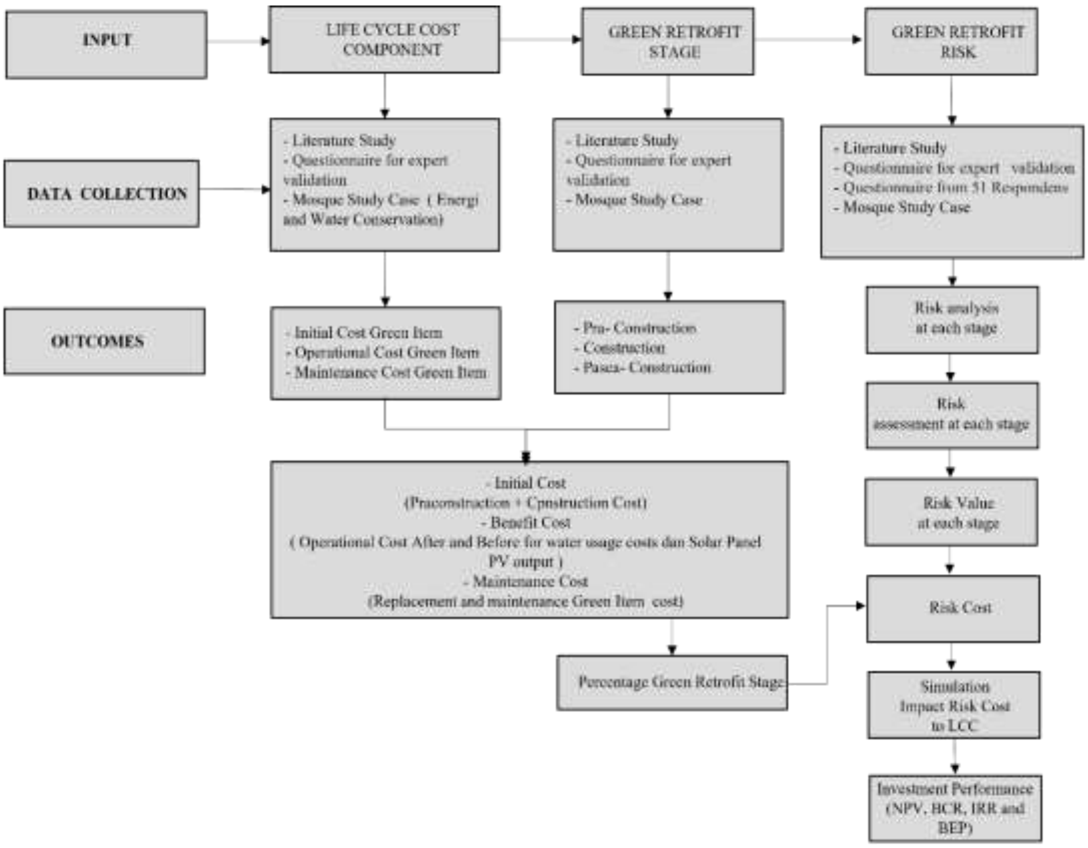

**Fig. 1 Flowchart of Research Methods**

# Results and Discussion

## Life Cycle Cost

The initial cost components in the life cycle cost method for green retrofit work encompass the pre-construction and construction costs of mosque buildings implementing green retrofit features. These components specifically pertain to the green building items in the mosque building chosen for this case study. The initial cost covers all expenses from the pre-construction stage to installing the solar panel item, including procurement and installation for energy conservation purposes.

As for procuring other green items in the work of toilets and ablutions, the initial cost from the preconstruction stage to the construction includes a demolition cost item from the previously existing conditions. The total value of the initial cost for the green building item work on the energy conservation item is Rp 2,520,000,000,- and the price for water conservation on the green building item of this mosque is Rp 911,403,354,-.
In the context of this mosque building, operating costs refer to the operational expenses required to run and maintain the facility, including energy and water consumption costs. Considering operational costs illustrates the savings realized after green retrofitting, contributing to the overall cost-benefit analysis for the mosque building.

Using operational costs demonstrates the savings achieved through green retrofitting, resulting in a cost-benefit for the mosque building. Specifically, the reference for the solar panel item is based on the kWh/day production generated by the solar panel for operational use. Data for this mosque building have been obtained through metering connected to existing solar panels from the PLTS system, showing the kWh/day production as indicated below.

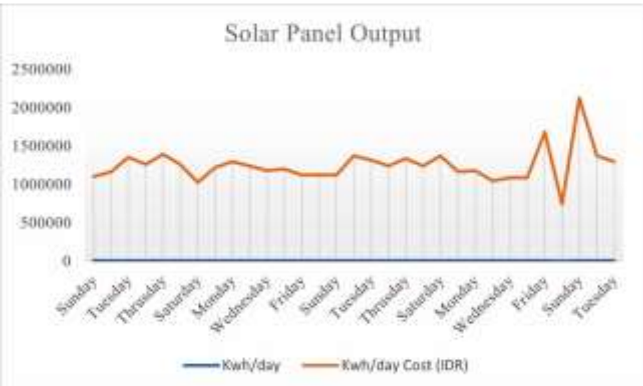


**Figure 2. Solar Panel Output/Day**
(Source : Data Riayah Masjid, 2023)

From that data, the contribution of solar panels to the mosque's operational activities is IDR 462,309,779 per year, representing the benefit-cost of the green item in the energy conservation of the mosque building.

For operational water use, the profit from the green item is determined by comparing water consumption before and after the green retrofit, especially after replacing ablution taps, flush toilets, and other facilities in the mosque building's Petersen toilet and ablution area. Water efficiency is calculated based on the difference in cubic meters of water usage before and after each year's green retrofit. The variation in water usage is illustrated below.

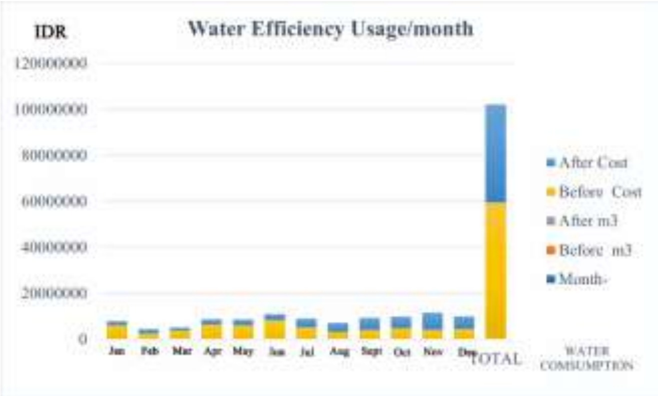


**Figure 3. Mosque Building Water Usage**
(Source : Data Riayah Masjid, 2023)

The difference in water usage before and after the green retrofit in the mosque building above results in an efficiency of Rp16,742,620 each year. The cost value represents a benefit to the building for water conservation in the mosque.

Based on the data above, the savings generated from operational costs contribute to the total cost benefit of energy and water conservation in mosque buildings—consequently, the overall cost-benefit results from the use of green.

Maintenance costs encompass all expenses associated with maintaining the green items. The maintenance involves the cost of cleaning items and replacing green items in the mosque building. Items replaced annually include those damaged or malfunctioning, such as ablution taps, jet washers, etc. Regarding cleaning, the tools required for cleaning green building items include brushing pads, rubber toilet brushes, and others. The total annual maintenance cost for this building is Rp 32,531,000.- This value will be simulated using the life cycle cost method, impacting investment performance

**Green Retrofit Stage**

Based on the Government Regulation of the Republic of Indonesia Number 16 of 2021 concerning the Implementation Regulation of Law Number 28 of 2002 concerning Building, there are three main stages in the construction process: Pre-Construction, Construction, and Post-construction. The scope of activities in the stages of this research is based on the validation of 5 experts. Of all the stages and activities carried out, 2 stages did not impact the mosque's construction, namely the approval and the acquisition of the land.

The Pre-Construction Stage of the mosque building includes activities from the preparation or feasibility study and the planning stage of the mosque building. In the activity of green items for mosque buildings, the pre-construction stage work is carried out from preparing needs, funding, auctioning, and design planning according to green mosque building specifications and technical items to the auction process. These stages will also integrate with the risks of work at the preconstruction stage, which will be integrated with the weight achieved at the pre-construction stage in the case study, accounting for 7.37% of the overall stage.

The construction phase of the mosque building encompasses all activities in implementing the mosque building construction work, starting from financing, demolition, and construction implementation to handling force majeure in mosque buildings. Funding the implementation of green items involves purchasing items that have been budgeted, implementing quality control of green items that meet existing technical specifications, and installing and testing green items to ensure proper functionality. Force majeure events, such as the outbreak of the COVID-19 disease causing delays in work on case studies, are also considered. This is about the risk of construction phase work that impacts the cost, with a weight of 82.73% achieved at this stage in the mosque's construction.

The post-construction stage is the phase of construction work after the implementation period. Activities in post-construction include operational activities and building maintenance, such as the maintenance and cleaning of green items in the mosque building. For cleaning and replacement work, there are risks associated with post-construction activities, resulting in additional costs proportional to the weight of the work. The weight of post-construction work is 10% of the overall work.

**Green Retrofit Risk**

Risk factors in the green retrofitting of mosque buildings are identified through archival analysis, literature review, and expert validation. Subsequently, identifying these risk factors represents the potential risks in green retrofit building work for buildings, contributing to the overall risk costs. In the initial identification, 73 risk factors were identified in green retrofit buildings that could impact the performance of green retrofit investments. Experts then validated these risks to identify the most influential risks in green retrofits. As a result, only 38 risk factors were found to be most influential in the mosque building. It should be noted that the identified risks were appropriately addressed in the actual case study of the mosque building. However, this study conducted further research to consider addressing the risks of future green retrofit work on mosque buildings.

Validation was then carried out with 51 respondents involved in green building retrofit projects to assess the significance of the 38 risk factors for green retrofitting mosque buildings in frequency and impact. This assessment was conducted using a Likert scale, as shown in the table below.

**Table 1**
**Likert scale of probability risk factor**

| Probability of Risk Factor Value | |
|---|---|
| Almost certain | 5 |
| Likely | 4 |
| Moderate | 3 |
| Unlikely | 2 |
| Rare | 1 |

Source: Project Management Institute (2017)

**Table 2**
**Likert scale of probability risk factor**

| Degree of Influence Value | |
|---|---|
| Very high | 5 |
| High | 4 |
| Avarage | 3 |
| Low | 2 |
| Very Low | 1 |

Source: Project Management Institute (2017)

Based on the table above, the frequency scale uses five categories: one to five in the order of rare, unlikely, moderate, likely, and almost inevitable. Meanwhile, the impact scale also consists of five categories: one to five in the order of very low, low, average, high, and very high.

From the validation carried out on 51 respondents, the risk level of each of the 38 factors was determined, resulting in the risk level at each stage, as shown in the table below.

**Table 3**
**Value of risk factors in mosque green building retrofits**

| Risk Factor Stage | Number of Factors | Average Value |
|---|---|---|
| Pra- Construction | 10 | 0,44 |
| Construction | 21 | 0,42 |
| Pasca Construction | 7 | 0,40 |

In the pre-construction stage, the risk factors consist of understanding the hazard identification and scoping method, authenticity of the building approval document, completeness of the certificate of fitness for use document, the approval process of the certificate of fitness for use document, conformity of the building permit to the green retrofit building, authenticity of the dismantling technical plan document, complexity of project characteristics, design conformity (specifications and technical), consistency of agency regulations compliance with technical standards of utilization, and conformity of building technical standards.

In the construction phase, the risk factors consisted of inflation of material and labor prices, accuracy of estimation and cost recovery, fluctuations in the import exchange rate of green materials, fluctuations in the price of materials and labor, delays in contract payments, difficulties in budgeting for green building projects, high cost of sustainable materials and equipment, changes in design during construction, inaccuracies in quality control, inaccuracies in the work process, changes in the scope of work, poor communication with stakeholders, lack of green construction experience, insufficient supporting manufacturers and suppliers, renovation construction affects the surrounding environment, lack of green retrofit construction capability, unproven quality of green products, lack of new products to meet green building requirements, delay in the delivery of green building materials, disease outbreak, and changes in local government regulations.

In the post-construction stage, the risk factors consist of inappropriate use of green retrofit equipment and units by occupants, incomplete recording of green retrofit trial operations, unstable green retrofit building performance, the building not having green management experience, an increase in exchange rates (inflation), taxes, and changes in local government regulations.

**Analysing Life Risk Value Life Cycle Cost Analysis**

After obtaining the risk value for each stage of work, the risk value is calculated based on the weight of the work at each stage performed. The pattern of the relationship between the magnitude of risk and the life cycle cost component is shown in the flowchart in Figure 1, where the initial cost affects the risk value at the pre-construction and construction stages. As a result, the value of the risk magnitude for the work is multiplied by the initial cost of the mosque building green retrofit work. The amount of risk is determined by multiplying the post-construction risk by the weight of post-construction work, which is integrated with the cost components at the maintenance stage of the mosque building green items. This results in the value of risk costs on green building items at each stage, as shown in the table below.

**Table 4**
**Amount of risk costs in mosque green building retrofits**

| Risk Factor Stage | Average Value | Work Per | Cost | Risk Cost |
|---|---|---|---|---|

| | | cen tag e | | |
|---|---|---|---|---|
| Pra-Construction | 0,44 | 7,37% | Rp3.431.403.354 | Rp111.273.548 |
| Construction | 0,42 | 82,7% | Rp3.431.403.354 | Rp1.192.295.998 |
| Post-Construction | 0,40 | 10% | Rp32.531.000 | Rp1.301.240 |

A risk rating classification range is produced based on the impact frequency matrix on the Project Management Institute matrix (2017). Low risk falls within a scale of 0.01-0.07, medium risk between 0.08-0.018, and high risk on a scale of 0.24 -0.72. So, according to the data above, all the average stages of work have a high-risk rating. Integrating the life-cycle cost components into the risk value of each phase, the risk value is Rp111,273,548 in the pre-construction phase, Rp1,192,295,998 in the construction phase, and Rp1,301,240 in the post-construction phase.

**Investment Performance**

This study has four performance evaluation benchmarks for investment centers: NPV, IRR, BCR, and BEP. NPV is considered feasible if the results obtained are positive. The IRR value is possible if the results exceed the discount rate value. The investment is deemed feasible if the BCR value is more than 1 (one). The Break Even Point (BEP) is the break-even point where the cost-benefit obtained is equivalent to the initial cost incurred, making investing in the green item feasible.

In the life cycle simulation, financial assumptions are made based on the inflation value from Bank Indonesia data averaged from 2022-2023 at 4%, with a discount rate assumption of 10%. The results of the life cycle cost analysis of the green retrofit item for the mosque building are presented in the table below.

**Table 5**
**Life Cycle Cost Results**

| Aspects performance value | Investment |
|---|---|
| Initial Cost | Rp3.431.403.354 |
| O/M Cost | Rp32.531.000 |
| Benefit-Cost | Rp479.052.398 |
| NPV | Rp140.797.698 |
| IRR | 10,26% |
| BCR | 2,21 |
| BEE | 6,7 Years |

Based on the life cycle cost analysis of the green retrofit for the mosque building, the financial feasibility of investment performance criteria occurs in the 17th year, based on the 50-year building plan life period. In principle, applying green retrofits, including using solar panels and replacing ablution faucet items and energy-efficient flush toilets, is feasible for mosque buildings, considering the life cycle cost of the mosque building.

**Sensitivity analysis**

Sensitivity analysis on Life Cycle Cost (LCC) aims to evaluate how changes in various parameters can affect the total cost over the life cycle of a system, product, or project. The parameters that change in the analysis are based on the dominant risk value at each stage, impacting the initial and operational maintenance costs of the mosque building's green retrofit work. The influence of these values will affect the investment value of the mosque building. The following is a simulation of the results of investment feasibility if these risks occur in the green items of the mosque building.

**Table 6**
**Simulation Results of Green Retrofit Risks of Mosque Buildings**

**Table 6** Simulation Results of Green Retrofit Risks of Mosque Buildings

| Risk Stage | Risk Cost | Impact LCC | NPV | IRR | BCR | Feasibility investment - |
|---|---|---|---|---|---|---|
| Pra-Construction | Rp111.273.548 | IC | Rp29.524.150 | 9,72% | 2,14 | 18 |
| Construction | Rp1.192.295.998 | IC | -Rp1.051.498.300 | 5,61% | 1,64 | >50 Years |
| Post-Construction | Rp1.301.240 | OM | Rp139.570.113 | 10,25% | 2,21 | 17 |

Based on the simulation results of risk sensitivity at each stage concerning feasibility in the 17th year, the feasibility values are obtained if the risk at the pre-construction stage occurs. The NPV value is IDR 29,524,150, IRR is 9.72%, and BCR is 2.14, experiencing investment feasibility in the 18th year. Meanwhile, if the risk at the construction stage occurs, the NPV value is -Rp1,051,498,300, IRR is 5.61%, and BCR is 1.64, experiencing investment feasibility beyond 50 years. If the risk at the post-construction stage occurs, the last simulation results in an NPV value of Rp139,570,113, an IRR of 10.25%, and a BCR of 2.21, experiencing fixed investment feasibility in year 17.

Visualization of the sensitivity value of the risk to investment performance is illustrated using the Tornado Chart. The figure below will show the significance of each risk effect at each stage on the NPV value.

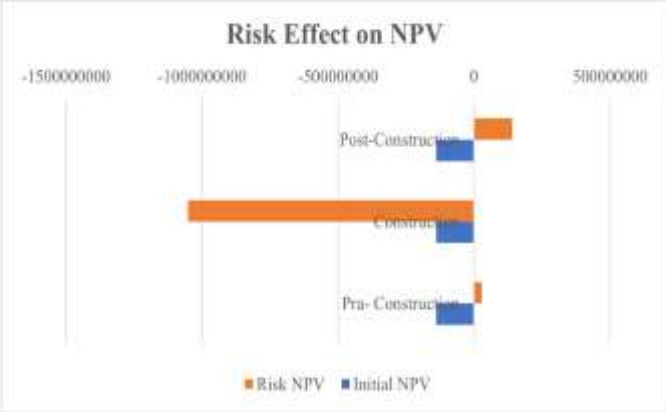


**Figure 4**
**Risk Effect on NPV Value**

In the NPV values obtained for each risk stage, the initial NPV value is significant compared to the NPV after being affected by the risk of the green mosque building item.


**Figure 5. Risk Effect on BCR Value**

In the BCR values obtained for each risk stage, there is no significant difference between the initial BCR value and the BCR value after being affected by the risk of the green mosque building item. The significance of the BCR value is seen only in the construction phase.

**Figure 6. Risk Effect on IRR Value**

In the IRR values obtained for each risk stage, there is no significant difference between the initial IRR value and the IRR value after being influenced by the risk in the green mosque construction item. As with the BCR, the significance of the IRR value is only seen in the construction phase.

## Conclusion

The results of the LCC method for the mosque building show that, with an initial cost of Rp. 3,431,403,354, and OM Cost of Rp. 32,531,000, the benefit-cost of Rp. Four hundred seventy-nine million fifty-two thousand three hundred ninety-eight results in an NPV of Rp. 140,797,698, with an IRR of 10.26%, BCR of 2.21, and BEP of 6.7 years, feasible in the 17th year, classified as possible compared to the building's 50-year lifespan. Based on the risk analysis of the life cycle cost, the most significant risk occurs at the construction stage. Applying green items in the mosque building affects investment performance if the risk occurs. According to the feasibility simulation, it will exceed 50 years, making applying this green retrofit item unfeasible. This is also evident in the risk simulation results on the value of investment performance in the sensitivity analysis.

In the future, it is hoped that further research will not only focus on one mosque object but will include multiple mosques certified green with more complex and comprehensive green items. Additionally, a more detailed identification of the application of the risk of green retrofitting of mosque buildings is needed for more accurate risk validation. This information can be considered in investment decisions for mosque building green items, and anticipation measures can be taken before facing green factors' risks in mosque buildings.

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