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Implementation the Last Indonesian Minister Regulation of 2022 uses SEM-PLS and Blockchain-BIM to Green Cost Efficiency

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Implementation the Last Indonesian Minister Regulation of 2022 uses SEM-PLS and Blockchain-BIM to Green Cost Efficiency

Albert Eddy Husin*, Priyawan Priyawan

Universitas Mercu Buana, Faculty of Engineering, Jakarta, Indonesia

*Corresponding author: **albert_eddy@mercubuana.ac.id**

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Abstract

Today's threats and crises are about climate change and its consequences. Therefore, the target towards Net Zero Emission (NZE) in 2060 must be an obligation in all countries. A Green Building (GB) is a building that meets Building Technical Standards and has significant measurable performance in saving energy, water, and other resources. Applying GB principles by function and classification at each implementation stage will reduce greenhouse gas emissions. This study aims to analyze the cost of improvements based on GB assessment, where these improvements are the factors affecting the implementation of the Ministry of Public Works and Public Housing (PUPR) regulations from the Indonesian government. The Technical Guidelines for GB Performance, through the Minister of PUPR No.1 of 2022 Republic of Indonesia, is the latest regulation used as the GB concept. Implement Blockchain-BIM and GB using Structural Equation Model - Partial Least Squares (SEM-PLS) for the analysis. By applying Blockchain-BIM to overcome cost constraints, it has been found that it is possible to increase GB's cost-performance ratio in the retail and commercial estate to 3-3.8% at the basic level, while compared with other ratings is higher up to 2.1%, at which the choice of renewable energy model has a great influence.

Keywords: green building (GB), cost performance, Blockchain-BIM, SEM-PLS, retail and commercial estate, renewable energy.

Introduction

One of the main causes of climate change is the high energy consumption in buildings, which poses a major threat to the environment (Dandia et al., 2021). The big problem facing the world due to global warming affects private sector organizations and governments, so all companies need to develop new business plans that focus on finding solutions to environmental problems (Benamer et al., 2021). The World Green Building Council declares that we have entered a critical period for the implementation of the results of the Paris Agreement, in which all sectors of the economy must achieve significant reductions in greenhouse gas emissions. emissions and by 2050, all buildings must have net zero carbon emissions (Benamer et al., 2021), (Besana & Tirelli, 2022). The construction industry is responsible for the excessive use of natural resources and energy consumption. Buildings are responsible for about 30% of total global CO^2 emissions (Le et

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al., 2021). The GB has thus emerged as a promising avenue for the architecture, engineering and construction (AEC) industry to contribute to sustainable development (Darko et al., 2017).

The GB concept has several advantages related to the economy, society, and environment that make buildings have the concept of sustainable resource conservation (energy, water, land, and nature), resource efficiency (groundwater energy and materials), and public facilities on transportation and employment (Sutikno et al., 2023). Many previous studies have discussed the determinants of the success of GB, but there has been no research that discusses GB in retail commercial estates based on the Technical Guidelines of the Minister of PUPR No.1 of 2022, which is the latest GB regulation in Indonesia, and by analyzing renewable energy factors in the application of GB. According to this regulation, there are 3 (three) rankings; Main Rating (80% - 100%), Middle (65% - 80%), and Basic (45% - 65%), where the maximum total points obtained are 165.

The concept of an energy-free building is a building that does not need to use fossil fuels. Rather, all required energy is supplied from renewable energy sources such as solar energy and this can be achieved when combined with various design strategies to reduce energy requirements in building (Dwaikat & Ali, 2018). Solar energy is a clean and free energy source that does not harm the environment (Nejad & Asadpour, 2019). In addition, the development of renewable energy is growing rapidly along with the development of technology and one of the applications of renewable energy is hydroelectricity or water turbine generators (Rochman & Hermawan, 2022). Hydroelectric applications can have significant positive implications for the management of natural and man-made water resource systems (Novara et al., 2019). Renewable energy regulations prioritize both the use of renewable energy sources and improving energy efficiency (Shayan et al., 2022); this is consistent with GB's energy usage concept.

Blockchain is a decentralized transaction and data management technology (Aitsam & Chantaraskul, 2020). Blockchain is a technology that allows the exchange of information and transactions between two or more participants through completely secure and immutable encryption (Daffa & Azizah, 2022). Blockchain is a distributed database system that acts as an “open ledger” for storing and managing transactions (Zheng et al., 2019). Blockchain technology is based on distributed ledger technology – a ledger shared among all participants (nodes) in the network (Wouda & Opdenakker, 2019).

BIM model that prototypes the appearance of actual building design and construction, can generate sufficient information needed by users (Ismail et al., 2021). Lessons learned include the fact that, while BIM can provide certain benefits to projects, it also extends project duration and increases project costs (Dao & Nguyen, 2021). In the context of driving a new cultural design approach to Sustainable Architecture that aims to understand and implement buildings with a low environmental impact, BIM, center as a supporting tool for sustainable integrated design, acquires great relevance (Andreani et al., 2019). Integrated BIM and Blockchain technologies promise an increasingly secure and private environment for conducting business with full governance over processes (Lokshina et al., 2019). Blockchain-smart contracts have emerged as a new value proposition in improving certain aspects of sustainability in projects (Cheng et al., 2023).

The focus of this research is to find out further the influence of the application of the GB concept on investment decisions in high-rise buildings with Blockchain-BIM implementation in terms of the application of renewable energy technology. The performance evaluation standards follow the Technical Guidelines for Minister of PUPR No. 1 of 2022 concerning the performance appraisal of GB consisting of the Planning Stage having criteria for applying renewable of electrical energy as mentioned in Table 1, which should be included in the assessment points. Table 2 shows the variables in implementing the GB stage, and Table 3 shows the variables for Blockchain-BIM. Besides that, there are other research variables, and all the sub-factors will be used to analyze and produce factors that influence the implementation of GB in retail and commercial estate.

Table 1

Point Assessment of the Planning Stage in Green Buildings based on the Minister of PUPR's Technical Guidelines No.1 of 2022

No	Criteria(Sub Factor)	Point	No	Criteria (Sub Factor)	Point
1	Clarity of entry & exit	1	9	Rainwater managed for ≥2 hours	2
2	Complete Waste Treatment	1	10	Dust filters	2
3	Quality of wastewater standard	1	11	Electric Vehicle Charging Station	2
4	Pre-processing waste volumes	1	12	Air conditioning temp. ≥ 25°C±1°C	2
5	Recycled water for Cooling Tower	1	13	Standard artificial lighting	2
6	Roof covering with Albedo	1	14	Lighting switches for every ≤30m2.	2
7	Has one of the vegetation	1	15	Grouping lighting areas	2
8	Waste based materials	1	16	kWh meter electricity consumption	2
17	The coefficient rainwater absorption	1	49	Renewable of electrical energy	2
18	Basement ≤2 layers	1	50	Treated rainwater	2
19	Vertical parking area	1	51	Recycled water from used water	2
20	Facility with light sensor	1	52	Groundwater output meters	2
21	Shower facilities for cyclers	1	53	Saving water consumption	2
22	Recycled water with 2 functions	1	54	Smoke-free building	2
23	Non- HTM Environmentally roof	1	55	Garbage shelter capacity,	2
24	Garbage pipe network	1	56	Paint without contaminants	2
25	Eng. view to the outside building	1	57	Smoking prohibition sign	3
26	Water & energy efficiency	1	58	Air conditioning Management System	3
27	Have a waste processor	1	59	Surface water is treated with a permit	3
28	Standard traffic lift	1	60	Recycled water from dirty water	3
29	Reduce-Reuse-Recycle(3R)waste manag.	1	61	Room with natural ventilation	3
30	Vertical Transport. with slow motion	1	62	Ventilation follows Indonesian Standard	3
31	Water Company for Efficiency	1	63	CO2 concentration ≤1000 ppm	3
32	Pedestrian to public ≤400meters	1	64	CO concentration. ≤ 25 ppm	3
33	Local source wall ≤ 1000 km	1	65	Ozone Depletion Potential Value = 0	3
34	Recycled wood value ≥50% of wall	1	66	ISO 14000 for Concrete Materials	3
35	Source concrete ≤1000 Kilometre	1	67	Paint Materials with ISO 14001	3
36	Natural air engineering	1	68	Complete treatment of waste	3
37	Vertical transport with VVVF	1	69	Recycled Water Use	3
38	Grouped Garbage bins	1	70	The longest wall faces East-West	3
39	Independent garbage	2	71	HTM contaminated land restoration	3
40	Waste volume	2	72	Green Open space >50% of site area	3
41	Global Warming Potential Value Max. 700	2	73	Pedestrian access path	3
42	Non HTM for stainless paint	2	74	Window to Wall Ratio (WWR) ≤30%	4
43	Timber with legal provisions	2	75	Grouping lighting lamps	4
44	Local materials ≥40%.	2	76	Vegetation Crown ≥20% of site area	4
45	Wood non- Hazardous & Toxic Material (HTM) adhesive	2	77	Overall Thermal Transfer Value (OTTV) ≤ 35 Watt/m2	5
46	Organic waste process.	2	78	75% water-saving fixture Unit	5
47	Garbage Pre-Processing Tool	2	79	Electrical consumption < baseline	5
48	Garbage Storage environment	2	80	kW/TR follows Indonesian Standard	5
			Total		165

Source; (PUPR, 2022)

Table 2

Point Assessment of the Implementation Stage in Green Buildings based on the Minister of PUPR's Technical Guidelines No.1 of 2022

No	Criteria(Sub Factor)	Point	No	Criteria (Sub Factor)	Point
1	Control of the environment	1	47	Monitoring electricity usage	1
2	Domestic component materials ≥40%.	1	48	Project Electrical Procedures.	1
3	Effective material management	1	49	Rainwater to clean water alternative	1
4	Effective material warehousing	1	50	Rainwater Utilization	1
5	Electricity usage of equipment	1	51	Raw water source from City Water	1
6	Environmental Management policy	1	52	Smoking area facilities	1
7	Equipment energy audit report	1	53	Work Method Document	1
8	Identify the right material	1	54	Worker barracks facilities	1
9	Impact of construction activities	1	55	Rainwater infiltration	2
10	ISO 14001-certified material	1	56	3R (reduce, reuse, recycle)	2
11	Material supplier ≤200 km away	1	57	Disposal type of waste type	2
12	Material wrapping packaging	1	58	Facilities for hazardous waste	2
13	No feeling during construction	1	59	Construction waste sorting	2
14	No use of CFC materials	1	60	Construction waste reduction	2
15	Potential green suppliers	1	61	Heavy equipment security	2
16	Proper utilization of materials	1	62	Material fall safety	2
17	Rewards for Green Culture	1	63	Operating Licence of heavy equipment	2
18	Decent worker canteen	1	64	Operational Certificate heavy equipment	2
19	Building Orientation	1	65	Shop drawing for test com	2
20	Dangerous Work Mechanism	1	66	Building Envelope Efficiency	2
21	Project Innovation Improve	2	67	Refrigerant Control	2
22	'Green' Improvement	2	68	CO2 and CO control	2
23	Efficient innovation	2	69	Air quality	2
24	Has integrated building data	2	70	Water-saving sanitary ware	2
25	Improvement mechanism	2	71	Water usage efficiency	2
26	Comprehensive work plan	2	72	Water source efficiency	2
27	**Validated as-built drawings**	2	73	Electrical energy efficiency	2
28	**Equipment Operation Document**	2	74	Energy Efficiency Calculation	2
29	**Main equipment warranty**	2	75	Building Transp. efficiency	2
30	**Document of equipment training**	2	76	Lighting energy efficiency	2
31	**Documentation of test com**	2	77	Environmentally Materials	2
32	**Copy material approval list**	2	78	Ventilation energy efficiency	2
33	**Optimal construction equipment**	2	79	Construction tool monitoring	3
34	**Waste Water (WW) Recycling**	2	80	Air-conditioning efficiency	3
35	**WW Treatment to Outside**	2	81	Clarity of access in and out	3
36	Collect. Recording System	2	82	Outdoor Lighting	3
37	Waste Manage. System	2	83	Parking Lot	3
38	Application of the 3R	2	84	Basement Tread Management	3
39	Rainwater Storage 50%	2	85	Provision of Pedestrian Path	3
40	Hazardous Material Control	2	86	Private green space	3
41	Energy Conservation Rules	1	87	Hazardous waste Management	4
42	Gen-set operation feasibility test	1	88	Site & Access Management	4
43	HSE Mechanism	1	89	Plan & site management	5
44	HSE Plan	1	90	Site suitability implementation	6
45	kWh meters on the panel board	1	91	Mutual check GB Implementation	8
46	Lighting & air cond. ≥30% usage	1			
				Total	165

Source; (PUPR, 2022)

Table 3
Blockchain-BIM Variables

No.	Sub-factor	Source	No.	Sub-factor	Source
1	Project requirements	(Pedroza, 2019)	8	Blockchain Transactions	(Pedroza, 2019)(Kfoury, 2021)
2	Consistent of data	(Pedroza, 2019), (Baig & Wang, 2019)	9	Blockchain data sources	(Pedroza, 2019)(Kfoury, 2021)
3	Professional role	(Pedroza, 2019)	10	Bitcoin Blockchain	(Pedroza, 2019)
4	Secure information	(Pedroza, 2019), (Akbarieh et al., 2021)	11	Block chain-BIM Usage	(Kfoury, 2021)(Sreckovic & Sibenik, 2021)
5	Blockchain-BIM Specifications	(Pedroza, 2019), (Li et al., 2022)	12	Block chain-BIM Adoption	(Kfoury, 2021)(Sreckovic & Sibenik, 2021)
6	Blockchain Verification	(Pedroza, 2019)	13	BIM Level on Blockchain	(Pedroza, 2019)
7	Blockchain Transparency	(Pedroza, 2019), (Kfoury, 2021)			

Literature Study

In this section, we briefly review the literature related to the issues studied in this paper. The thing that underlies the importance of the green concept in all aspects of life today is the issue of global warming, namely increased development which is followed by economic development and has an impact on increasing national energy needs, according to Putri, 2014 (Ratnaningsih et al., 2019). In Indonesia, Green Ship is a GB certification system, which is a member of the World Green Building Council (WGBC), for the conservation and efficiency of water, energy, land, nature ,and materials published by (Sutikno et al., 2023). And the goal of carbon-neutral cities appears to be a new way to curb pollution and irrefutable climate change (Tsirigoti et al., 2021).

In the implementation of GB in Indonesia, several problems occurred, including the very high initial investment costs compared to conventional buildings, lack of understanding and awareness of the community about GB concept buildings, the availability of environmentally friendly products on the market being very minimal, and there is no financial and non-financial support from the government (Pahnael et al., 2020). Looking at the average eco-cost subsidy, office buildings, condominiums, and school buildings cost 4% more than conventional buildings, and other commercial buildings only had a 2% higher green fee (Hu & Skibniewski, 2021).

The energy efficiency of buildings is one of the most important characteristics to be assessed to achieve sustainability in the built environment (Haruna et al., 2020). One of those things, BIM is a powerful tool that simulates a real model of a building to determine its characteristics and the actual solar insolation values it has (Al Janahi, 2020). Then, the implementation of Building an Integrated Photovoltaic (BIPV) system is expected to be one of the best options for tropical countries like Indonesia, with abundant solar radiation (Harani, 2022). In another research by (Husin et al., 2021) about the implementation of solar PV on the walls of the Hotel building, it can be concluded that the decrease obtained is 47.32% of electricity. BIM has become even more common in design, construction, and management in the construction field, and recently BIM has attracted some attention from the hydropower sector, and BIM technologies can be used throughout the hydropower project (Niraj Niraula, 2020). Among all renewable energy sources, hydroelectricity is the most economical and reliable source (Syahputra & Soesanti, 2021). It is more relevant for commercial and public sub-sectors as it increases construction productivity (Olanrewaju et al., 2020).

It has been discovered that Blockchain has the potential to address the challenges that prevent industries from adopting BIM for sustainable design (Liu et al., 2019). The economic benefits of Blockchain applications in construction from some of the literature we have examined; include reducing transaction costs in the retail industry by 3-7% due to the elimination of transaction intermediaries (Kfoury, 2021). Transaction costs themselves, according to research conducted by ((Abdel-Galil et al., 2022), concluded that at the pre-contract stage of construction projects, the average is around 3-4% of the contract value, and the average value for post-contract transaction costs is around 8-9% of the contract value. The Blockchain-BIM model can guarantee the integrity and origin of BIM data by adding the Blockchain to the current BIM database and facilitating mobile computing and widespread access to BIM information (Zheng et al., 2019). Blockchain can offer the capability to apply levels of "trust" to individual BIM objects and a more secure framework of collaboration across stakeholders (Celik et al., 2023). Blockchain and its potential for inclusion in the communication between the project participants showed that it is not just about a standard technology, but for a holistic approach, it requires in-depth knowledge of the design process of stakeholders in a given area, their interests, and the flow of joint work and the solution is supported by BIM and Blockchain in scenography (Sreckovic & Sibenik, 2021).

Methodology

First, the Structural Equation Modelling (SEM) - Version 3.0 of the Partial Least Squares (PLS) software was used to determine sample size and whether the data meets the requirements of the SEM-PLS model. **Fig. 1** is the research flow used in this study, with reference to previous research for SEM-PLS tested.

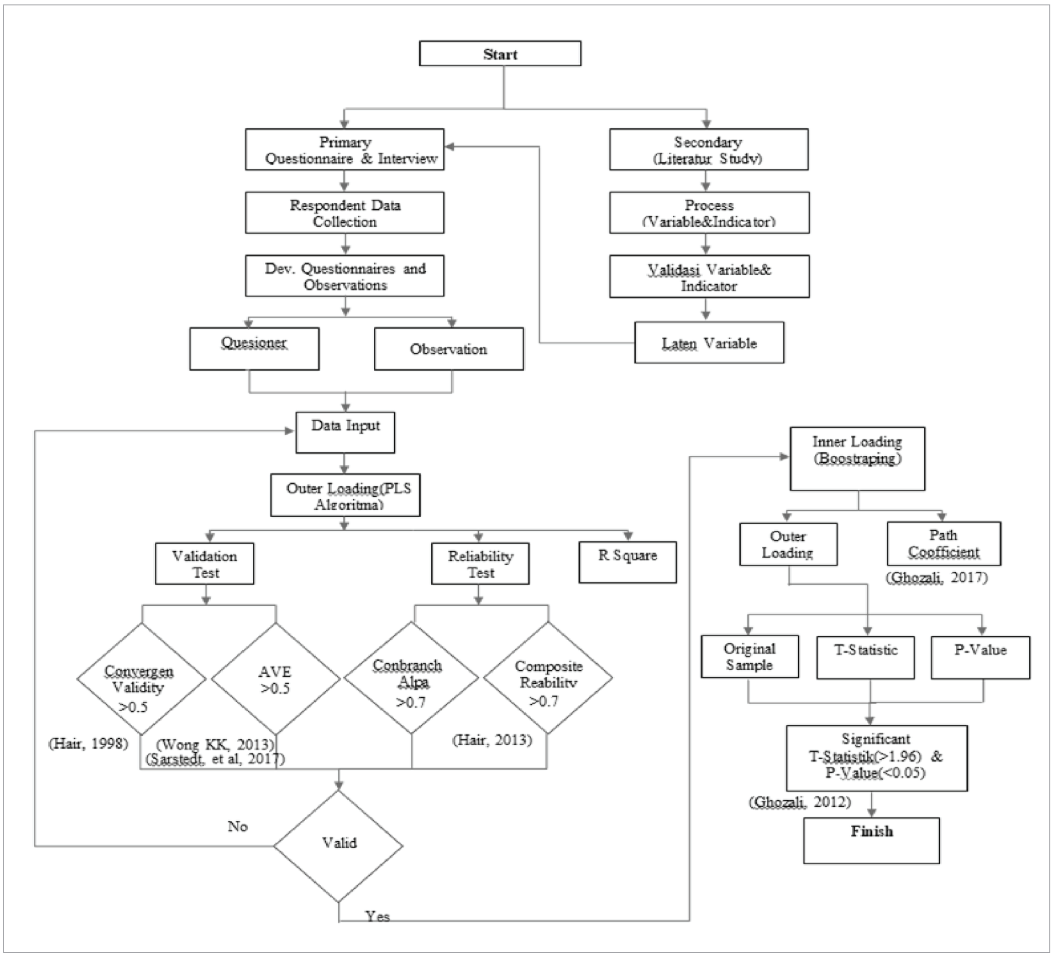


Fig. 1
Data Processing Diagram

Considerations include model properties, sample size, the shape of data distribution missing values, and measurement scale. The minimum sample size results from the path factor (p-min) and the elevation difference during the 80% statistical stress test (Hair Jr et al., 2021). To achieve the research goals, the next step of the researcher is to develop a research scheme for each step to get statistical analysis and steps to apply the research in the case studies. In one study (Vu-Ngoc et al., 2018), only half of the systematic review included flow charts to provide insight into the process of study evaluation.

According to the Blockchain-BIM implementation, the network configuration can be said to be a smart contract in the Blockchain network (Fig. 2), which is divided into three basic components, namely the contractor application, the Owner application, and the Blockchain network itself so that the smart contract can work.

Second, at this early stage, the assessment must meet a minimum standard of 74.25 for the Basic Rating. The research method is described in Fig. 3, about Research Flow for GB Concept.

Fig. 2

Blockchain-BIM Configuration, an adaptation of (Ye, 2019)

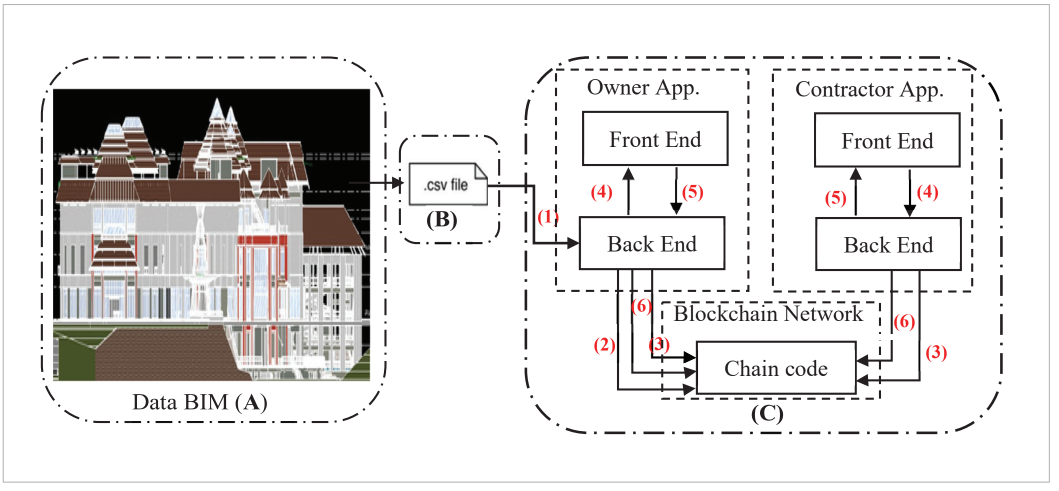
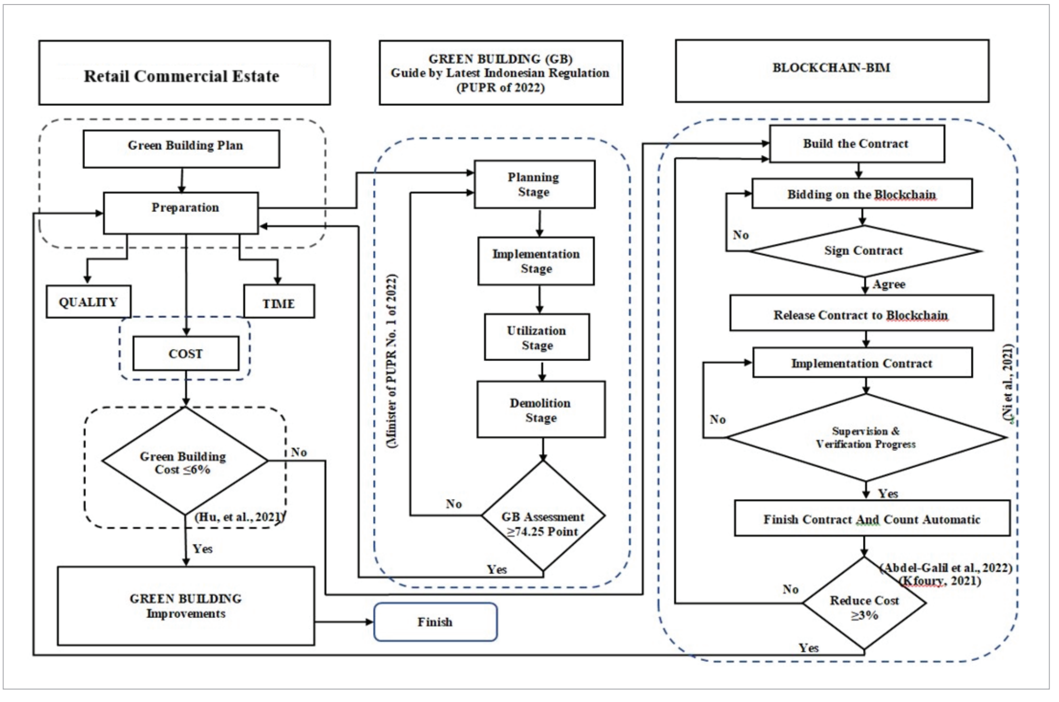


Fig. 3

Research Implementation of GB Concept on The Retail and Commercial Estate



Third, the application of renewable energy is carried out by finding alternative sources found in the research object, allowing it to be realized per the assessment results and GB requirements of 2022 from the Minister of PUPR's Regulation. The researcher proposes that Micro hydro and Solar PV plants can be applied to research objects, as shown in **Fig. 4**, the Identification Analysis for Renewable Energy Implementation, and the result that renewable energy modeling through BIM is needed to calculate the cost components of GB.

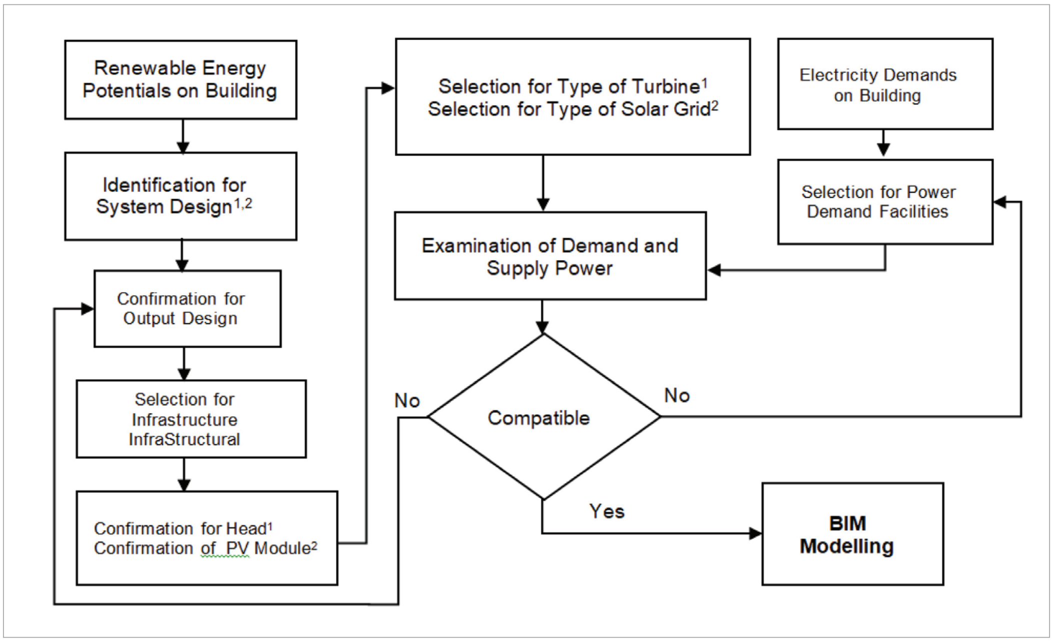
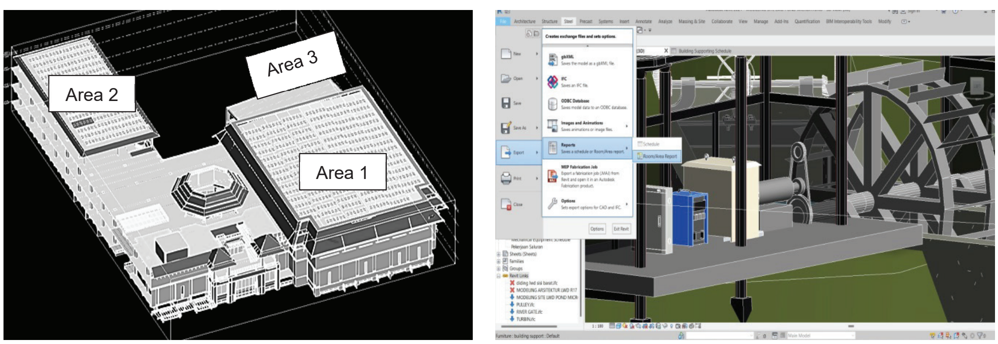


Fig. 4
Identification Analysis for Renewable Energy Implementation

Case Study

The research was conducted at a retail and commercial estate construction project in Denpasar - Bali, Indonesia. The results of the assessment, according to the assessment point planning stage, the value obtained is 62.3 points; this means that there are still several items part of the building planning that need to be supplemented with several improvements so that a minimum rating of 74.25 points for a Basic rating can be achieved.

Using the method previously described, we have identified the use of solar PV (**Fig. 5, a**) that can be applied to this building for renewable energy implementation. Details of the capacitance analysis of solar PV in this building can be explained in **Table 4**; the installation unit produces an electrical energy capacity of 550 Kilowatt-Peak. And **Table 5** is the result of technical analysis for electrical capacity and other information with the application of a micro hydro application.



(a) Solar PV Plant (b) Micro Hydro Plant

Fig. 5
BIM Modelling for Renewable Energy

Table 4
Solar PV Capacity Analysis

A	Purpose Capacity		B	Estimation Energy Simulation	
1	Area roof 1 (1.948 m2)	356.4 kWp	1	Annual Energy Production for 1 year	874.000 kWh
2	Area roof 2 (990 m2)	140.8 kWp	2	Annual Saving percentage	5.10%
3	Area roof 3 (327 m2)	52.8 kWp	3	Performance Ratio	85%
4	Solar Module	1000pcs@550 Mono-crystalline	4	Annual Reduction of Carbon Emission	11.257 tons (after 25 years)
5	Inverter	9 unit of 50kW + 1 unit of 20kW	5	Energy Consumed	805 Houses
6	Solar Mounting System		6	Planting	10.242 tree seedlings for ten years
	Building 1	Aluminium Speed Rail system			
	Building 2&3	Ground Mount, steel HDG			

Table 5
Micro-Hydro Analysis

A	Purpose Capacity		B	Estimation Energy Simulation	
1	Generator 1	30 kW	1	Annual Energy Production for 1 year	194.400 kWh
2	Generator 2	30 kW			
3	Controller + Stabilizer	Islanding Phenomenon Detection System, AVR	2	Annual Saving percentage	1.14 %
4	Head of water	2-3 Meter	3	Performance Ratio	80%
5	Type of Equipment		4	Annual Reduction of Carbon Emission	2.278 tons (after 25 years)
	Turbine 1&2	Cross Flow			
	Generator 1&2	Synchronous			

Result and Discussion

Measurement Model Evaluation (Outer Loading – PLS algorithm)

The first stage is the calculation of the SEM-PLS program. Convergent Validity analysis refers to the extent to which a measure is positively correlated with alternative measures of the same construct (Al-emran & Mezhuyev, 2019). The tools used to assess this are Composite Reliability and Cronbach's Alpha. Composite reliability values of 0.6-0.7 are considered to have good reliability (Sarstedt et al., 2022). Cronbach's alpha values are used to determine the internal consistency of the scales and reliability values are obtained for all variables, and the overall scale used in the study is determined to be above 0.6 (Kiraz et al., 2020).

The validity test can be accepted or valid if the Average Variance Extracted (AVE) value is > 0.5. If AVE > 0.5, it means that the latent/median variable construct explains more than half of the indicator's variance (Hair et al., 2014). The results of the reliability test for the variable are reliable if the Cronbach Alfa is greater than 0.7 and the Composite Reliability is greater than 0.7 (as the standard value of generally accepted research instrument reliability (Jonathan, 2010). All indicators with outer loading values >0.5 based on outer loading validity value stated that all indicators have convergent validity as Average Variance Extracted, as shown in Table 6.

The AVE and Composite Reliability values in the table can be concluded that:

- The AVE value shows the latent and median variables > 0.5, which means that the convergent variables are valid and sufficient.
- The value of Composite Reliability and Cronbach's alpha > 0.7 which means the instrument is reliable and acceptable.

Table 6

Convergent Validity Based Convergent Validity Check Results

No	Main Factor	Cronbach's Alpha	Composite Reliability	AVE	R^2	R^2 Adjusted
1	Green Building (X2)	0.996	0.996	0.501	0.961	0.9612
2	Retail Commercial Estate (X1)	0.971	0.973	0.506	0.807	0.8094
3	External Cost (Y2)	0.750	0.886	0.796	0.808	0.8076
4	Internal Cost(Y1)	0.905	0.938	0.796	0.952	0.9525
5	Cost(Y)	0.913	0.936	0.716	0.873	0.8713
6	Blockchain-BIM (X3)	0.937	0.946	0.578	0.915	0.9142
7	Blockchain-BIM Reliability (X3.1)	0.898	0.920	0.595	0.964	0.9643
8	Implementation of Retail Commercial Estate (X1.2)	0.953	0.958	0.541	0.952	0.9524
9	Implementation of Green Building Stage (X2.2)	0.989	0.989	0.512	0.9965	0.9961
10	Utilization Stage(X2.3)	0.984	0.985	0.501	0.9963	0.9962
11	Disassembly Stage (X2.4)	0.926	0.936	0.513	0.9562	0.9561
12	Maintenance Stage (X1.3)	0.871	0.906	0.622	0.8273	0.8275
13	Technology Adjustment(X3.2)	0.854	0.896	0.635	0.9294	0.9281
14	Plan of Retail Commercial Estate Stage (X1.1)	0.893	0.914	0.542	0.9253	0.9241
15	Plan of GB Stage (X2.1)	0.987	0.988	0.503	0.9842	0.9840

Then at that point in **Table 6**, it can be explained that the research results of the R^2 value, which is a goodness-fit-model test taken from model data at the outer loading stage and is a value that shows how much the independent (exogenous) variable influences the dependent (endogenous) variable, found that the R^2 value has an effect together with Cost (Y) is 0.873 with an R^2 adjusted value of 0.871, thus it can be explained that all independent variables simultaneously influence Cost (Y) by 0.871 or 87.1%. Because R^2 adjusted is 87.1% > 50%, the influence of all independent variables on Cost (Y) is strong. The influence of all independent variables on X1, X2, and X3 is moderate because it is > 0.80.

Evaluation of Measurement Models (Inner Loading – Bootstrapping)

Look for statistical T coefficients as a test of the research hypothesis. Where the results or output of SEM-PLS from the Calculate PLS Bootstrapping command produce T Statistics, as shown in **Fig. 6**. Based on the tested questionnaire data, the most influential factors can be obtained from the 304 sub-factors that have been analyzed. The first step in evaluating a structural model is to test the collinearity between the constructs and the predictive power of the model. Then, the criteria of coefficient of determination (R2), cross-validation redundancy (Q2), effect size (f2), and path coefficients are used (Ghozali & Latan, 2020). Q2 > 0 indicates that the value of the observation reconstruction is large. The model has predictive relevance, Q2 < 0 indicates the model has no predictive relevance (Sarstedt et al., 2022), parameter The estimated value of the path coefficient for path correlation in the structural model must be evaluated for the strength and significance of the correlation P value < 5% and T Statistic > 1.96 (Ghozali & Latan, 2020).

The ten influential factors are sorted in the order of the greatest. Where the most influential factor is the validation of GB, which is shown in **Table 7**.

Fig. 6

SEM-PLS T-Value and P-Statistics Diagram

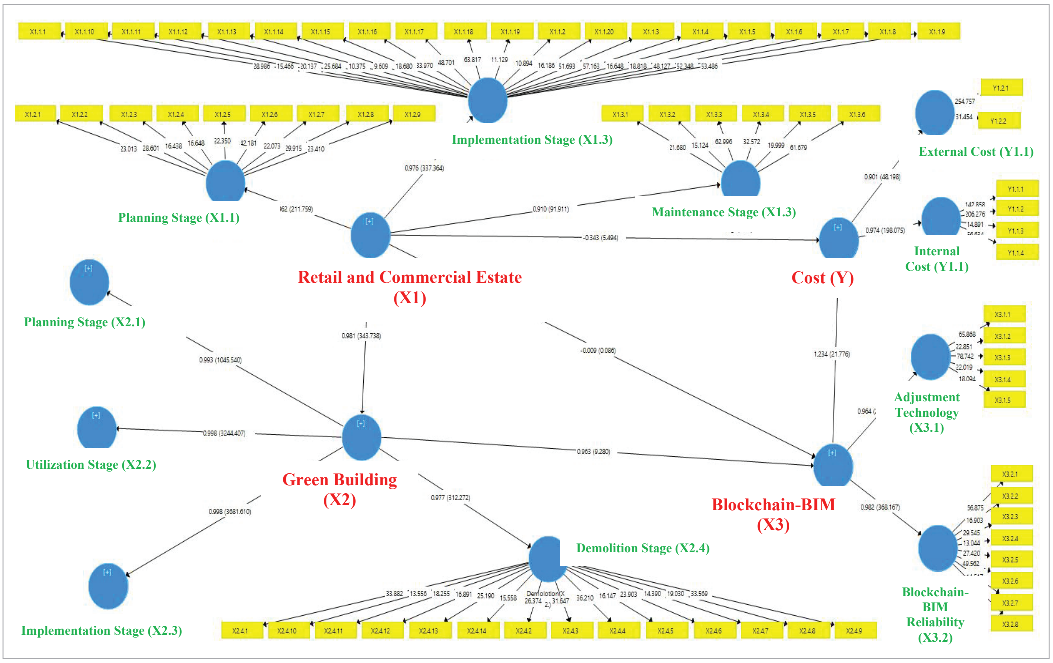


Table 7

The Most Influential Factor

No	Sub Factor		Original Sample Value	T. Statistics > 1.96 (p < 0.05)	Against R Square
1	The Building Orientation	X2.2.34	0.811	40.969	
2	Air-Conditioning energy efficiency	X2.2.80	0.802	39.131	
3	Building envelope efficiency	X2.2.46	0.801	38.219	
4	Building integrated data	X2.2.50	0.798	36.342	
5	Construction Equipment Monitoring	X2.2.79	0.798	36.864	0.996
6	HSE Plan	X2.2.24	0.797	36.654	
7	Identify material requirements	X2.2.5	0.796	35.832	
8	Main equipment certificate	X2.2.55	0.795	36.043	
9	Wastewater treatment Plant	X2.2.61	0.794	34.519	
10	Energy Conservation Rules	X2.2.30	0.794	34.234	

Relationship between Green Building and Blockchain-BIM

The researchers attempted to simulate a Blockchain-BIM application by following the procedure described on the previous page. In the simulations performed, the researchers only ensured that the backend network could be deployed, especially for validating smart contracts integrated into the Blockchain network. Furthermore, Visual Studio Code, the Integrated Development Environment (IDE) used as a Blockchain simulator, is a software application that can efficiently program and develop software code. In these applications, productivity gains for GB can be achieved by combining features such as editing, drafting, testing, and packaging software into one easy-to-use application. This IDE has comprehensive and powerful features such as debugging, scalability, marketplace, IntelliSense, and Git central integration, and it supports almost all programming languages like Node.js, JavaScript, and Typescript (Del Sole, 2021), and these scripts are needed to create a network of smart contracts. Visual Studio Code software, where the IBM Blockchain platform is available, and to simulate the model. The IBM Blockchain accelerator helps startups quickly scale enterprise Blockchain networks. IBM Blockchain provides a way to improve process efficiency through intelligent process creation and data collection, especially for inter-agency data exchange (R & Aithal, 2020).

The simulation is carried out by creating a smart contract network on the Micro Hydro work package. The first step is to define the user, Client (User 1), Contractor A (User 2) Contractor B (User 3). There are several steps for this simulation. In the first stage, Contract documents containing project data in csv form are uploaded to the Blockchain network. Second, After the data is on the Blockchain, a data link containing the work files will be sent to the bidders in the form of a download link. At this stage, the bidders will receive information on work, length of time for work, and costs required. Third; Next, the contractor will send bids into the Blockchain network. Fourth; Furthermore, the client will check the value of the bid submitted, whether it is in accordance with the contract document or not; if it is not appropriate, the client will send a notification to the bidders to correct or reject the offer. Fifth, The confirmation process will be confirmed by both parties involved in the work at this stage; all information about the volume of work, price and duration of work will be confirmed by both parties, and the work contract will begin. Sixth, Along with the project time, the work contractor will make claims on the progress of the work by entering data on photos of the work field and the amount of the claim submitted. Seventh; Then the owner will check the document claim. Can it be accepted or rejected, or does it need to be revised? If it turns out that the work is not in accordance with what was claimed by the contractor, then the client has the right to refuse, and if accepted, the client will process the payment stages. In this model simulation (Fig. 7), micro hydro work progress can be fully accepted.

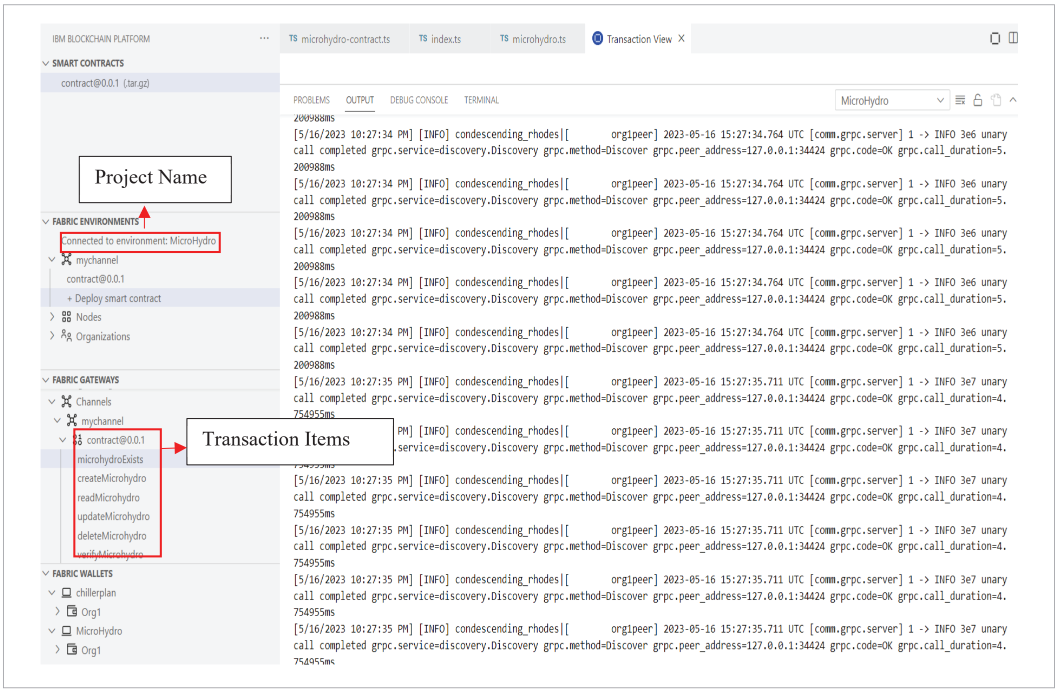


Fig. 7
Transaction Network

Researchers took the work of increasing the Renewable energy item for Blockchain-BIM simulation in the retail and commercial estate, as shown in Table 8, according to the assessment results of GB. Previously, we have summarized the costs from the results of the BIM modelling that was done before, based on the improvement in the assessment results.

The result of increased cost and performance for all work is described in Table 9 for all ratings. For the total factory budget with Blockchain-BIM implementation, we have converted the cost from Indonesian to international currency for easy understanding.

Table 8

Budget Plan Base on Green Building Per Item Assessments

No	Work Improvement Base On GB Assessment	Detail of Work	Budget Cost Become Green Building		
			Basic	Middle	Main
1	Rain Water management ≥ 2 Hours	Detention Pond & Water Pump	N/A	10,301	10,301
2	OTTV max. 35 Watts/m2 (1), WWR ≤ 30% sheath building (2)	Façade & Window Wall	958,598	958,598	958,598
3	Room with Natural Ventilation	Ventilation Lobby	N/A	N/A	14,253
4	kW/TR follow Indonesian Standard(1), ODP = 0 (2), GWP Refrigerant ≤700 (3)	Chilled Plant Enhancement	1,024,133	1,237,388	1,288,961
5	Electricity Consumption ≤ baseline.	Building Monitoring System	67,399	101,099	202,198
6	Lighting with Natural Sources	Lighting on Skylights	25,423	25,423	25,423
7	Sensors CO2 and CO for Basement Ventilation Parking	Ventilation for Basement Parking	18,096	18,096	18,096
8	Utilization of Rain Water	Rain Water Filtration	N/A	9,660	9,660
9	Sanitary unit with Saving Water	Water Fixtures Unit	21,676	38,530	40,987
10	Electricity with Renewable Energy.	Solar PV (Op. 1) Micro Hydro (Op. 2)	1,317,93 249,787	1,317,9362 49,787	1,317,936 249,787
11	Rubbish Shelter	Garbage Building	N/A	21,215	21,215
12	Facility Processing of Wastewater	STP Completed	104,987	129,933	129,933
13	Water Recycle for Cooling Tower	Water from STP	N/A	46,000	46,000
		TOTAL 1 (USD)	3,538,249	3,914,180	4,083,562
		TOTAL 2 (USD)	2,401,628	2,777,559	2,946,941

Table 9

Total Budget Plan with Blockchain-BIM Implementation

No	Work Item	Previous Building Cost (A)	Green Building Cost (B)			Green Building Cost with Block-chain-BIM (C)		
			Basic	Middle	Main	Basic	Middle	Main
1	Structural	14,590,560	14,590,560	14,625,628	14,625,628	14,225,796	13,923,598	13,923,598
2	Architectural	5,366,764	5,837,813	6,363,694	6,381,218	5,697,706	6,058,237	6,074,919
3	Interior	5,137,093	5,137,093	5,137,093	5,137,093	5,013,803	4,890,513	4,890,513
4	Electrical	4,753,062	6,163,821	6,197,520	6,312,872	6,015,894	5,900,092	6,009,852
			5,027,200	5,060,899	5,176,252	4,906,547	4,817,976	4,927,793
5	Landscape	297,047	297,047	297,047	297,047	289,918	282,789	282,789
6	MVAC	5,064,972	5,513,161	6,320,456	6,385,001	5,380,845	6,017,074	6,078,521
7	Plumbing	1,367,865	1,381,198	1,553,458	1,553,458	1,348,050	1,478,892	1,478,892
8	Consultant Fee	-	166,667	166,667	166,667	162,667	158,667	158,667
	Total 1 (USD)	36,577,363	39,087,360	40,494,897	40,692,319	37,972,006	38,551,126	38,739,087
	Total 2 (USD)	37,950,739	39,358,276	39,555,698	36,813,779	37,534,804	37,728,008	
	Deviation (D= Total B-Total A; Total C-Total A)		2,509,997	3,917,537	4,114,955	1,394,643	1,973,779	2,161,740
			1,373,376	2,780,913	2,978,335	1,136,960	1,823,472	1,827,690
	Percentage (D/Total A)		6.9%	10.71%	11.25%	3.8%	5.4%	5.9%
			3.8%	7.6%	8.1%	3.0%	4.6%	4.6%

The examination of the cost category itself can be briefly explained, includes several tasks, and is ordered from highest to lowest. Solar photovoltaic installations are the largest contributor to renewable energy deployment in the GBs. Another option is to use a small hydroelectric plant to reduce the initial cost. Still, efficiency must be considered with the demand and the electric power generated in this building.

The prerequisites for kW/TR to meet GB requirements and cooling plant improvement work, the centrifugal-type cooler efficiency value d is at least 0.67 for capacity above 300 TR. Third, the building facade is closely related to the building envelope. It is the most important factor in calculating OTTV and WWR required by GB. To meet the requirement of OTTV value required by GB, the researcher performed the analysis by replacing the glass sample with a lower shading coefficient value. STP modernization works, which means that in addition to the STP treated water must meet the standards issued by the Environment Agency and refer to the GB requirements, the STP treated water must be reused as clean water without any chemical or biological adverse effects on the surrounding environment. Other works include; constructing a monitoring system, rainwater filtration, strengthening the lighting system in the skylight area, provision of a waste treatment building, an efficient water supply unit, detention tank systems and ventilation system for the parking lot in the basement.

Conclusion

Renewable energy, environmental sustainability, and cost-effectiveness are the main discussions in this study; therefore, the economics of using Blockchain-BIM to increase costs in the GB’s requires further analysis and discussion. At this time, Blockchain constitutes a major breakthrough and its ultimate consequence is that sustainability depends on the vision and underlying strategy chosen to manage the business and operations. The GB's construction cost performance implementation flow for modern Blockchain-BIM-based retail and commercial estate has been proven effective in increasing GB's cost performance. From the results of research by applying the Blockchain-BIM method to overcome cost constraints, it is proven to be able to increase the cost performance of GB in retail commercial estate by 3.8% in the Basic Rating, while for the Middle and Main Ratings, it is 2.1% higher, where the use of energy from roof solar panels is applied. While the application of micro hydro technology results in an increase in cost performance of 3.0% in the Basic, while for the idle and Main Ratings, it is less than 0.8% higher. Then from the results of statistical tests have been carried out, that there is a significant relationship between the results of the SEM-PLS testing and the green building assessment result items. Which means they have similarity item between the influential factors and improvement work items for green building requirement.

The selection of renewable energy technologies has an important role in initiating the cost aspects of GB and is very influential, as evidenced by the results of this study, where at a lower cost, the requirements for implementing renewable energy can be achieved. The other side of the costs required will be directly proportional to the electrical energy generated, depending on the stakeholder, which technology is profitable both in terms of cost and energy required. Besides that, the policies, rules, and government incentives have an important role and can force the concept of GB to be applied to all buildings in general and retail buildings in particular, to be able to achieve the objective of sustainable development in Indonesia, as well as following the goal of Net Zero Emissions by 2060.

In this study, researchers experience difficulty making smart application contracts on the Blockchain network because of the limitations of technology researchers. Researchers have several times experienced failure in making applications based on Blockchains. In the future, studies need to be done and need to work the same with Blockchain practitioners, so that this method can be easily assembled and applied, such as collaboration in creating Blockchain network configurations with Blockchain practitioners to simplify the simulation.

Adopt Blockchain-BIM to increase the cost performance of GB needs to be pushed with facilitating skills construction engineers in getting value for other buildings. Whatever, the effective use of Blockchain-BIM depends on the user in adapting the technology, as well as the knowledge base about encryption technology. Future analysis should take more into the complexities of GB and the needs of various stakeholders. The research novelty of this study depends on the contribution of a set strategy that combines Blockchain-BIM deep increase practice for GB with renewable energy by the stakeholders. Researchers provide election of the application of renewable energy, so that it can meet the green building criteria by the government, and the required cost options. Another thing that needs to be strengthened is the modeling skills for renewable energy in GB, but also the control knowledge in its Blockchain technology.

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About the Authors

ALBERT EDDY HUSIN

Associate Professor

Faculty of Engineering, Magister of Civil Engineering Program, Universitas Mercu Buana, Indonesia

Main research area

Construction Management, Infrastructure Management and Green Infrastructure

Address

Jakarta, Indonesia
Email : albert_eddy@mercubuana.ac.id

PRIYAWAN PRIYAWAN

Master of Civil Engineering

Faculty of Engineering, Magister of Civil Engineering Program, Universitas Mercu Buana, Indonesia

Main research area

Construction Management, Renewable Energy and Automation Engineering

Address

Jakarta, Indonesia
Email : priyo.cinko@gmail.com