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Risk analysis and investment feasibility for green retrofits in high-rise office buildings using the life cycle cost method

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A B S T R A C T

Greenhouse gases (GHGs) have caused extreme temperature changes. In January 2023, temperatures were 0.1°C higher than the normal 30-year monthly average. Construction, especially high-rise offices, which occupy 42% of Jakarta, contributes significantly through energy con-sumption. To reduce carbon emissions, Indonesia has started to implement green retrofits as part of the Net Zero Emission 2050. Due to high costs and lack of public education on new and existing green buildings, the implementation of green retrofits is inhibited and owners prefer conven-tional buildings. This research aims to analyse the feasibility and investment risk of implementing green retrofits in high-rise office buildings using the life cycle cost method and the Minister of Public Works and Public Housing Regulation No. 21 of 2021 to generate a feasible and safe in-vestment. It has been proven with cost savings in energy and water consumption of up to 15% compared to conventional office buildings. Profits have also been achieved by providing 9 bene-fits to the building owner, building manager and building occupants. Therefore, this research has the potential to accelerate the green revolution through feasible and safe green retrofit invest-ments in Jakarta's office buildings.

1. Introduction

Global population growth has led to an imbalance in human activities, resulting in rising carbon gas emissions from energy consumption. In 2019, Indonesia was ranked as one of the top 10 countries in the world for emitting the most carbon gases (World Bank Group, 2021). In 2018, the building sector in Indonesia accounted for almost 20% of primary energy consumption, with air conditioning, lighting and plugs being the largest contributors in office buildings (Purbantoro & Siregar, 2019; B2TKE, 2021). By 2050, Indonesia will experience a temperature anomaly of 0.1°C above the normal monthly average temperature from 1991 to 2020, leading to extreme fluctuations in water flow and severe droughts, and eventually affecting 50 million people due to the effects of sea level rise (BPS, 2022; IPCC, 2022).

Indonesia has committed to contributing to the Net Zero Emission 2050 (NZE) movement through the implementation of zero energy buildings. This will be achieved through a three-pronged approach focusing on economy, energy and environment (Hu, 2023). The Ministry of Energy and Mineral Resources has stated that Indonesia may only be able to achieve the global target by 2060 due to periodic temperature increases, with global data since November 2022 showing a difference of 4-5ºC from the initial planning target (Kementerian ESDM, 2012; Climate Action Tracker, 2022). The Green Building Performance Scheme Roadmap is one of the main breakthroughs managed by the Ministry of Public Works and Housing (EBTKE, 2022). The presence of green retrofit is the key that can be applied in Jakarta City, consisting of 42% office buildings of which 18

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buildings are certified green buildings (Wafa, 2020; Senja, 2022). However, the implementation of green retrofit is limited by the mindset of building owners and developers regarding financial risk, which is a basic constraint, and the lack of knowledge of the value of building costs at all stages of construction (Dewi & Diputra, 2015). Conventional buildings have enormous life cycle costs over 30 years, with 79% of the entire cost used for operation and maintenance (OM), making them unprofitable (Gunawan, 2012). Therefore, it is necessary to conduct a risk factor analysis and cost analysis using the LCC method to determine the impact of design decisions made during the early stages of construction on the economic value of the building.

Currently, the GREENSHIP certification process can be burdensome for building owners and developers due to the high cost and lack of government incentives (Nugroho & Hidayat, 2012; Finaka, 2021). In the author's previous research, the Minister of Public Works and Housing Regulation No. 21 of 2021 was used as the regulatory basis for the Green Building Performance Scheme Roadmap, which focused on energy efficiency aspects and resulted in investment simulations that provided a feasible investment feasibility value, but the estimated costs did not include risk factors. Therefore, this research aims to identify risk factors for green retrofits that may affect the feasibility of the investment, and to analyse the level of risk along with the feasibility value of implementing green retrofits in office buildings.

2. Materials and Methods

2.1. Research Methodology

Research methodology is a structured approach used to achieve a predetermined goal by collecting relevant information related to the activity under study. To create such a methodology, a good research framework is required. A framework is a conceptual structure that provides a sequence of steps in the research process. (Fig. 1) below shows the methodology used in this research, represented visually by the research flow.

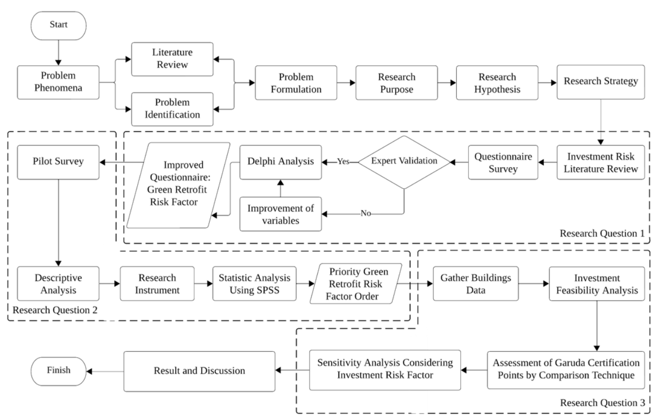


Fig. 1. Reseach Flow Framework

2.2. Certification Data Equatisation Method

This research process involves converting certification point data on office buildings using the certification data transfer method. The method equalises the original certification points with the target certification points, as set out in Garuda from Regulation No. 21 of 2021 of the Minister of Public Works and Housing. The process steps have been discussed by green building experts from the Ministry of Public Works and Housing of Indonesia. The following as show in (Fig. 2**)** is the process that needs to be implemented:

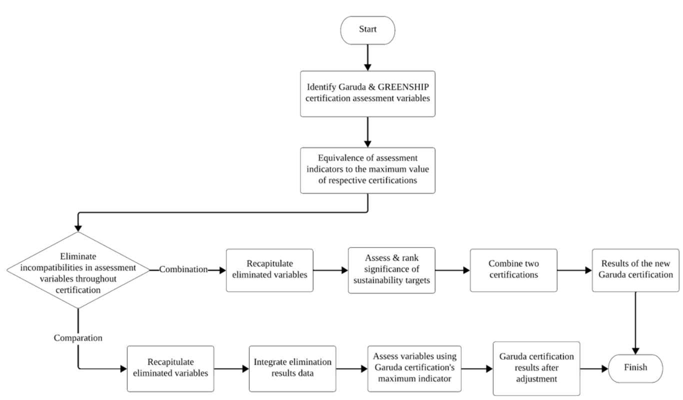


Fig. 2. Certification Data Equatisation Flow

In the application of this method, only one approach is allowed: a comparison or a combination. If the comparison technique is used, it is only for the purpose of equalisation of the certification point data and no additional advice will be required. However, if the combination technique is used, it is mandatory to provide a study on the reliability of the new type of certification as a proposal to the government and to analyse the feasibility of the point evaluation parameter variables with the sustainability target.

2.3. Life Cycle Cost Method

This research applies LCC in construction to analyse four types of costs, investment costs in the pre-construction stage, construction stage and several costs in the post-construction stage consisting of operation and maintenance costs, replacement costs and demolition costs (Marszal & Heiselberg, 2011). However, this research only requires operation & maintenance cost during the post-construction stage since there is no demolition and additional area in the green retrofit case study implementation.

LCC = Capital Cost + Operation & Maintenance Cost - Residual Cost (1)

To simplify calculations with numerous cost aspects, present value conditions are used. For the estimation of future value, inflation can be considered by using the formula below (Islam et al., 2015).

$$\mathrm{FV} = PV\ (1+f)^n \tag{2}$$

The method is used to determine the feasibility of investment by calculating the net present value (NPV), break-even point (BEP), internal rate of return (IRR), and benefit-cost ratio (BCR) for each research object. NPV is a convenient method for cash-flow comparisons over a long period of time, such as for infrastructure projects financed by public-private partnerships (Kelly et al., 2014). When the NPV is greater than 1, the investment is feasible because it can be profitable.

$$NPV_I \sum_{t=0}^{T=N} \frac{(B_t + C_t^i)}{(1+r)^t} \tag{3}$$

BEP refers to an investment's payback period, the length of time it takes to fully recover the funds invested. The shorter the payback period, the more favourable the investment. As shown in the equation below, the payback period calculation ignores the time value of money and uses an equation that relates the net cash flow for each period to the investment cost.

$$\sum_{t=1}^{n} Cf_t = I \tag{3}$$

In addition, once all the cost components have been identified through the LCC analysis, it is important to compare the IRR value obtained with the minimum attractive rate of return (MARR) and the weighted average cost of capital (WACC). MARR is the interest rate set by a company to evaluate and select project alternatives. On the other hand, the IRR is the interest rate that must be earned on the investment costs incurred so that the final payment results in a balance sheet of 0. A profitable and feasible investment has an IRR higher than MARR or WACC.

$$0 = NPV \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0 \tag{4}$$

Or

$$i_1 + \frac{NPV_1}{(NPV_1 - NPV_2)}(i_2 - i_1) = IRR \tag{5}$$

The last step is to calculate the benefit cost ratio. The investment cost can be determined whether it is greater or less than the profit through the comparison in the formula below. A positive value represents a feasible investment due to profitability.

$$BCR = \frac{|PV\ [Beneft]|}{|PV[Cost]|} \tag{6}$$

Investment feasibility has a significant impact on a project's profitability or loss after calculating its cash flow over a specific period. The process of investment feasibility takes place during the planning stage, when alternative considerations regarding the feasibility of the project (Heralova, 2017).

2.4. Research Material

Case studies of office buildings and structured surveys were used to collect material for the study. The building data was divided into two types to determine which type is more important in accelerating the implementation of green retrofit buildings as shown in (Table 1). The data takes the form of annual operating and maintenance cost data of energy and water consumption aspects, as well as data on equipment additions or replacements during green retrofits.

Table 1
Office Building Information

Office Building Information	Type B	Type C
Year fo Construction	2007	1992
Floor(s)	9	5
Shape	Trapezoid	Rectangular
Area (m2)	7244	3772.3
Heigt (m)	40	20.8
Age	16	31
Certification	GREENSHIP (2022)	GREENSHIP (2021)
Certification Rating	Gold	Silver
Type of Certification	Existing Building	Existing Building
Location	Menteng, Central Jakarta	Tendean, South Jakarta

The survey data were collected using a standardized questionnaire developed through a literature review and construction and building guidelines for toll road investment risk analysis 2005 by the Ministry of Public Works and Housing of Indonesia. Adapted data from the guidelines represents the stage of a project, consisting of pre-construction, construction and post-construction, with components that comply with Indonesian regulatory requirements. The questionnaire was completed by five experts with more than five years of experience in green retrofit applications. Table 2 shows the questionnaire data that the experts considered to be risk factors.

Table 2
Green Retrofit Risk Factor

Code	Stage Type	Code	Stage Component	Code	Risk Factor	References
X.1.	Pre-Construction	X.1.1.	Permission	X.1.1.1	Planning document type completeness	(Hidayati, 2016) (Pham et al., 2021) (Simanjuntak & Manik, 2019) (Dixit, 2022) (Osipova & Eriksson, 2011) (Suatan et al., 2012)
				X.1.1.2	Inappropriate environmental technical aspects of building modification considerations	
				X.1.1.3	Inadequate completion of testing database and EIA administration	
				X.1.1.4	Difficult administration of permits requirements	
				X.1.1.5	Complex manual procedures for acquiring building approval documents	
				X.1.1.6	Duration of all tender stages until the winner is selected too long	
				X.1.1.7	Lack of clarity of content and completeness in tender package documents	
				X.1.1.8	A complicated system of electronic procurement of goods and services	
				X.1.1.9	Incompatibility between tender contract type and green retrofitting works required by the owner	
				X.1.1.10	Delay of the contractor's tender team during the tender process	
				X.1.1.11	The tender team of contractor participated in several tenders that affect the tender process during the pre-construction stage	
				X.1.1.12	Incomplete pre-qualification document type before tendering process	
		X.1.2.	Study	X.1.2.1	Insufficient understanding of existing building hazard identification and scoping methods	(Ulibarri, 2018) (Hidayati, 2016) (Sudjatmiko, 2005) (Yao & Li, 2022) (Kaiser et al., 2013)
				X.1.2.2	Invalid authenticity of the required documents (letters, specification data, soil testing information) of the building approval	
				X.1.2.3	Improper building approval for green retrofit building	
				X.1.2.4	Invalid authenticity of documents (legal deeds and environmental documents) technical plan for demolition	
				X.1.2.5	Inefficient review of document compliance	
				X.1.2.6	Incompatible amount of information between permit and applicants	
				X.1.2.7	Unsuitable new technology in green retrofit implementation (too difficult, over specification, over budget)	
		X.1.3.	Design	X.1.3.1	Complexity of project characteristics increases green retrofit cost requirements	(Ulibarri, 2018) (Hidayati, 2016)

Code	Stage Type	Code	Stage Component	Code	Risk Factor	References
				X.1.3.2	Design (specifications and technical) increases the need for green retrofit costs	
				X.1.3.3	Inconsistency of department regulations related to fulfilment of technical standards for green retrofit building utilization	
				X.1.3.4	Building technical standards compliance does not reach or exceed parameters	
		X.1.4.	Land Clearance	X.1.4.1	Insufficient geographical visualisation for additional areas of the building	(Nikolaos & Panos, 2019)
				X.1.4.2	Complexity of geographic covariance of additional building area	
				X.1.4.3	Inconsistency between the planned location of additional building area and the regional spatial plan map	
X.2.	Construction	X.2.1.	Cost	X.2.1.1	Price inflation of materials and labour	(Nguyen, & Macchion, 2022) (Hwang et al., 2017) (Wuni et al., 2023)
				X.2.1.2	Low accuracy of estimation and payback	
				X.2.1.3	Long duration of payback	
				X.2.1.4	Underestimating the initial investment cost of green retrofits, leading to avoiding	
				X.2.1.5	Exchange rate fluctuations of imported green materials affect the contract value	
				X.2.1.6	Material and labour cost fluctuations affect the value of the contract	
				X.2.1.7	Contract payment delays prevent the construction of green retrofits	
				X.2.1.8	Difficulties in green retrofit project budgeting	
				X.2.1.9	High cost of sustainable materials and equipment	
				X.2.1.10	Inaccurate prediction of market demand	
				X.2.1.11	Financial failure of subcontractors	
				X.2.1.12	High certification costs	
		X.2.2.	Construction	X.2.2.1	Design changes during construction	(Dixit, 2022) (Nguyen & Macchion, 2022) (Hwang et al., 2017) (Qin et al., 2016)
				X.2.2.2	Inaccuracy of quality control	
				X.2.2.3	Inaccuracy of work process	
				X.2.2.4	Changes in the scope of work	
				X.2.2.5	Improper construction technique selection and sequence	
				X.2.2.6	Lack of communication with stakeholders	
				X.2.2.7	Inexperience of green construction	
				X.2.2.8	Unavailability of relevant equipment	
				X.2.2.9	Inadequate supporting manufacturers and suppliers	
				X.2.2.10	Environmental impact due to waste of green retrofit construction	
				X.2.2.11	Lack of green retrofit construction capability	
				X.2.2.12	Non-strictness of health and safety regulations at green retrofit project sites	
		X.2.3.	Tools	X.2.3.1	Unproven quality of green products	(Wuni et al., 2023)
				X.2.3.2	Lack of new products to fulfil green retrofit requirements	
				X.2.3.3	Delivery delays of green retrofit materials	
		X.2.4.	*Force Majeur*	X.2.4.1	Potential occurrence of rainstorms that will hinder green retrofit construction	(Hwang et al., 2017) (Wuni et al., 2023) (Anthopoulos, 2013)
				X.2.4.2	Potential occurrence of earthquakes that will hinder green retrofit construction	
				X.2.4.3	Potential flooding that will hinder green retrofit construction	
				X.2.4.4	Potential labour demonstrations that will hinder green retrofit construction and performance	
				X.2.4.5	Local government regulation changes	
				X.2.4.6	Corruption and bribery will hinder green retrofit construction in regulatory, administrative, and field progress.	
X.3.	Post-Construction	X.3.1.	Operation & Maintenance	X.3.1.1	Inappropriate use of green retrofit equipment and units by occupants	(Huo et al., 2023)
				X.3.1.2	Incomplete records of green retrofit trial operations	
				X.3.1.3	Unstable green retrofit building performance	
				X.3.1.4	Lack of green retrofit insurance product	
		X.3.2.	Building Handover	X.3.2.1	Building management lacks green management experience	(Nguyen & Macchion, 2022) (Qin et al., 2016)
				X.3.2.2	Green retrofit project evaluation results did not reach the standard	
				X.3.2.3	Incomplete document of fit-for-purpose certificate	
				X.3.2.4	Long duration of certificate of fitness for purpose document review process	

Code	Stage Type	Code	Stage Component	Code	Risk Factor	References
				X.3.2.5	Delay in approval process of certificate of fitness for purpose document	
		X.3.3.	Liability	X.3.3.1	Inflation	(Hwang et al., 2017) (Bahamid et al., 2020)
				X.3.3.2	Tax rate increase	
		X.3.4.	*Force Majeur*	X.3.4.1	Local government regulation changes	(Hwang et al., 2017)
				X.3.4.2	Government opposition	

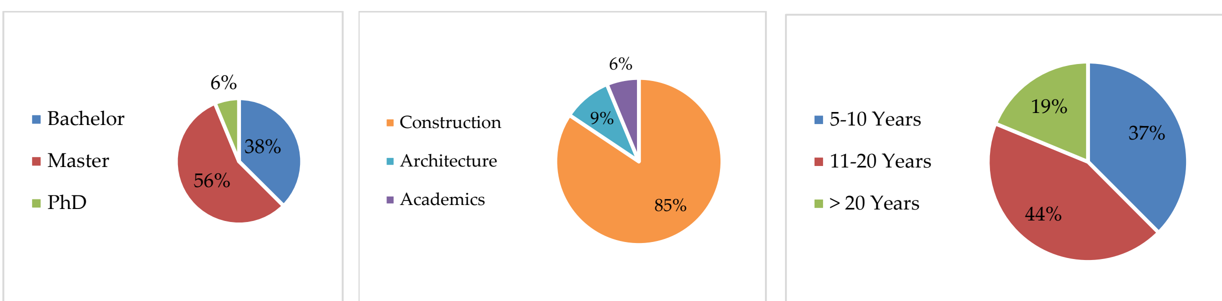
The data was then processed through delphi data analysis, descriptive analysis, statistical data analysis using SPSS application, investment feasibility analysis, and sensitivity analysis. During the study, additional data was collected through interviews with building management for both building data and survey data.

3. Results

The number of results presented at this point was determined by the three types of research questions. The research questions were classified into two interrelated studies: the risk factor study for research questions 1 and 2, as well as the investment feasibility study for research question 3. Both studies contain different supporting analysis elements that make it possible to achieve feasible and secure green retrofit investments in office buildings. In the following, the results of the analyses are explained in order.

3.1. Green Retrofit Investments Risk Study

By distributing questionnaires to 32 respondents, the majority have a master's education background (56%), work in the construction field (85%), and have more than 5 years of work experience as requirements shown in (Fig. 3). The respondents agreed that there are 72 risk factors (Table 2) can affect green retrofit investment from pre-construction, construction and post-construction stages. All risk factors were derived from the literature review to correspond to the existing condition of new green building or green retrofits building in Indonesia through government guidelines. In this regard, risk factors are unforeseen events that can occur during pre-construction, construction and post-construction and involve all stakeholders in the process.



(a) Respondent’s Education (b) Respondent's Occupational (c) Respondent's Work Experience

Fig. 3. Personal characteristics of the participants

In order to determine the impact of risk factors on green retrofit investment, respondent by rating the frequency and impact of each of the risk factors on a scale from the lowest (1) to the highest (5). The collective data provides an average frequency and risk value, which is then multiplied in order to produce a risk value. The results demonstrate that all of the risk values have a high risk level, in accordance with the PMBOK 6th edition. Subsequently, a ranking is established based on the PMBOK guidance. A statistical data analysis was conducted using the SPSS application, with the initial test being the validity and reliability test. This test is employed to assess the accuracy of the function of a measuring instrument and the assurance of the function of a measuring instrument, as indicated by the Cronbach's Alpha value, using the Pearson's correlation method due to the data being normally distributed. The results obtained for all green retrofit risk factors are valid and reliable based on Pearson's correlation, with all values exceeding 0.3. Furthermore, the Cronbach's Alpha value of 0.974 is greater than 0.6 between the tested variables, that is, X variable with X variable. In this test, α was set at 0.025 (one-tailed) for the r table value. A validity test was also applied between variables X and Y to provide a correlation decision between variables in one population. The results of the tested variables were significantly correlated. No elimination process was applied to the green retrofit risk factors by making a decision on the Pearson correlation value. A significant correlation is indicated by a Pearson correlation value exceeding 0.3 and a significance level below 0.005. Therefore, all green retrofit risk factor data is not eliminated due to the validity and reliability tests. The second test employs a factor reduction test, whereby the Kaiser-Meyer-Olkin (KMO) value is initially satisfied to produce Varimax with the rotation method. The KMO result exceeds the minimum threshold of 0.5, indicating that the sampling in factor analysis is adequate and suitable. The results of data simulation are sufficient for factor reduction, where nine factors are formed through the SPSS application system. The variable with the greatest value is selected as a latent variable (Fig. 4). This grouping is employed to test regression by taking the most dominant value, which is then idenitfied as the strongest correlation value.

The linear regression process utilises the bivariate correlation test, employing the 'enter' method to enter data simultaneously and without any exit or entry processes, thereby ensuring the data processed is significant and the f value is smaller than 0.05.

The hypothesis to be tested can be expressed as follows:

H_0: *There is no relationship between green retrofit risk factors in high-rise office buildings and the investment feasibility of green retrofit high-rise office buildings.*
H_1: *There is a relationship between green retrofit risk factors in high-rise office buildings and the investment feasibility of green retrofit high-rise office buildings.*

The F test results indicate that H1 is accepted and H0 is rejected if the calculated F value of the study is greater than the F table value at the 95% confidence level. The research F value obtained is 3.788, which is greater than the F table value of 2.34 (Figure 5). While the t test results obtained are negative on the five selected latent variables representing risk factors. The negative value obtained is considered absolute because the decision-making method employs a smaller number than that permitted in a one-tailed test, thus accepting H1 and rejecting H0. It is reiterated that the use of a one-tailed test is based on the directional hypothesis test, whereby the decision-making process employs a greater or lesser number than the table value.

FX1	FX2	FX3	FX4	FX5	FX6	FX7	FX8	FX9
X.1.1.10	X.1.1.8	X.1.1.2	X.1.2.1	X.2.1.11	X.1.1.9	X.1.1.5	X.1.1.12	X.1.1.6
X.2.1.5	X.1.1.11	X.1.2.2	X.1.3.3	X.2.2.9	X.2.1.3	X.1.2.3	X.2.4.5	X.2.1.2
X.2.4.1	X.1.4.1	X.1.2.4	X.1.3.4	X.2.3.3	X.2.1.4		X.3.2.5	X.2.1.7
X.2.4.2	X.2.1.10	X.2.1.9	X.3.2.1		X.2.1.6		X.3.3.1	
X.2.4.3	X.2.4.6				X.2.1.12			
X.2.4.4					X.2.2.1			
X.3.1.3								

Fig. 4. Selected Reduction Factor Variable

The results of the one-tailed test system indicate that there are five risk factors in the green colour (Fig. 5) which show a strong relationship through the final stage of statistical data analysis, linear regression. These five main factors were determined to be continued in further stages of testing, i.e. the risk level assessment and the risk factor assessment through actual condition of green retrofit office building investment cost.

Coefficient					
Model	B	Std. Error	Beta	t	sig
(Constant)	1.145	0.36		3.179	0.005
X.2.4.1.	0.322	0.13	0.563	2.466	0.024
X.2.1.10.	0.02	0.143	0.026	0.143	0.888
X.1.2.4.	0.219	0.145	0.302	1.515	0.147
X.1.3.3.	-0.217	0.146	-0.314	-1.483	0.155
X.2.2.9.	0.076	0.151	0.095	0.508	0.618
X.1.1.9	0.241	0.125	0.377	1.925	0.07
X.1.2.3.	0.082	0.107	0.133	0.767	0.453
X.3.2.5.	-0.066	0.133	-0.1	-0.495	0.627
X.2.1.7.	-0.042	0.13	-0.061	-0.322	0.751

Fig. 5. Strongest Correlation Linear Regression Coefficients for Green Retrofit Investment

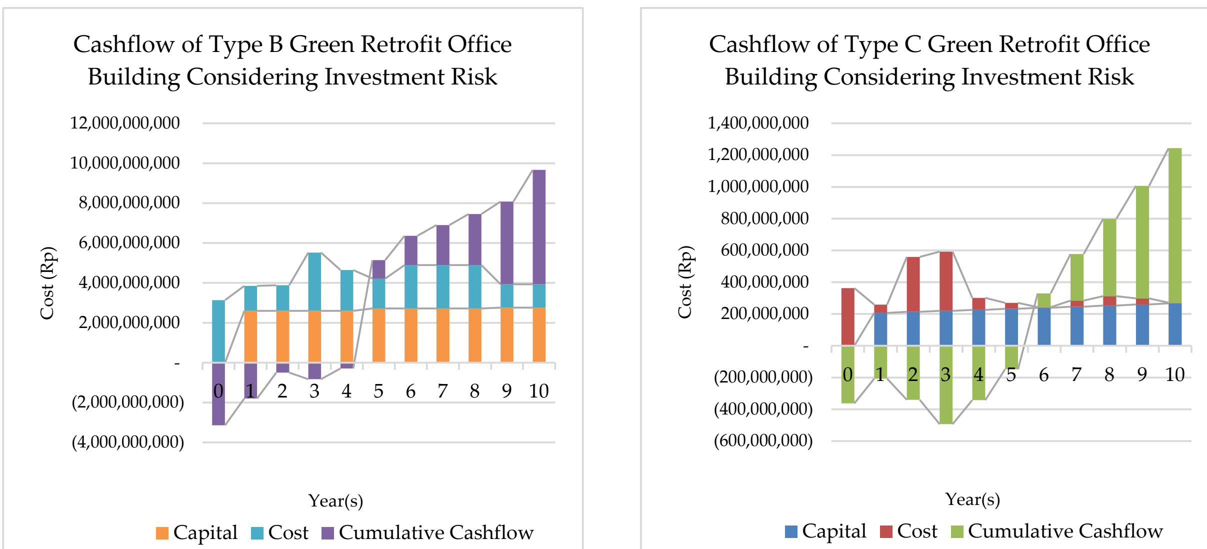
Table 3
Priority Green Retrofit Risk Factor Order

Rank	Risk Level	Avg. Frequency	Avg. Impact	Risk Score	Risk Factor Code	Actual Type B Risk Factor Code	Actual Type C Risk Factor Code
1	High	0.747	0.439	0.858	X.2.2.10.	X.3.3.1	X.2.2.10.
2	High	0.650	0.513	0.829	X.2.1.11.	X.2.1.4.	X.2.1.4
3	High	0.725	0.366	0.826	X.2.1.6.	X.2.2.10.	X.2.1.11
4	High	0.694	0.414	0.821	X.2.2.9.	X.2.2.2.	X.2.2.2.
5	High	0.728	0.300	0.810	X.1.1.8.	X.2.1.9.	X.2.1.5

It has been proven that the risk factors of the system results (Figure 4) are not identical to the risk level assessment results according to PMBOK 6th Edition and the risk factor costs of green retrofit investments (Table 3). Therefore, both the system results and the risk level assessment results can be used as a guideline for the priority green retrofit risk factor, but it does not represent 100% accuracy with the actual conditions.

3.2. Green Retrofit Investment Feasibility Study

The life cycle cost (LCC) method was used to estimate the cash flows, with a 10-year investment period, and the investment risks as discussed in the "Green Retrofit Investments Risk Study" were added. The cashflow results are shown in (Fig. 6), indicating positive profitability for both office buildings.



(a) (b)

Fig. 6. (**a**) Cashflow of Type B Green Retrofit Office Building Considering Investment Risk; (**b**) Cashflow of Type C Green Retrofit Office Building Considering Investment Risk

This section discusses the investment feasibility of green retrofit office buildings. Feasibility is determined by positive cash flow and investment values. The Type B office building achieved an IRR value of 24.40%, which is higher than the MARR. The BEP was achieved in the 5th year of investment with a BCR value of 1.27 and an NPV value of IDR 2,190,782,330.00. Meanwhile, the Type C office building achieved an IRR value of 20.18%, which is higher than the MARR value, and also has a payback period of 6 years, a BCR value of 1.70 and an NPV value of Rp 316,391,033.00. The MARR of 9.03% is derived from a combination of Bank Indonesia interest rate of 6% and inflation of 2.86% in the year of the research. All of the feasibility values are within the minimum requirements for each parameter. Both green retrofit office building investments are feasible and safe to implement. The sensitivity analysis results indicate a positive NPV value, indicating profitability.

The investment feasibility is also stated by obtaining garuda certification points through the comparison technique. For type B green retrofit office buildings, the 'BGH Utama' rating was obtained, as well as for type C green retrofit office buildings. This is the highest rating that can be achieved in this type of certification.

The results are also indicated by the benefits obtained by the owner, such as the number of tenants renting office space with a low possibility of office space experiencing vacancies, a fairly rapid cost recovery so as to optimise the operation and maintenance managed in-house, minimising the possibility of replacing tools and materials for office buildings, and the minimum number of complaints that enter the database of building management and owners, as well as the benefits obtained by tenants or occupants in the form of occupant productivity, increasing the stability of body health, reducing daily stress levels, increasing cognitive intelligence, and creating a good working atmosphere after using green retrofit office buildings.

4. Discussion

This discussion will explain in more detail the correlation of each element with the novelty generated in this research. Utilization of risk analysis and investment feasibility of green retrofit is based on the need for green construction development in Indonesia. As a research novelty, the existence of green building regulation helps and facilitates building owners to implement green retrofit. However, as the Minister of Public Works and Housing Regulation No. 21 of 2021 is still relatively new, there is currently no evidence to support the interest of building owners. Therefore, this research has relied solely on national sources of information that can support the regulation. As with the risk analysis process, the Ministry of Public Works and Housing guidance has been used, and the investment feasibility process also uses financial information from Bank Indonesia.

To reassure building owners and management, it is necessary to conduct a risk analysis that is appropriate for the condition of buildings in Indonesia, particularly office buildings. Office buildings dominate the Jakarta area and are limited by available space and cost. Therefore, the adoption of building construction stage components should provide more detailed and directed information. The resulting risk factor is expected to comply with the constraints of other building owners. This risk factor can serve as a benchmark for customising green retrofit and, hopefully, can be further developed to accelerate the progress of green development in Indonesia.

This analysis helps to address the cost constraints that have been underestimated by building owners. An investment feasibility study proved that green retrofits can reduce costs by focusing on energy and water aspects. These two aspects are the most realistic actions that can be taken in green retrofit initiatives in Indonesia. Strategic actions are also needed for the green retrofit of office buildings in Jakarta. Investment feasibility is supported by the existence of energy performance savings of 11% and water conservation performance savings of 10% for class B office buildings that have not been green retrofitted. In addition, for Class B office buildings that have not undergone a green retrofit, energy performance savings of 15% have been identified.

In addition, according to the object of this case study, type B office buildings will be prioritised to be able to green retrofit first, as evidenced by the better and faster NPV and BEP values of type C office buildings. This is due to the fact that type B buildings have larger areas, are more strategically located for national and international offices, have easier access to public infrastructure, and have in-house management that can reduce budgets.This research has the potential to be further developed for other types of buildings or infrastructure, and increase people's awareness of the importance of green retrofitting in order to accelerate and increase the possibility of suppressing carbon emissions in Jakarta.

5. Conclusions

This research provides a reference for pursuing green retrofit in Indonesia, particularly in Jakarta. It is based on risk analysis and investment feasibility, as outlined in the Minister of Public Works and Housing Regulation No. 21 of 2021. This approach can increase the confidence of building owners to use the national certification, the Garuda certification, by demonstrating the investment feasibility in building types B and C. There are 72 risk factors that are preventable in the form of contingency costs, where the relationship between risk and cost is very strong. It has been proven that green retrofit investments have a high potential to be financially feasible over a 10-year investment period, as well as providing 9 benefits for building owners, building management and building occupants. Additionally, cost savings have been observed in energy and water usage, with up to a 15% reduction compared to conventional office buildings. This research has the potential to accelerate the green movement in building construction and reduce carbon emissions in Jakarta. Future research may consider other building types, development areas, and methods of financial and risk analysis.

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The data presented in ths study are available on request from the corresponding author due to privacy restrictions.

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