Journal of Infrastructure, Policy and Development 2024, 8(5), 3790.
https://doi.org/10.24294/jipd.v8i5.3790

Article

Analysis of critical factors affecting green office retrofits based on the latest green building regulations in Indonesia

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CITATION

Husin AE, Kristiyanto, Sinaga L, Arif EJ. (2024). Analysis of critical factors affecting green office retrofits based on the latest green building regulations in Indonesia. Journal of Infrastructure, Policy and Development. 8(5): 3790. https://doi.org/10.24294/jipd.v8i5.3790

ARTICLE INFO

Received: 21 December 2023
Accepted: 11 January 2024
Available online: 25 April 2024

Abstract: The construction industry is responsible for over 40% of global energy consumption and one-third of global greenhouse gas emissions. Generally, 10%–20% of energy is consumed in the manufacturing and transportation stages of materials, construction, maintenance, and demolition. The way the construction industry to deal with these impacts is to intensify sustainable development through green building. The author uses the latest Green Building Certification Standard in Indonesia as the Green Building Guidelines under the Ministry of Public Works and People's Housing (PUPR) Regulation No. 01/SE/M/2022, as a basis for evaluating existing office buildings or what is often referred to as green retrofit. Structural Equation Modeling-Partial Least Squares (SEM-PLS) is used by the authors to detail the factors influencing the application of green building by analyzing several variables related to the problem studied, which are used to build and test statistical models of causal models. From this study, it is concluded that the most influential factors in the implementation of green retrofitting on office buildings are energy savings, water efficiency, renewable energy use, the presence of green building socialization programs, cost planning, design planning, project feasibility studies, material cost, use of the latest technology applications, and price fluctuations. With the results of this research, there is expected to be shared awareness and concern about implementing green buildings and green offices as an initiative to present a more energy-efficient office environment, save operating costs, and provide comfort to customers.

Keywords: green retrofitting; green office; energy saving; sustainability construction; SEM-PLS; PUPR's Technical Guidelines

1. Introduction

Environmental pollution and excessive use of natural resources are two major effects of the building industry on the environment during the implementation phase (Azhary et al., 2021). The sustainability of a healthy living environment is at risk, hence a strong development control mechanism is required. Sustainable and ecologically friendly growth is a crucial answer for humanity. Environmental hazards can also be identified by the occurrence of events brought on by the warming of greenhouse gases and a rise in carbon dioxide.

In the fight against environmental harm, construction projects are essential. To support a worldwide aim for reducing greenhouse gas emissions in the construction sector, green building rules have been enacted in several nations. Managing climate change's effects is the main issue for the building industry (Jung et al., 2013). Since the environment is not quickly adapting to these events, which are influenced by natural and human causes, the consequences of climate change due to human activity have grown alarming (Raphael et al., 2023).

The purpose of this study is to analyze the factors that play the most role in the implementation of green building systems in Indonesia concerning the latest Green Building Certification Standard in Indonesia as the Green Building Guidelines under the Ministry of Public Works and People's Housing (PUPR) Regulation No. 01/SE/M/2022.

2. Study literature

These days, the primary goal of energy policy at the regional, national, and worldwide levels is building energy efficiency (Amani and Soroush, 2020). Integration of renewable energy in large and small-scale settlements is beginning to be well-managed in both developed and developing countries (Wei et al., 2019) and the good news is that renewable energy use in several countries has increased for at least the last four decades. Furthermore, the objective of carbon-neutral cities is to effectively mitigate air pollution and climate change (Tsirigoti et al., 2022).

Using energy and natural resources is very common in the construction industry, which is why construction is said to be responsible for 36% of CO_2 emissions (Atabay et al., 2020). Green Building emerges as an alternative solution that enables Architecture, Engineering, and Construction (AEC) to support sustainable development (Darko et al., 2017).

Green spaces are the development of the concept of sustainable development (Bai and Liu, 2023). Green construction is a sustainable movement that aims to make environmentally friendly construction products through the planning, implementation, and utilization stages (C. H. Wu et al., 2021). Examples of green implementation in the world that are already ongoing include the construction of new green buildings, retrofitting green buildings, green infrastructure, green industries, and other green ideas. Using renewable energy becomes one of the real solutions to the challenges of the future climate crisis (Mansour, 2023). Renewable energy sources include solar, wind, water, earth heat, biofuels, ocean currents, biomass, nuclear, and hydrogen, so this energy won't run out (Hadiwijoyo et al., 2013). The primary focus of renewable energy legislation is to prioritize the use of renewable energy sources and enhance energy efficiency. (Ramli et al., 2022); this aligns with the green building concept of energy use (Shayan et al., 2022). Controlling the impact of energy policies in social, economic, and environmental dimensions is one of the strategies in sustainable development efforts (Drobyazko et al., 2021; Y. Wu et al., 2019). Energy-efficiently oriented buildings will increase tenant demand while increasing renewable energy supply (Sahu, 2018).

The contribution cost of green design is 5% higher than conventional design which usually ranges from 8% to 12% of construction costs (Abidin et al., 2016). In addition to design costs, costs related to preparation, such as ratings, management, commissions, and green rating, are also potentially emerging. Some loan requirements (including fulfillment of environmental and social management aspects) and the availability of skilled labor are some of the factors that at least affect the cost. For the cost performance incurred, green construction projects significantly exceed the budget by about 4.5% to 7% compared to conventional construction projects (Hwang et al., 2017).

Implementing sustainable interior design is crucial for optimizing energy efficiency. One way to do this is by including energy-efficient lighting systems, such as LED (Light Emitting Diode) or CFL (Compact Fluorescent Lamp) lights, and using passive solar designs to minimize the need for artificial illumination (Kineber et al., 2023). To implement a green retrofit system on office buildings, some rules must be followed to improve cost performance to make it more efficient and financially profitable.

The implementation of green building in Indonesia faces several challenges, such as exorbitant initial investment costs relative to conventional buildings, limited public understanding and awareness of green building concepts, a scarcity of environmentally friendly products in the market, and insufficient government support in terms of both financial and non-financial assistance (Pahnael et al., 2020). Retrofitting an existing building is usually more expensive than integrating into a new building. To turn the current building into a green building, the cost required is 10.77% of the initial cost (Sun et al., 2019).

The latest technology applications, such as Building Information Modelling (BIM), are a way to reduce the cost of green development projects (Husin and Priyawan, 2023). The civil engineering field's BIM approach has opened up new scenarios for the design idea concept, from planning to executive and constructive stages (Bongiorno et al., 2019).

In research in Switzerland, retrofit strategies were evaluated based on cost-effectiveness and environmental impact. This study looks at the retrofit of the building enclosure and the efficiency of the heating system. In this case, the combination of heat pumps and roof insulation is the most cost-effective option. This is because the result of the heating system is much more important in terms of cost efficiency than the retrofit of the building cover (Sigrist et al., 2019).

Based on research done in Malaysia, most of the green building surpluses range from 0% to 10%. Return on investment comes from electricity savings and employee productivity levels (Bin and Kashem, 2017). A study in Switzerland assessed retrofit strategies based on cost-effectiveness and environmental impact. The study examined the building enclosure's retrofit and the efficiency of the heating system. It concluded that combining heat pumps and roof insulation was the most cost-effective, as the heater resulted far more efficiently than a building envelope (Frei et al., 2021).

On the other hand, green buildings have offered an opportunity to minimize carbon emissions (up to 35%) while saving money on energy consumption (30%–35%), water use (up to 40%), and solid waste (up to 70%).

Retrofitting is an effort to adjust the performance of buildings utilized to meet the requirements of green buildings (Rastogi and Solanki, 2023). Green retrofitting strategies can improve building performance and energy efficiency (Gholizadeh et al., 2018). Green retrofitting is a method adopted by several countries; these include installing energy-saving devices, controlling technology tools, retrofitting windows and walls, advanced heating and cooling technologies, and renewable technologies (Wang and Jia, 2023). Building retrofitting aims to optimize energy savings and reduce capital return times (He et al., 2019). The quality, energy savings, and cost efficiency of maintenance are some of the improvements made by the green retrofit building, resulting in financial benefits for the owners (Abdelrazek and Yılmaz, 2020).

The real benefits of green buildings include water reductions of about 30%–50% and energy savings of about 20%–30%. The intangible benefits include improved air quality, natural lighting, health, comfort, and well-being of residents (Ebrahim and Wayal, 2020).

According to the Indian Ministry of Environment and Forestry, green construction refers to a construction process that takes into account the environmental impact and efficient use of resources at every stage of a building's life cycle, including design, construction, operation, maintenance, renovation, and deconstruction (Ebrahim and Wayal, 2020). The concept of green is emerging and becoming much-needed amidst ongoing climate change (Metaxas et al., 2023). It is considered one of the solutions to reduce environmental damage and carbon emissions from the construction industry.

3. Methods

Global warming can lead to rising global temperatures, uncertain climate change, and the depletion of the ozone layer (Sutikno et al., 2023). In many countries, the degradation of natural resources, energy, and the environment is a significant problem. The threat of global warming and climate change is causing the Earth's sustainability to decline to meet the needs and well-being of human beings worldwide. Due to global warming and the issues with increased development and economic growth, which have led to an increase in national energy needs, the concept of going green has become crucial in all facets of modern life.

The Indonesian government has announced that it will launch a national campaign (Husin, Ardiansyah, et al., 2023) to reduce energy consumption by reducing the amount of fuel used and the quantity of water and electricity used by governments, government companies, local companies, and private companies. Applying the concept of green building is the way they do this.

The criteria and certification of environmentally friendly buildings issued by the Minister of State for the Environment of the Republic of Indonesia define environmentally friendly buildings as buildings that apply environmental principles in planning, construction, operation, and management, as well as essential elements of climate change impact management.

One way to achieve global greenhouse gas emission targets in the construction sector is by implementing green building policies across countries. Green building certification is a prestigious accolade bestowed on newly constructed structures that aspire to adhere to environmentally sustainable standards. Alternatively, existing buildings can also undergo renovations to align with the principles of green construction (Husin, Priyawan, et al., 2023).

3.1. Green building assessment technical guidelines according to the minister's regulation PUPR No. 01/SE/M/2022

The green idea is currently a movement for sustainable growth in many sectors. According to the Republic of Indonesia's Regulation of Public Works and Public Housing Minister (PUPR) No. 01/SE/M/2022, retrofitting is a building performance adjustment used to meet the building requirements of green buildings and reduce greenhouse gas emissions and overall energy consumption. Green retrofitting involves improved performance of air cooling, lighting, and air-cooling systems (He et al., 2019).

A rating system is a tool containing details of an assessment aspect called a rating, and each rating element has a value or credit point. A building will receive a value point for each successful assessment element. A green building is a structure that satisfies building standards and demonstrates a substantial level of performance in conserving energy, water, and other resources (Jiang, 2023). The ranking according to the Minister of PUPR's Technical Guidelines No. 01/SE/M/2022 is as follows:

1) Primary Green Building/Bronze Medal with a score of 45% to 65% (74–107 points).
2) Middle Green Building/Silver Medal with a score of 65% to 80% (108–132 points).
3) Main Green Building/Gold Medal with a score of 80% to 100% (133–165 points).

The performance assessment standard by the Technical Guide of the Minister of PUPR's Technical Guidelines No. 01/SE/M/2022 on green building performance consists of several aspects of the criteria, as examined in **Table 1** below;

Table 1. Point assessment of the minister of PUPR's technical guidelines assessment No. 01/SE/M/2022.

No	Item Criteria	Point	No	Item Criteria	Point
1	Encourage public transportation	2	53	Evaluation, monitoring, and improvement mechanism	1
2	Energy saving	3	54	Has integrated building data	1
3	Environmentally friendly materials	2	55	Construction method ideas & innovations	1
4	Environmentally friendly- consumables	2	56	Value-added innovation	1
5	Sustainable use of used goods	1	57	Equipment mobilization plan and realization	1
6	No use of hazardous & and toxic materials	3	58	Efforts to optimize the utilization of construction equipment technology.	1
7	No use of plastic bags	1	59	Construction safety from falling materials.	1
8	Have a water-saving	1	60	Calculation of reducing construction waste	1
9	Commitment not to smoke inside the building	1	61	Construction waste sorting	1
10	Waste management policy	1	62	Provision of hazardous waste absorbent media.	1
11	Wastewater management policy	1	63	Cooperation & monitoring of construction waste management.	1
12	Manager of laws and regulations	1	64	Construction waste resource management	1
13	Experts must have been certified	1	65	Copy shop drawings testing and commissioning	1
14	Has a green procedure	1	66	Copy list of testing and commissioning support data	1
15	There are as-built drawings and other documents	1	67	Documentation of testing and commissioning	2
16	Building management performance	1	68	Documentation of equipment system operation training	1
17	Equipment operational logbook	1	69	Warranty certificate documents for significant equipment from the manufacturer	1
18	Conduct periodic inspections of the building	1	70	Manufacturer's operation and maintenance manual documents	3
19	Have an Emergency Response procedure	1	71	Submit as-built drawing	4
20	Training (maintenance)	2	72	Environmentally friendly pest and weed control	1

Table 1. (*Continued*).

No	Item Criteria	Point	No	Item Criteria	Point
21	Training to improve soft skills	2	73	Ventilation System: 2.3 m^2/person	1
22	OTTV and RTTV maximum-35 Watt/m^2	5	74	Air Conditioning System testing and commissioning results.	4
23	Window to Wall Ratio < 30%	3	75	Lightings according to the level System	2
24	Optimization of natural or mechanical ventilation	2	76	Transportation System in Building meets SNI 03-6573-2001.	1
25	AC usage ≥ 25 °C ± 1 °C; Humidity 60% ± 10%	1	77	Monitoring and recording energy consumption	2
26	Procedure according to the latest SNI	4	78	Ensure elevator performance is up to standard	1
27	Lighting planning according to SNI	1	79	Maintain energy consumption not exceeding 10%	1
28	One switch in a room < 30 m^2	1	80	Addition of 1 point (able to save 10%)	1
29	Use of lighting sensors	1	81	Re-commissioning: verification of key equipment efficiency.	3
30	Daylighting & grouping of lights	3	82	Suitability of customized water efficiency criteria	8
31	Use of photocells	1	83	No additional deep groundwater sources.	2
32	Traffic analysis lift according to the latest SNI	1	84	Suitability of water meters, including their functions	2
33	VVVF Elevator Usage	1	85	Water-saving sanitary ware	4
34	Escalator: slow motion or automatic on/off	1	86	Monitoring actual water consumption	1
35	Electric energy consumption saving plan	5	87	Actual water consumption does not exceed 10%	1
36	Electric load grouping and kWh-meters	1	88	Maximum use of 20% well water source	1
37	Use BMS of the Building.	2	89	Show laboratory results for water quality for the last 6 months.	1
38	Plan for utilization of renewable energy sources.	1	90	Report every 6 months in the last 3 years.	1
39	Water meter installation	1	91	Appropriateness of indoor air quality criteria.	8
40	Calculation of water saving plan	1	92	Suitability of indoor air quality parameters	8
41	At least 75% of the total procurement of fixture products	4	93	There are no smoking warnings or signs.	1
42	Smoke-free commitment.	1	94	Appropriateness of waste management criteria.	8
43	Warning and no-smoking signs	2	95	Waste segregation is carried out	3
44	The room is designed not to use refrigerant.	4	96	Waste bins that match waste generation	3
45	The value of ODP is equal to zero	2	97	Temporary garbage disposal following the amount of waste generated	1
46	GWP of 700 at most.	1	98	Ensure that waste does not accumulate in temporary garbage disposal	1
47	Waste resource management	1	99	Bookkeeping of monthly waste generation weight/volume.	1
48	Individual/communal waste container facilities	1	100	Checking the quality standards of treated water (WWTP)	2
49	Temporary garbage disposal	2	101	There is a socialization program about Green Building	2
50	Organic and Inorganic waste processing	1	102	There is an information board about the greenness of the building.	2
51	Recording the weight/volume of waste generation	1	103	Building user satisfaction survey	5
52	Project work-plan initiation document	1			
				Total	**165**

3.2. Structural equation modeling-partial least squares (SEM-PLS)

This research is a descriptive study with exploratory investigation, which means it is aimed at a specific population and aims to describe the existence of a particular concept or event while explaining some factors related to the investigated problem. Using relevant and related sources, further describe data covering research variables. A descriptive method is a technique used to evaluate data by describing or explaining data obtained in such a way without the purpose of generalizing results.

Data analysis is carried out after all respondent data is collected. The author uses the software application Structural Equation Modelling (SEM)—Version 3.0 of Partial Least Squares (PLS), which is used to build and test statistical models, commonly referred to as cause-and-effect models. Unique versions of various other analysis methods are considered exceptional cases by SEM-PLS, a common and valuable multivariate analysis technique. SEM-PLS is a hybrid technique that covers confirmatory aspects of factor analysis, path analysis, and regression that can be considered a particular case of SEM. These applications are often used to solve business statistics or research problems.

4. Results and discussion

Colliers International Indonesia reports that the annual occupancy rate of office buildings in the Jakarta Central Business District (CBD) was 74.7% (5.3 million m^2) by the end of 2022, while outside the CBD it was 70.8% (2.6 million m^2). These rates have decreased due to the pandemic but are expected to gradually improve in the coming year. This is shown in the following **Figure 1**:

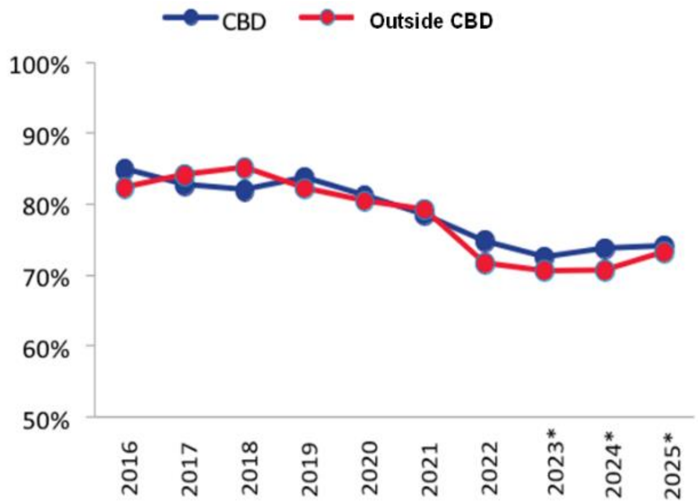


Figure 1. Office building occupancy in Jakarta.

With increasing demand for office space in early 2023, the office sector is undergoing improvement. Other sectors, such as medical manufacturing, consultants, software companies, and telecommunications providers, have expressed their desire for office space. Financial technology (Fintech), information technology (IT), and data centers are the most active renewable energy and technology sectors in the office rental market (Husin and Kussumardianadewi, 2018). While many building owners see the economic, social, and environmental advantages of green buildings, there is a prevailing belief that green construction is initially more costly compared to conventional buildings. (Alshamrani, 2020). Investors are rethinking values and emphasizing environmental, social, and governance aspects in response to current resident preferences; this increases regulatory requirements and the cost of operating assets.

The author conducted a case study in the National Research and Innovation Agency (BRIN) office building, located on Pasir Putih Road No. 1, Ancol, North Jakarta, Indonesia, as one of the state-owned buildings that should model a national sustainable movement as a green office building. The building and location are shown in the **Figure 2**:

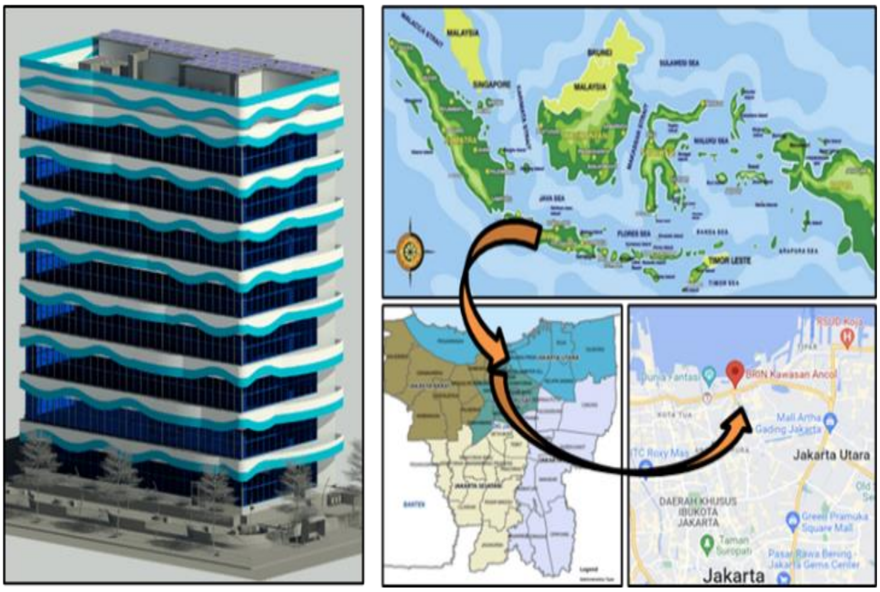


Figure 2. Geographical location of the National Research and Innovation Agency (BRIN) office building.

High environmental requirements and architectural sustainability are now essential considerations when selecting office space, especially for international corporations. Owners of businesses or buildings typically have a reluctance to adopt green practices since they are challenging to execute (F. Aini et al., 2023). Policies have made workplace safety a priority all around the world. Most people will be drawn to high-end office buildings that are conveniently accessible and feature amenities that enhance employee engagement and health. Companies will have a competitive edge if they adopt sustainable practices that align with their social and environmental objectives (Khan et al., 2021).

4.1. Assessment of the existing buildings by the minister's regulation PUPR No. 01/SE/M/2022

Following an evaluation of the BRIN office building based on the green building performance standards, the cumulative points are determined, particularly at the building utilization stage, along with the anticipated target after improvement (retrofitting), as shown in **Table 2** as follows:

Table 2. Assessment of existing buildings and target achievement of green retrofitting points based on the Minister of PUPR's technical guidelines No. 01/SE/M/2022.

No	Item	Green Building Ranking		
		Primary	Middle	Main
1	Standard Criteria	74–107	108–132	133–165
2	Assessment Result	67	67	67
3	Target Achievement	100	118	137
4	Points Deviation	33	51	70

From the green assessment data above, the conclusion is that the existing condition of the building gets 67 points, not meeting the standard criteria points of each green level (Primary, Middle, and Main). The target achievement of points to meet the green standard is planned 100 points for the Primary level, 118 points for the Middle level, and 137 points for the Main level. Points deviation for achieving the green target can be obtained by performing a simulation of an improvement plan that will improve the green performance of existing buildings. The next step is to perform improvement (retrofitting) of the building functions to improve the achieving of points for the green building category by the Technical Guidelines for the Evaluation of Green Buildings Ministerial Regulation PUPR No. 01/SE/M/2022. The following **Table 3** is a plan simulating the need for building retrofitting as a condition of reaching the expected point to getting the green building category:

Table 3. Retrofitting requirements towards green building.

No	Retrofitting Requirements	Retrofitting plan for each category		
		Primary	Middle	Main
1	Shelter bus and bicycle parking	-	-	√
2	Provision of smoking areas outside buildings and parks	√	√	√
3	Solar panels	√	√	√
4	Temporary garbage disposal	√	√	√
5	Organic waste composter machine	-	√	√
6	Inorganic waste recycling machine	-	-	√
7	Sewage Treatment Plan (STP)	√	√	√
8	Making vertical drainage and infiltration	√	√	√
9	Solar cell street lighting and garden lights	√	√	√
10	Energy-efficient lighting in buildings	√	√	√
11	Replacement of water-saving sanitary fixtures	√	√	√

Here are the results of green building renovation improvements, thereby adding value to the building itself; becoming more energy efficient, saving water use, getting clean air quality, and recycling solid waste, liquid waste, and reusable garbage.

Figure 3 is the design of the bus shelter and bicycle parking, as a public facility to provide mass bus transport and reduce fossil fuel vehicles, in its effort to limit motorized exhaust emissions, and this will help reduce carbon dioxide (CO_2) and carbon monoxide (CO) emissions.

Figure 3. Shelter bus and bicycle parking.

Figure 4 is the provision of a smoking area and green garden to provide a comfortable green building.

Figure 4. Smoking areas outside buildings and parks.

Through the use of concentrated solar power or photovoltaics, the solar panel converts sunlight directly into electricity to create clean, sustainable energy (Jahanfar et al., 2018), as shown in **Figure 5**.

Figure 6 shows the provision of a waste management building in an environmentally responsible manner by recycling organic waste into compost and recyclable used waste, including a wastewater treatment plant.

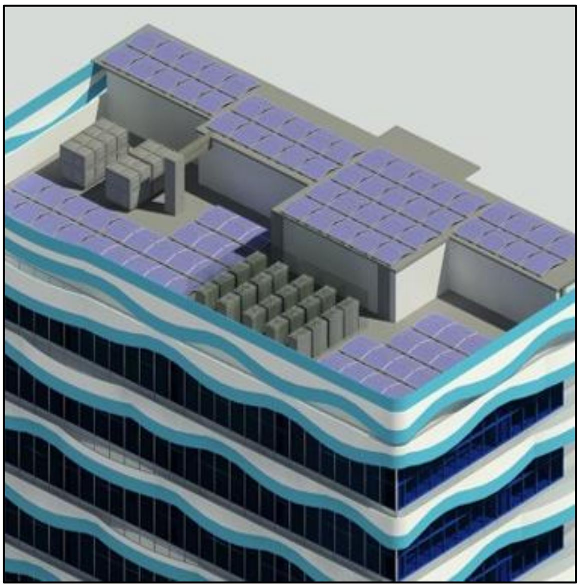


Figure 5. Provision of solar panels.

Figure 6. Waste management building.

After the improvement of the existing building, a re-assessment will be carried out so that the results will be obtained as planned target achievement points, namely for the Primary category getting 100 points, for the Middle category getting 118 points, and for the Main category getting 137 points.

4.2. SEM-PLS data processing

In this study, 171 variables were collected and used as questions in a variable questionnaire evaluated based on research reviews, supporting rules, and recommendations from expert judgment. The number of respondents is calculated by the formula:

$$m = \frac{Z^2 \times P \times (1 - P)}{\varepsilon^2}, n = \frac{m}{1 + \frac{m - 1}{N}}$$

Result:

$$m = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.05^2}, n = \frac{384.16}{1+\frac{384.16-1}{171}} = 384.16 = 119\ respondent$$

Description:

Z = 1.96 Distribution table value Z,

P = 0.50 Degrees of variation between population elements,

Ɛ = 0.05 Population sample value is limited,

N = 171 Sum of sub-factor variables,

n = Minimum number of respondents required.

In this case, the researchers distributed 130 questionnaires that were sent to the selected respondents, asking them to give a response by choosing one of the options from the list of options on a scale of 1 to 6 based on various response criteria. The scale defined by scale 1 was the least unwanted response and scale 6 was the most desired response.

Once the review of the 130 sample distribution of respondents was completed, the results indicated that 121 (93%) of the respondents had answered completely, and this has already exceeded the minimum sample required of 119 respondents. As can be seen in **Figure 7**, these answers came from the owner, planning consultant, supervision consultant, main contractor, and subcontractors currently involved in the construction implementation.

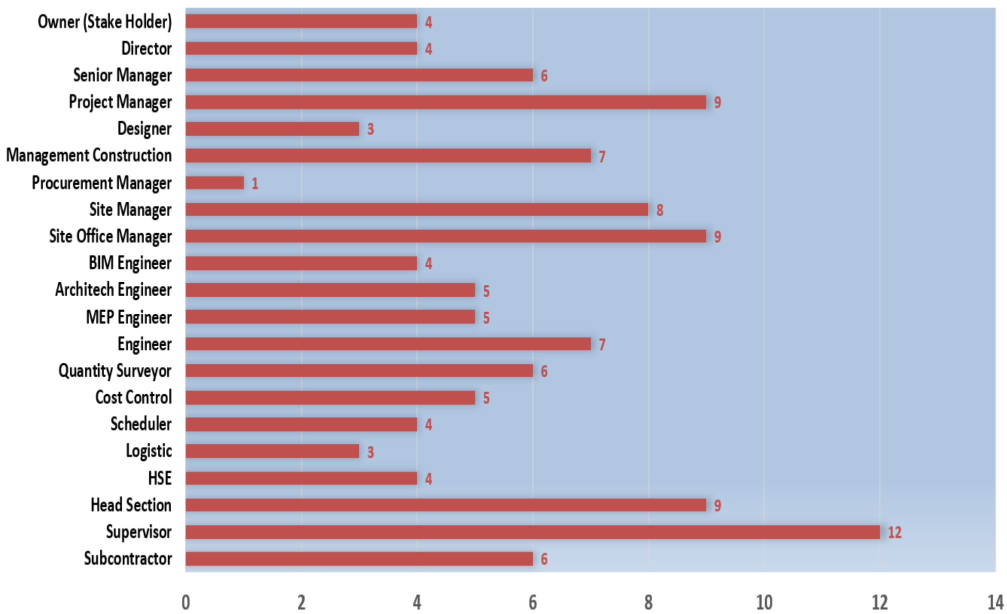


Figure 7. Respondent's job title.

Figure 8 shows respondents' backgrounds divided into five categories based on their work experience in the construction industry: under 5 years, 5 to 10 years, 15 to 20 years, and more than 20 years.

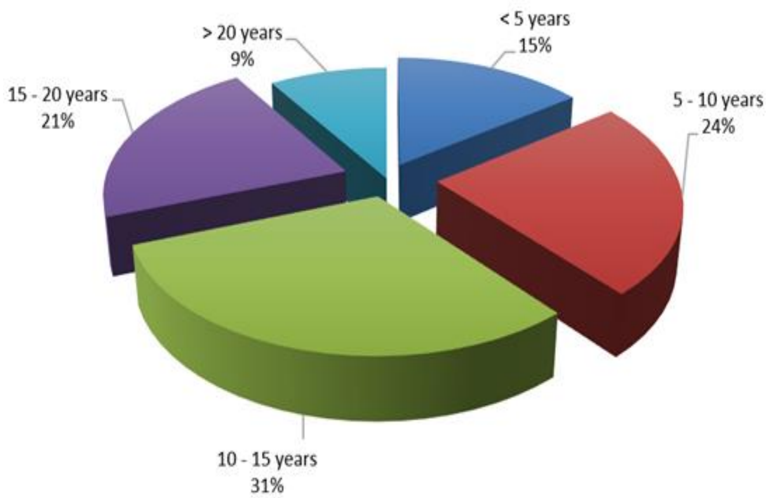


Figure 8. Respondent's experience.

The first steps in running a Structural Equation Modelling (SEM) application are confirmatory factor analysis, principal component analysis, path analysis, and structural modeling, all integrated into an analysis method known as Partial Least Squares (PLS). The measurement model, known as the Outer Model, connects indicators with latent variables used to evaluate the validity and reliability of the model. Based on the operational function of the variable, the outer model design specifies the type of indicator for each latent variable, either reflexive or formative. By reviewing the reflective indicator model, Outer SEM can obtain the following values:

a) Individual item reliability
b) Construct reliability or internal consistency
c) Average variance extract
d) Discriminant validity

Convergent validity includes the first three measurements. Convergent validity aims to calculate the correlation between constructs and latent variables. Using latent variables can determine the magnitude between constructs. The standardized loading factor value can be used to determine the convergent validity of the individual item reliability analysis.

Convergent Validity is the subsequent step in SEM-PLS program analysis, and it pertains to the extent to which a measure exhibits a positive correlation with other measures of the same structure (Al-Imran and Mezhuyev, 2019). The evaluation methods employed include Composite Reliability and Cronbach's Alpha. A composite reliability value ranging from 0.6 to 0.7 is deemed satisfactory (Sarstedt et al., 2022). The Cronbach alpha coefficient is employed to assess the internal consistency of a scale and the reliability value of its variables. A coefficient greater than 0.6 is seen to indicate validity (Kiraz et al., 2020).

A validity test is considered acceptable or valid if the Average Variance Extracted (AVE) number is greater than 0.5. If the Average Variance Extracted (AVE) is more than 0.5, it indicates that the latent/median variable construction accounts for more than half of the variations in the indicator (Hair Jr et al., 2021). The reliability test findings for a variable are considered trustworthy if the Cronbach Alpha is over 0.7 and the Composite Reliability is above 0.7, which are typical values for assessing the dependability of research instruments in general (Jonathan, 2010).

All indicators with outer loading values > 0.5 based on outer load values state that all indicators have convergent values as Average Variance Extracted, as seen in **Table 4** below.

Table 4. Construct reliability test results based on Convergent Validity.

Main Factor	Variable Number	Cronbach Alpha	Composite Reliability	Average Variance Extracted (AVE)
Utilization Level	(X2.1)	0.994	0.995	0.971
Green Retrofitting	(X2)	0.991	0.992	0.504
Planning Stage	(X1.1)	0.991	0.992	0.931
Operation & Maintenance	(X1.4)	0.990	0.991	0.504
Office Building	(X1)	0.988	0.989	0.739
Implementation Stage	(X1.3)	0.978	0.982	0.786
Demolition Stage	(X2.2)	0.960	0.968	0.691
BIM Reliability	(X3.1)	0.947	0.963	0.839
Blockchain-BIM	(X3)	0.932	0.942	0.571
Bidding Stage	(X1.2)	0.891	0.920	0.665
Technology Adjustment	(X3.2)	0.878	0.904	0.549
Cost	(Y.1)	0.873	0.923	0.764
External Cost	(Y2.1)	0.859	0.934	0.877
Internal Cost	(Y1.1)	0.793	0.867	0.627

Based on the data shown in **Table 4**, it is evident that each construct possesses a Cronbach alpha value of > 0.7, indicating that the conditions have been fulfilled. Consequently, it can be concluded that each construct is feasible. When a latent variable's Cronbach alpha, for example, 0.994 for the utilization stage (X2.1), is ≥ 0.7, it is considered reliable. **Figure 9** below is a diagram of the results of SEM PLS data processing for the analysis of Cronbach Alpha reliability and validity tests.

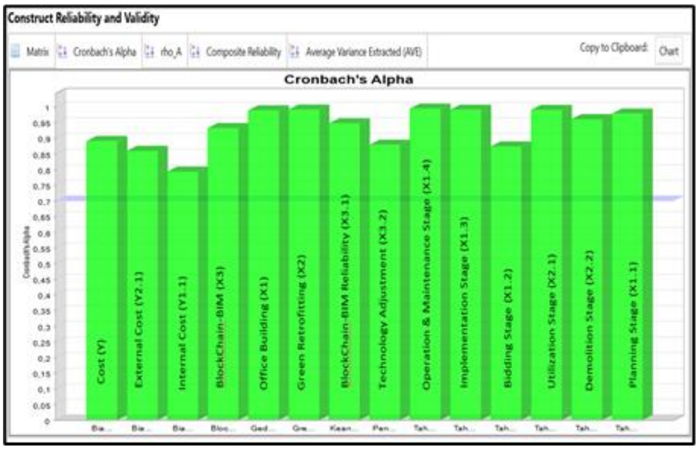


Figure 9. Outer loading validity Test-Cronbach.

Further tests will be conducted to confirm no measurement problems by utilizing Cronbach alpha and composite reliability indicators. **Figure 10** shows a diagram of the composite reliability test results:

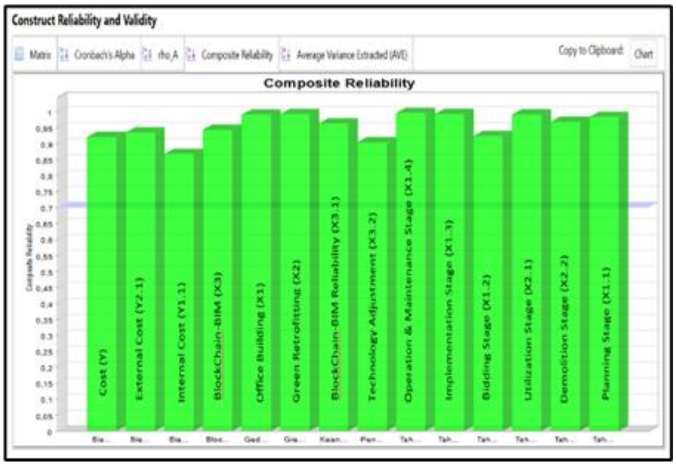


Figure 10. Outer loading validity Test-Composite Reliability.

Each construct meets the requirement by setting a cut value of 0.7 for both indicators because the composite reliability value is more significant than 0.7. For example, the planning stage latent variable (X1.1) has a composite reliability value of 0.992 > 0.7, claiming that the variable is realizable.

Based on the idea that the measurement of a construct should have a high level of correlation (Gholizadeh et al., 2018), The convergent validity of a construct is calculated by the Average Variance Extracted (AVE) evaluation. The AVE value of a construct must at least accommodate 50% of the item variation, or in other words, be ≥ 0.5 (Sarstedt et al., 2022). All constructs have achieved convergent validity, as evidenced by the Average Variance Extracted (AVE) value of all items ≥ 0.50. For example, the Implementation Stage variable (X1.3) has an AVE value of 0.786 or ≥ 0.50, so it is said to be convergently valid. **Figure 11** below is a diagram of the validity test Average Variance Extracted (AVE) and data processing results with the SEM-PLS application.

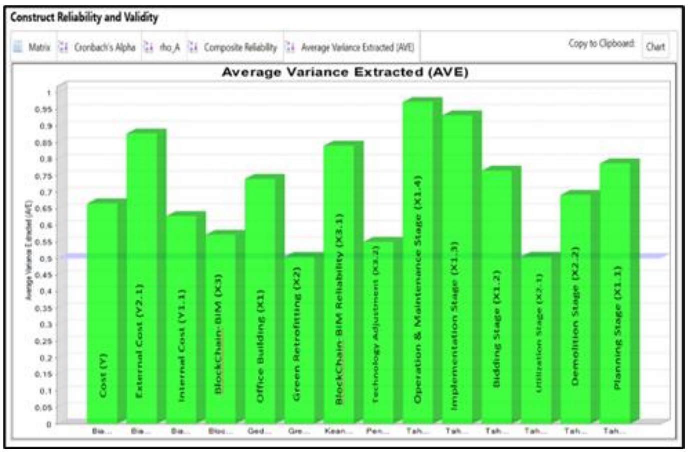
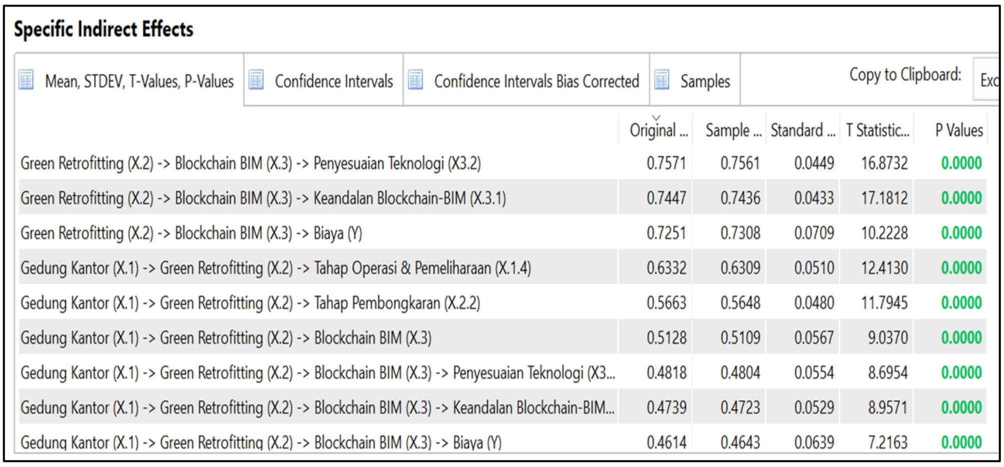


Figure 11. Outer loading validity test-average variance extracted.

The next step is to look for the *T* statistical coefficient and *P*-value to test the hypothesis. From the output of the bootstrapping command, the resulting *T* statistic value is ≥ 1.96, so it is said that there is a significant relationship. **Figure 12** shows the results of the *P*-value analysis of the loading factor and path coefficient.



Specific Indirect Effects

Mean, STDEV, T-Values, P-Values | Confidence Intervals | Confidence Intervals Bias Corrected | Samples | Copy to Clipboard: Exc

	Original ...	Sample ...	Standard ...	T Statistic...	P Values
Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Penyesuaian Teknologi (X3.2)	0.7571	0.7561	0.0449	16.8732	0.0000
Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Keandalan Blockchain-BIM (X.3.1)	0.7447	0.7436	0.0433	17.1812	0.0000
Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Biaya (Y)	0.7251	0.7308	0.0709	10.2228	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Tahap Operasi & Pemeliharaan (X.1.4)	0.6332	0.6309	0.0510	12.4130	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Tahap Pembongkaran (X.2.2)	0.5663	0.5648	0.0480	11.7945	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Blockchain BIM (X.3)	0.5128	0.5109	0.0567	9.0370	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Penyesuaian Teknologi (X3...	0.4818	0.4804	0.0554	8.6954	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Keandalan Blockchain-BIM...	0.4739	0.4723	0.0529	8.9571	0.0000
Gedung Kantor (X.1) -> Green Retrofitting (X.2) -> Blockchain BIM (X.3) -> Biaya (Y)	0.4614	0.4643	0.0639	7.2163	0.0000

Figure 12. *T* statistic and *P*-value results.

All indicator-forming constructs are valid if the *P*-value is < 0.05, and these constructs can be used to test the measurement structure hypothesis. The next step is to look for the *R*-square value as a result of testing the goodness-fit model at the outer model, as seen in **Table 5**.

Table 5. *R*-Square value results.

Main Factor	Variable Number	*R*-Square	R Square Adjusted
Utilization Level	(X2.1)	0.990	0.990
Internal Cost	(Y1.1)	0.959	0.958
External Cost	(Y2.1)	0.911	0.911
Implementation Stage	(X1.3)	0.911	0.910
Bidding Stage	(X1.2)	0.893	0.892
Technology Adjustment	(X3.2)	0.882	0.881
Planning Stage	(X1.1)	0.880	0.879
Cost	(Y.1)	0.862	0.858
BIM Reliability	(X3.1)	0.854	0.853
Demolition Stage	(X2.2)	0.792	0.790
Operation & Maintenance	(X1.4)	0.768	0.766
Blockchain-BIM	(X3)	0.649	0.646
Green Retrofitting	(X2)	0.608	0.603

Suppose the research *R*-Square value on Cost (*Y*) is 0.862 with an adjusted *R*-Square value of 0.858. In that case, all independent variables can be concluded to influence Cost (*Y*) of 0.862 or 86.2% because adjusted *R*-Square (85.8%) > 50%, all independent variables have a strong influence on Cost (*Y*). Furthermore, all independent variables moderately affect X1, X2, and X3 because > 0.60.

A square *F*-value of 0.02 is considered small, 0.15 is considered moderate, and 0.35 is considered large, while a square value of *F* less than 0.02 can be ignored or taken into account. **Table 6** below shows the square *F*-value of all variable items.

Table 6. Analysis result of *F* square value.

	(Y)	**(X3)**	**(Y2)**	**(X2)**	**(Y1)**	**(X1)**	**(X3.1)**
(Y)			10.29		23.155		
(X3)	2.06						5.86
(X2)		1.85					
(X1)				0.69			
	(X3.2)	**(X1.4)**	**(X1.3)**	**(X1.2)**	**(X2.1)**	**(X2.2)**	**(X1.1)**
(Y)							
(X3)	7.48						
(X2)					99.95	3.81	
(X1)		3.31	10.24	8.34			7.31

Out of the 171 variables that have been used as questions in the questionnaire, after being analyzed with the SEM PLS application, the final results state that there are ten most influential attempts to implement green retrofits in office buildings. It is concluded that of these ten factors that occupy the first place is electric energy consumption savings. The next influential factors are customization of water use efficiency, utilization of renewable energy sources, socialization program about green building, cost planning, design planning, project feasibility studies, material cost, use of Blockchain-BIM application, and price fluctuations as shown in **Table 7** as follows;

Table 7. Outer loading *T* Statistic analysis results.

No.	**Factor**	**Variable Number**	**Original Sample Value**	**Mean**	***T* Statistics > 1.96 (*p* < 0.05)**	**Against *R* Square**
1	Electric energy consumption savings	X2.1.35	0.993	0.994	392.771	0.990
2	Customization of water use efficiency	X2.1.40	0.993	0.993	377.439	
3	Utilization of renewable energy sources	X2.1.38	0.989	0.989	216.549	
4	Socialization program about green building	X2.1.101	0.988	0.988	194.651	
5	Cost planning (budgeting)	X1.1.5	0.986	0.786	184.667	
6	Design planning	X1.1.10	0.985	0.985	186.502	
7	Project feasibility study	X1.1.9	0.985	0.985	151.732	
8	Material cost	Y1.1.1	0.984	0.984	218.661	
9	Use of Blockchain-BIM application	X3.2.6	0.980	0.979	132.052	
10	Price fluctuation	Y1.2.1	0.979	0.979	146.877	

5. Conclusion

To support sustainable construction in Indonesia, governments must play an active role in establishing adequate rules, policies, and incentives to encourage the development of Green Buildings. Plans for transforming old buildings into Green Retrofitting buildings must be adapted to the needs and functions of the buildings so that the results are consistent with the Green Building classification objectives but retain the primary function of the building and remain cost-effective.

The benefits expected from green retrofitting buildings, especially office buildings, are:

- Increases the valuation of the building.
- The building will not feel the heat outside or inside.
- May conserve water from the rainwater system and the recycling system.
- Potentially reduce electricity use.
- Will get comfort in the buildings.

In this study with the SEM-PLS application obtained, the most influential factors in the implementation of green retrofitting on office buildings are saving electrical energy consumption, customization of water use efficiency, utilization of renewable energy sources, socialization program about green building, cost planning, design planning, project feasibility studies, material cost, use of Blockchain-BIM application, and price fluctuations.

Future research can be conducted to analyze the financial implications of green building investment and its impact on investor interest in developing green building assets.

Author contributions: Conceptualization, K; methodology, K; validation, AEH; formal analysis, K; resources, AEH; writing—original draft preparation, EJA; writing—review and editing, LS; visualization, EJA; supervision, AEH; project administration, LS. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest: The authors declare no conflict of interest.

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