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Renewable Energy Approach with Indonesian Regulation Guide Uses Blockchain-BIM to Green Cost Performance

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Abstract

Climate change is a threat and crisis that hit the world today; one of them is causing drought, rising sea levels, melting polar ice, and heat waves; therefore, the target towards Net Zero Emission (NZE) in 2060 must be an obligation in all countries. Green Building (GB) is a building that meets Building Technical Standards, and has demonstrated demonstrable success in conserving resources such as water, energy, and other resources. The application of GB principles following the function and classification in every stage of their implementation is expected to reduce greenhouse gas emissions. This research aims to analyze the cost of improvement work based on GB assessment in applying the Technical Guidelines from Minister of Public Works and Public Housing (PUPR) No. 1 of 2022, which is the latest regulation in Indonesia. The blockchain-BIM method and the implementation of the GB component will be analyzed using Structural Equation Modeling-Partial Least Squares (SEM-PLS) to find the most influential factors. The results of this study show that by applying Blockchain-BIM to overcome the cost constraints, it is proven to be able to increase the cost performance of GB in modern shopping center buildings by 3–3.8% in the Basic rating, while for other ratings, it is 0.5–2.1% higher, where the selection of a renewable energy model is very influential.

Keywords: Green Building (GB); Cost Performance; Blockchain-BIM; SEM-PLS; Renewable Energy.

1. Introduction

High energy use by buildings poses a serious environmental risk and is one of the main contributors to climate change [1]. In the world, buildings are responsible for 30% of all CO2 emissions [2]. Other than that, global warming is a major problem affecting private sector institutions and governments; all societies must create new business plans focusing on finding solutions to environmental problems [3]. Because of these several things, the World Green Building Council states that we have entered a crucial period to implement the results of the Paris Agreement, where all sectors of the economy must achieve significant reductions in gas emissions, and by 2050 all buildings must implement net zero carbon emissions [3, 4]. This has made GB a prospective route for the Architecture, Engineering, and Construction (AEC) sector to support sustainable growth [5]. Because 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 for transportation and employment [6].

In the application of green building, there has been an idea behind a "zero-energy building" that doesn't require the usage of fossil fuels. Instead, all needed energy is provided by renewable energy sources like solar energy, which can

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be accomplished with several design techniques to lower the building's energy consumption [7]. One of them is the application concept of solar energy, which is a cost-free, environmentally friendly energy source with no negative impacts [8], as well as the application of hydroelectric power, often known as water turbine generators, which is one application of renewable energy that is expanding quickly alongside technological advancements [9]. Hydropower applications can significantly improve the management of natural and artificial water resource systems [10]. With the implementation of those approaches, technology, which is energy efficiency improvements and the usage of energy sources, are prioritized under renewable energy regulations [11]. This is consistent with the GB philosophy of energy use.

However, in the implementation of GB, several studies concluded that a problem occurred. The field shows that 30% of green construction projects are undergoing rework, 50% of green construction projects are disrupted by delays [12], and 90% of green construction projects require a cost premium of up to 21% to ensure their completion [13]. The results show that the green cost premium ranges from 5% to 10%, with project type and size being the main factors affecting the cost premium. Moreover, the price performance is almost over budget, ranging from 4.5% to 7% [14]. The latest researcher mentioned that, looking at the average eco-cost subsidy, office buildings, condominiums, and school buildings cost 4% more than conventional buildings, and other commercial buildings had a 2% higher green fee [15]. To overcome the cost constraints on these green buildings, researchers propose using the blockchain-BIM method. And the focus of this research is to find out further how the application of the GB concept influences investment decisions in high-rise buildings with blockchain-BIM implementation in terms of the application of renewable energy approaches.

2. Literature Study

In this study, we used literature related to green building concepts in modern shopping center buildings, blockchain-BIM, and renewable energy approaches.

2.1. Green Building Concept in Modern Shopping Centre Building

The green concept is the process of building a structure based on the environment and resources efficiently throughout the life cycle of the building, from design, construction, operation, maintenance, renovation, and demolition [12]. And the measurement indoor environmental quality (IEQ) results show that a green shopping mall building is superior to a conventional one in terms of the indoor thermal environment, indoor illumination, relative humidity, carbon dioxide concentration, and noise level [16].

In the process of implementing a green concept building, there are provisions that must be made in order to be approved if there is an official organization to rate the "green" level of an industrial building as respecting the environment, and receive incentives or amenities from the local government. Perhaps even the stakeholders themselves are not aware that there are already many organizations around the world and in Indonesia as the green review unit for the Modern Shopping Center Building.

In Indonesia, a GB certification system previously existing is Green Ship, a member of the World Green Building Council (WGBC) for the conservation and efficiency of water, energy, land, nature, and materials [6]. However, that differs from the GB concept of the Indonesian Minister of PUPR of 2022. The Indonesian Government, through the Technical Guidelines of Minister of Public Works and Public Housing (PUPR) No. 1 of 2022, which is the latest GB regulation in Indonesia, has released According to this regulation, there are 3 (three) GB rankings: Main Rating (80%–100%), Intermediate (65%–80%), and Basic (45%–65%), where the maximum total points obtained are 165.

2.2. Blockchain-BIM

Blockchain is a decentralized system for managing transactions and data [12]. Blockchain is a technology that enables the exchange of information and transactions between two or more participants through encryption that is completely secure and immutable [13]. Blockchain's distributed database system is an "open ledger" to record and manage transactions [14]. Blockchain technology relies on distributed ledger technology—a shared ledger between all participants (nodes) in the network [15]. It has been discovered that blockchain has the potential to address the challenges that prevent industries from adopting BIM for sustainable design [17].

The economic benefits of blockchain applications in construction, according to 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 [18]. Transaction costs themselves: according to research conducted by Abdel-Galil et al. [19], the average value of post-contract transaction expenses is estimated to be 8–9% of the contract value, while pre-contract costs for building projects typically range from 3-4% of the contract value. By integrating the blockchain into the existing

BIM database, simplifying mobile computing, and providing extensive access to BIM information, the blockchain-BIM model may ensure the authenticity and origin of BIM data [20]. Blockchain may allow for the application of different "trust" levels to specific BIM elements as well as a more secure framework for stakeholder collaboration [21]. 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 [22]. The integrated blockchain and BIM technology promise a more private and secure company environment with complete process control [19]. Smart contracts on the blockchain have become a new value proposition for enhancing some facets of project sustainability [20].

From the literature above, it can be concluded that blockchain applications are decentralized systems for managing transactions and data, enabling a secure, immutable exchange of information. They address challenges in adopting Building Information Modeling (BIM) for sustainable design, offering economic benefits like reduced retail transaction costs, simplified mobile computing, and smart contracts for project sustainability.

2.3. Renewable Energy and BIM

The energy efficiency of buildings is one of the most important characteristics to be assessed to achieve sustainability in the built environment [23]. Then, the implementation of building an integrated photovoltaic system is expected to be one of the best options for tropical countries like Indonesia, which have abundant solar radiation [24]. In another study by [25] 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. Among all renewable energy sources, hydroelectricity is the most economical and reliable source [26]. It is more relevant for commercial and public sub-sectors as it increases construction productivity [27].

A BIM model that prototypes the appearance of actual building design and construction can generate sufficient information for users [16]. BIM, acting as a supporting tool for sustainable integrated design, has tremendous relevance in fostering a new cultural design approach to sustainable architecture that seeks to comprehend and implement buildings with a minimal environmental effect [18]. BIM has gained popularity in the design, construction, and management of buildings, and it has recently drawn some interest from the hydropower industry because BIM technology can be used in any hydropower project [28]. So, the lessons learned include the fact that, while BIM can improve projects in some ways, it also raises project costs and lengthens project duration [17].

The presentation above shows that energy efficiency is crucial for sustainable built environments, with photovoltaic systems promising options in tropical countries like Indonesia. And BIM technology, particularly in hydropower projects, increases construction productivity while reducing costs and project duration.

3. Research Material and Methodology

The application of the Blockchain-BIM method for increasing the cost performance of green buildings requires accurate objects and information about influential factors to support the implementation of this method. In this study, the methodology adopted to obtain the cost performance of green buildings in the Modern Shopping Center Building with the renewable energy approach consists of the following steps:

- Collecting variables used in research.
- Perform statistical tests using Structural Equation Modeling (SEM)-Partial Least Squares (PLS).
- Analysis of the application of renewable energy.
- Blockchain-BIM method simulation.

3.1. Research Material

The performance evaluation standards follow the Technical Guidelines from Minister of PUPR No. 1 of 2022 concerning the performance appraisal of GB, consisting of the Planning, Implementation, Utilization, and Demolition Stages. Where are the criteria for the application of renewable energy as mentioned in point 33, Table 1, which should be included in the assessment points? Table 2 shows the variables in the implementation of the GB stage, and Table 3 shows the variables for blockchain-BIM. Those tables, which are part of a total of 304 variables, will be used to analyze and produce factors that influence the implementation of GB in the modern shopping center building. The observed data was obtained through a questionnaire that was distributed to 255 participants, including engineers, owners, consultants, contractors, and some IT practitioners [29].

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	OTTV ≤ 35 Watt/m2	5	15	Garbage Storage environment	2
2	75% water-saving fixture Unit	5	16	Non-HTM stainless paint	2
3	Electrical consumption < baseline	5	17	Timber with legal provisions	2
4	KW/TR follows Indonesian Standard	5	18	Local materials ≥40%.	2
5	Window to Wall Ratio (WWR) ≤30	4	19	Garbage shelter capacity	2
6	Grouping lighting lamps	4	20	Organic waste process.	2
7	Vegetation Crown ≥20% of site area	4	21	Garbage Pre-Processing Tool	2
8	Restoration of land contaminated with Hazardous and Toxic Materials (HTM)	3	22	Wood non-Hazardous and Toxic Materials (HTM) adhesive	2
9	Green Open space >50%	3	23	Independent garbage	2
10	Pedestrian access path	3	24	Waste volume	2
11	Smoking prohibition sign	3	25	Clarity of entry & exit	1
12	Air cond. with Management System	3	26	Complete Waste Treatment	1
13	Surface water is treated with a permit	3	27	Quality of wastewater standard	1
14	Recycled water from dirty water	3	28	Pre-processing waste volumes	1
29	Room with natural ventilation	3	55	Recycled water for CT	1
30	Ventilation follows Indonesian Std.	3	56	Roof covering with Albedo	1
31	CO2 concentration ≤1000 ppm	3	57	Has one of the vegetation	1
32	CO concentration. ≤ 25 ppm	3	58	Waste based materials	1
33	Ozone Depletion Potential (ODP) = 0	3	59	The coefficient of rainwater absorption	1
34	ISO 14000 Concrete Materials	3	60	Basement ≤2 layers	1
35	Paint Materials ISO 14001	3	61	Vertical parking area	1
36	Complete treatment of waste	3	62	Facility with light sensor	1
37	Recycled Water Use	3	63	Shower facilities for cyclers	1
38	The longest wall faces East-West	3	64	Recycled water with two functions	1
39	Rainwater is managed for ≥2 hours	2	65	Non-HTM Environmentally roof	1
40	Dust filters	2	66	Garbage pipe network	1
41	Electric Vehicle Charging Station	2	67	Eng. view to the outside building	1
42	Air conditioning temp. ≥ 25°C±1°C	2	68	Water & energy efficiency	1
43	Standard artificial lighting	2	69	Have a waste processor	1
44	Lighting switches ≤30m2.	2	70	Standard traffic lift	1
45	Grouping lighting areas	2	71	3R waste management	1
46	KWh meter electricity consumption	2	72	Vertical Trans. with slow motion	1
47	Renewable electrical energy	2	73	Water Company for Efficiency	1
48	Treated rainwater	2	74	Pedestrian to public ≤400meters	1
49	Recycled water from used water	2	75	Local source wall ≤ 1000 km	1
50	Groundwater output meters	2	76	Recycled wood ≥50% wall value	1
51	Saving water consumption	2	77	Source concrete ≤1000K	1
52	Smoke-free building	2	78	Natural air engineering	1
53	Global Warming Potential Max. 700	2	79	Vertical transport with VVVF	1
54	Paint without contaminants	2	80	Grouped Garbage bins	1
	Total				**165**

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

Table 3. Blockchain-BIM variables

No.	Sub-factor	Source	No.	Sub-factor	Source
1	Project requirements	[30]	8	Blockchain Transactions	[18, 30]
2	Consistent data	[30, 31]	9	Blockchain data sources	[18, 30]
3	Professional role	[30]	10	Bitcoin Blockchain	[30]
4	Secure information	[30, 32]	11	Block chain-BIM Usage	[18, 22]
5	Blockchain-BIM Specifications	[30, 33]	12	Block chain-BIM Adoption	[18, 22]
6	Blockchain Verification	[30]	13	BIM Level on Blockchain	[30]
7	Blockchain Transparency	[18, 30]			

3.2. Methodology

In this research, the methodology is done through a series of scientific stages. As for the implementation of the research carried out in the outline, referring to Figure 1, which increased the cost of green buildings in modern shopping buildings by using the blockchain-BIM method. According to Figure 1, research implementation consists of four main variables, which are then explored and analyzed to make the research accurate. In this case, on the next step, the researcher explains the steps of exploration, development, and analysis of the main factors in this research to achieve the research objective.

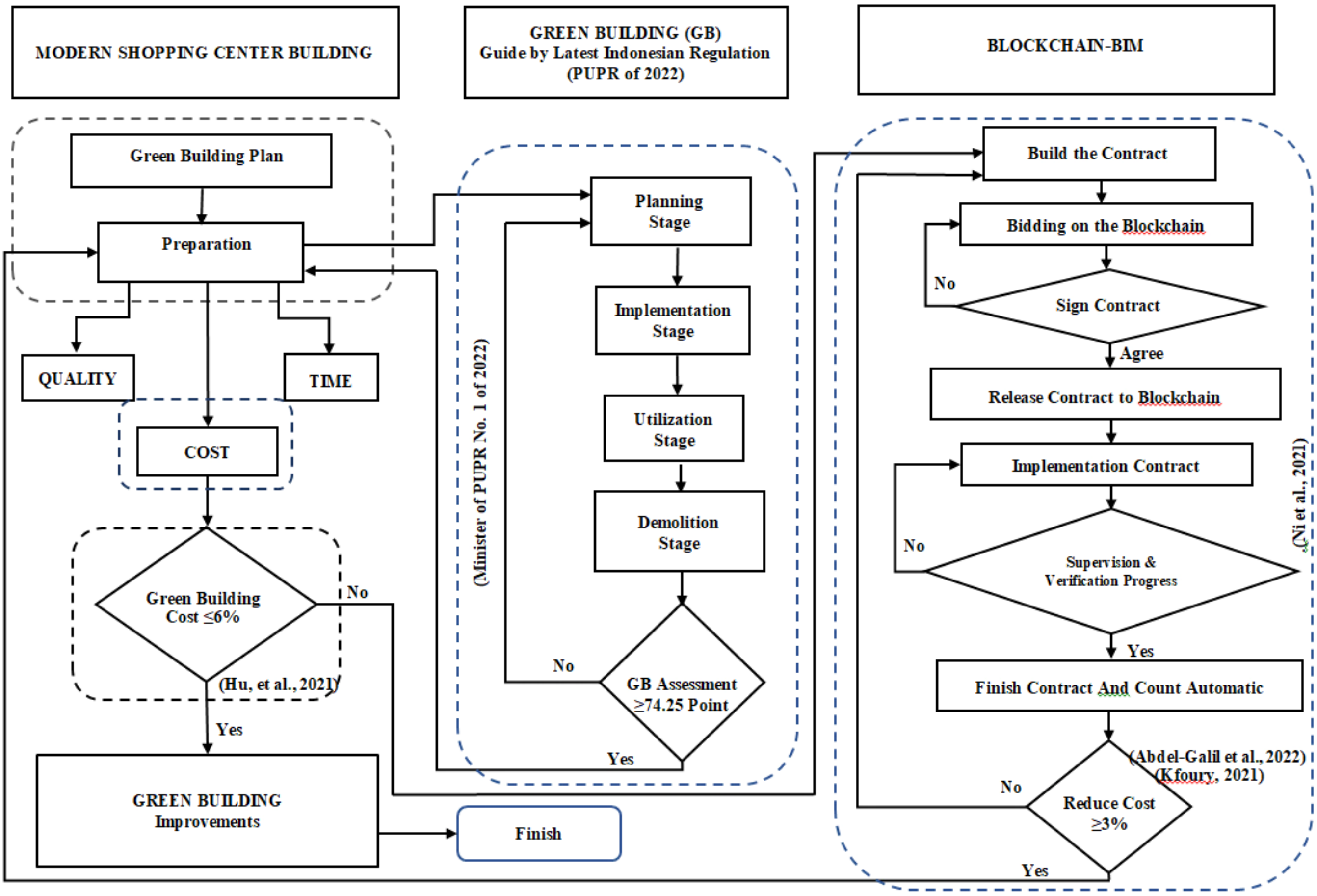


Figure 1. Research implementation of GB concept on modern shopping center building, configured of [15, 18, 19, 29, 34, 35], and flow adoption of [36]

After the research implementation steps are determined, an instrument is needed to test the variables contained in the main factor of this research. Structural Equation Modeling (SEM): Version 3.0 of the Partial Least Squares (PLS) software is selected and used to determine sample size and whether the data meets the requirements of the SEM-PLS model. The flow of testing with SEM-PLS is explained in Figure 2, where the requirements of the model are used based on the results of previous researchers for SEM-PLS.

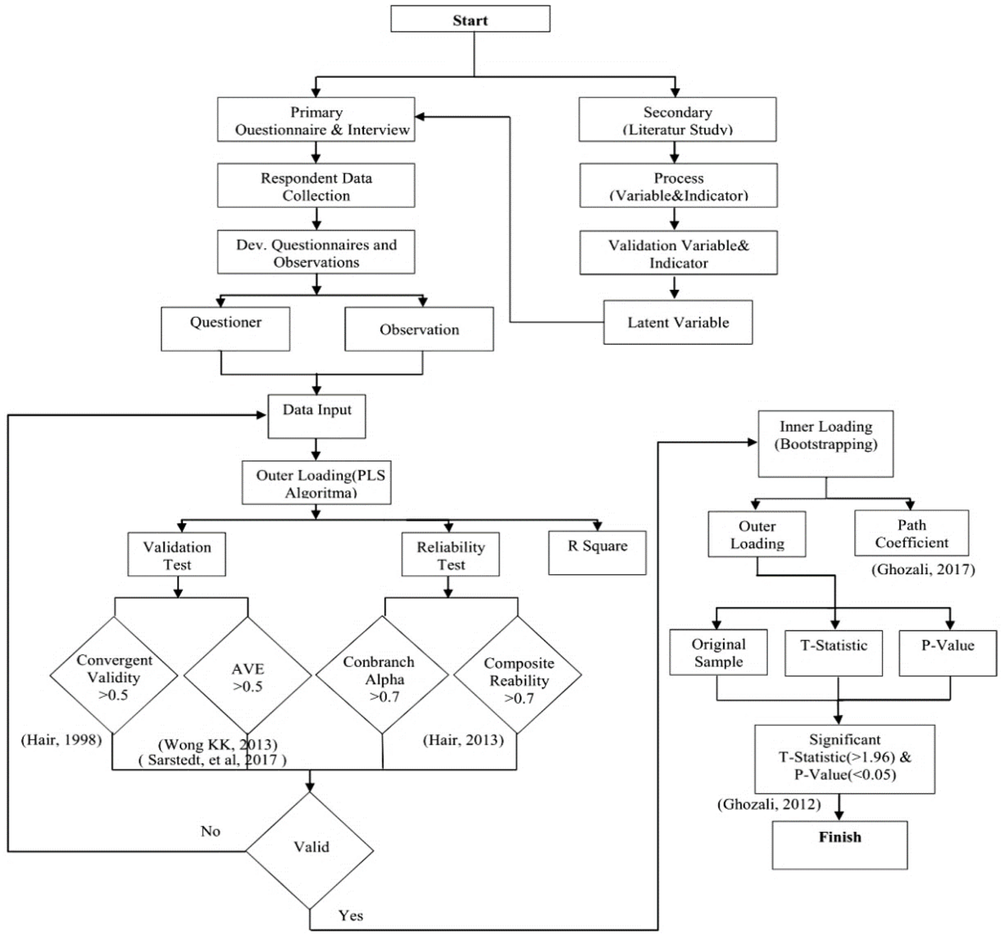


Figure 2. Data processing diagram, adaptation of [37]

On the SEM-PLS tested, considerations include model properties, sample size, the shape of the 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 [38]. To achieve the research goals, the next step for 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 [39], only half of the systematic review included flow charts to provide insight into the process of study evaluation. The researcher assesses PUPR's 2022 Regulation's Technical Guidelines for renewable energy and explores alternative sources like microhydro and solar PV plants, as shown in Figure 3, and BIM modeling is necessary for cost calculations [40-45].

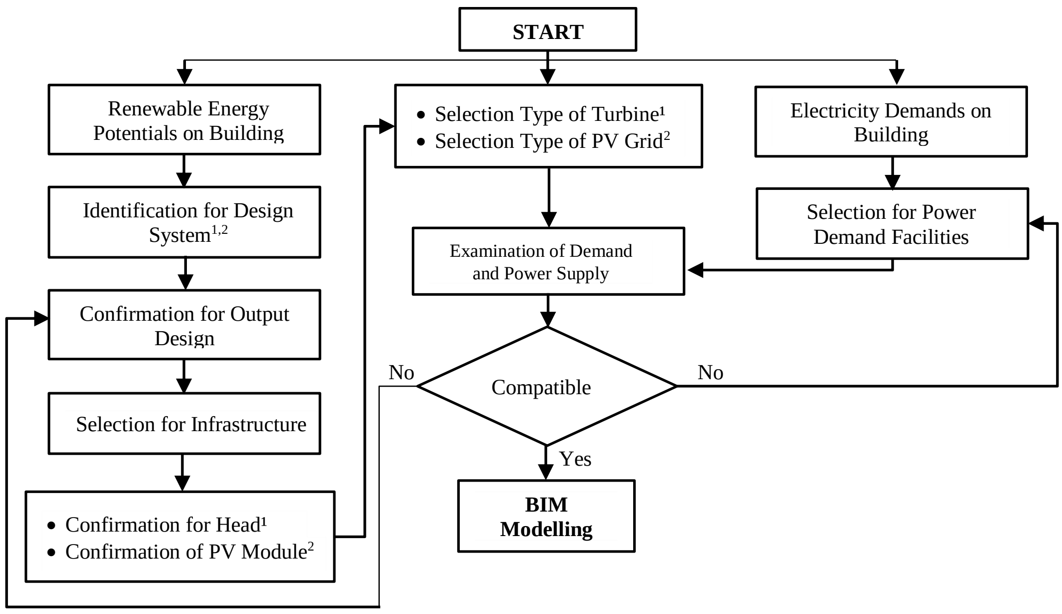


Figure 3. Identification analysis for renewable energy implementation

Furthermore, by referring to the research method explained in Figure 2 previously, the modeling simulation of the Blockchain-BIM method is required in this research; this is presented in Figure 4, which aims to prove its effectiveness, utilizing the network configuration that consists of components of contractors, owners, and Blockchain as a smart contract functionality.

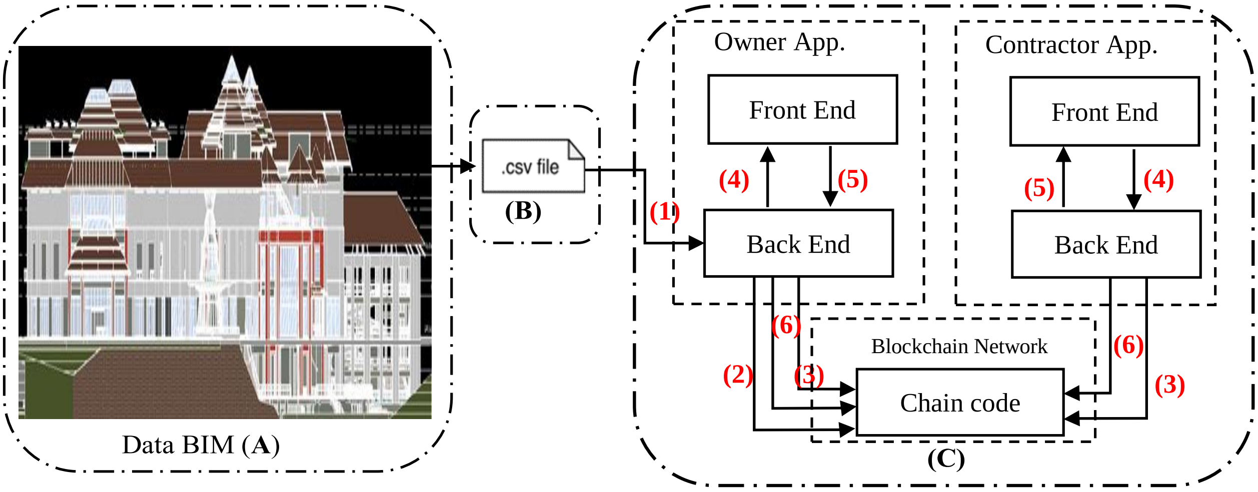


Figure 4. Blockchain-BIM configuration, an adaptation of [46]

4. Case Study

The research was conducted at a modern shopping center building project in Denpasar, Bali, Indonesia. This project is quite complex, involving ± 40,000 m^2 of area, and supports all the parameters required from the technical guideline on implementing the latest green building regulation from the Indonesian government (Figure 5).

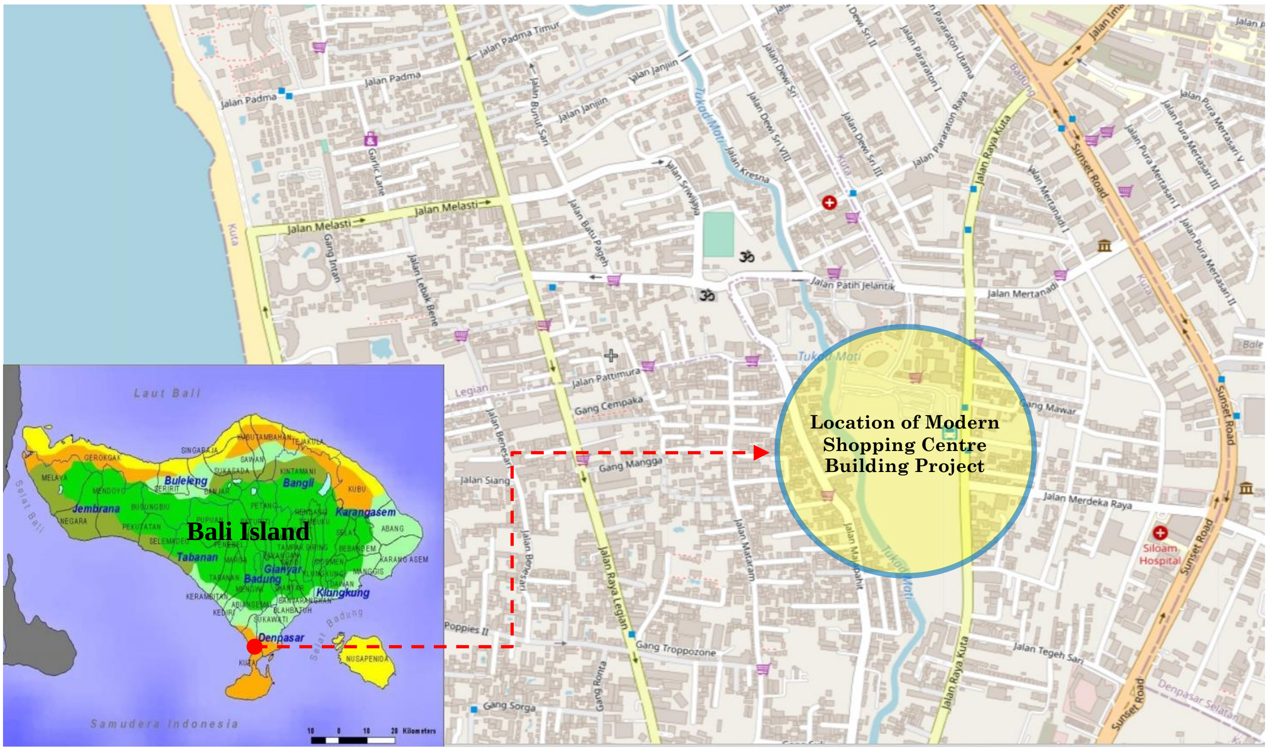
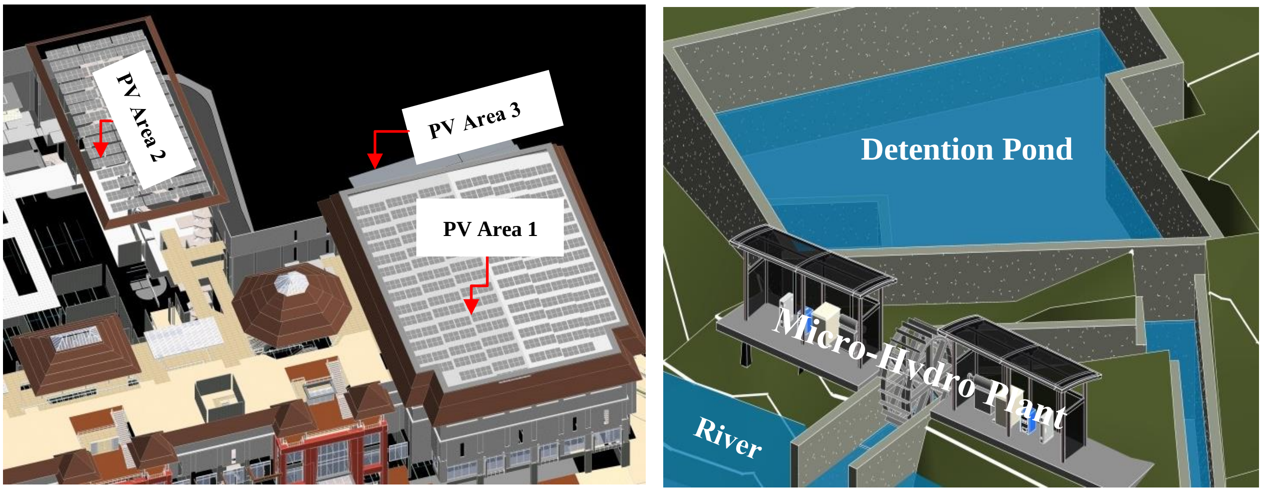


Figure 5. Location of the study area (Bali, Indonesia)

In accordance with the latest Indonesian government's green building regulations, this building must meet the criteria of a green building. However, based on the assessment results, it is 62.3 points for the requirements of the planning stage, so several items need improvement to achieve a minimum basic rating of 74.25 points. Energy-related points are crucial for achieving this goal.

Using the method previously described, we have identified the use of solar PV (Figure 6-a) that can be applied to this building for renewable energy implementation. Researchers have made two models, and the first is the installation of solar PV on the roof of a building, which consists of three areas and technically produces 550 kW of electrical energy.

As for the second model, the researchers built a microhydro installation (Figure 6-b). The electrical power produced is less considerable than solar PV due to the limited discharge and head of water in the irrigation canals of the building area; however, it is sufficient to fulfill the required aspects of the implementation of renewable energy.



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

Figure 6. BIM Modelling for Renewable Energy, by Revit 2021

Other modeling related to the results of the GB assessment, including the chilled plant unit improvements, improvement of the sewage treatment plant, water filtration on detention ponds, and garbage buildings, as well as several others, was carried out to look for cost aspects required from the green buildings. But the researchers did not show it, given the limitations of the paper.

5. Result and Discussion

5.1. 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 [47]. 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 [48]. Cronbach's alpha values are used to determine the internal consistency of the scales; reliability values are obtained for all variables; and the overall scale used in the study is determined to be above 0.6 [49]. 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 [50]. The results of the reliability test for the variable are reliable if the Cronbach alpha is greater than 0.7 and the composite reliability is greater than 0.7 (as the standard value of generally accepted research instrument reliability) [51]. All indicators with outer loading values >0.5 based on the outer loading validity value stated that all indicators have convergent validity as Average Variance Extracted, as shown in Table 4.

Table 4. AVE and Composite Reliability Test Results

No.	Main Factor	Cronbach's Alpha	Composite Reliability	Average Variance Extracted
1	Green Building (X2)	0.996	0.996	0.501
2	Modern Shopping Centre Building (X1)	0.971	0.973	0.506
3	External Cost (Y2)	0.750	0.886	0.796
4	Internal Cost (Y1)	0.905	0.938	0.796
5	Cost (Y)	0.913	0.936	0.716
6	Blockchain-BIM (X3)	0.937	0.946	0.578
7	Blockchain-BIM Reliability (X3.1)	0.898	0.920	0.595
8	Implementation of Shopping Centre Build. (X1.2)	0.953	0.958	0.541
9	Implementation of Green Building (X2.2)	0.989	0.989	0.512
10	Utilization (X2.3)	0.984	0.985	0.501
11	Disassembly (X2.4)	0.926	0.936	0.513
12	Maintenance (X1.3)	0.871	0.906	0.622
13	Technology Adjustment (X3.2)	0.854	0.896	0.635
14	Plan of Shopping Centre Building (X1.1)	0.893	0.914	0.542
15	Plan of Green Build. (X2.1)	0.987	0.988	0.503

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 is> 0.7, which means the instrument is reliable and acceptable.

5.2. 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 Figure 7.

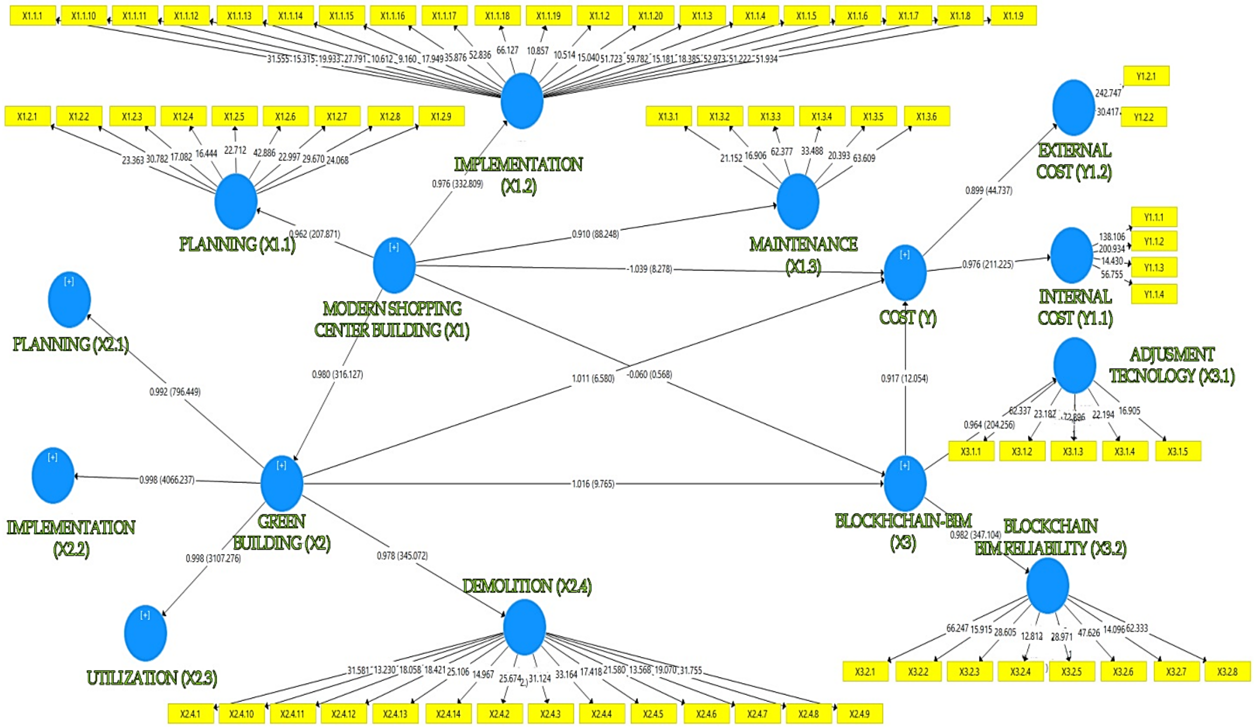


Figure 7. T-Value and P-Statistics Diagram, by Smart-PLS 3.0

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 (R^2), cross-validation redundancy (Q^2), effect size (f^2), and path coefficients are used [52]. $Q^2>0$ indicates that the value of the observation reconstruction is large. The model has predictive relevance; $Q^2<0$ indicates the model has no predictive relevance [48]. 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 [52]. Then, the direct and indirect influence of individual factors was analyzed in detail using the calibrated SEM model [53].

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 5.

Table 5. The most influential factor

No	Sub Factor		Original Sample Value	T. Statistics > 1.96 (p < 0.05)	Against R^2
1	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	
6	HSE Plan	X2.2.24	0.797	36.654	0.996
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	X2.2.61	0.794	34.519	
10	Energy Conservation Rules	X2.2.30	0.794	34.234	

From the factors that are produced according to Table 5, the researcher compares them with the results of previous research where SEM-PLS was used to analyze the green building issue. The factor that has the highest effect is building orientation. This means that for humid tropical areas like Indonesia, it is actually more directed to get a good position relative to the sun's orbit, which creates problems in predicting high solar radiation. The design process is complicated further by the fact that many building design factors, like the building envelope, window-to-wall ratio, building orientation, and building shape, affect how much energy is consumed [54]. So, determining the direction of the building is very important to ensure energy savings.

Then, energy efficiency standards for building envelopes are intended to provide guidance to all parties involved in the design, construction, monitoring, and management of buildings to achieve energy efficiency. Proper building envelope design is critical to significantly reducing energy consumption. In fact, in the case of multi-purpose buildings, more than 50% of energy demand is caused by heat loss through the building envelope, so the increase in the energy efficiency of the envelope is neglected. In this case, Fan & Xia (2017) [55] and Ascione et al. (2019) [56] show that optimizing the design of the building envelope can provide quite large energy savings, around 50%. And an automated HVAC control system can reduce up to 20% of a building's total heating load [57]. Apart from efficiency from the air conditioner side, due to global warming, the scarcity of fossil fuels, and the high cost of energy, industrial wastewater treatment plant energy consumption needs to be reduced [58]. Referring to Patrick et al. (2020) [59], implementing energy conservation involves planning and selecting energy-efficient facilities and operating systems. And the energy-efficiency standard is one of the most popular strategies for building energy savings, which is dynamic and renewed based on the current available technologies [60]. But there are also researchers [61] who use SEM-PLS analysis to reveal how cost risk, knowledge barriers, and financial incentives impact green building implementation. So, energy efficiency is a popular strategy for building energy conservation, focusing on energy-efficient facilities and systems and influencing cost performance and implementation levels.

According to building integrated data, BIM can be a solution to the industry's long-standing issues with low productivity and a lack of integration between project participants and processes. However, BIM implementation is not without dangers and difficulties [62]. BIM simulates 3D to 7D building projects using building information, timetables, cost estimation, energy analysis, and maintenance [63]. In the past decade, an increasing number of construction projects have utilized BIM for their success [64]. In addition to data integration, the HSE plan is made up of policy definitions, program assessment plans, or audit processes designed to ensure that the results of the HSE program can be verified and evaluated. According to the outcomes of the structural modeling used, project management strongly emphasizes every facet of HSE management, including health monitoring programs, safety preventive monitoring programs, environmental monitoring plans, and the efficacy of professional health monitoring programs [65].

The principles of GB are not only applied to the physical building but are also needed at the construction stage [66]. Procurement of energy-efficient and environmentally friendly materials generally has good physical properties; that is, they can be reused effectively, save resources, and their durability can meet project engineering requirements [67]. And in summary, building orientation plays a crucial role in energy efficiency in humid tropical areas like Indonesia. In this case, optimizing building envelope design and implementing energy efficiency strategies, BIM, and HSE plans are essential for project management.

5.3. Relationship between Renewable Energy on Green Building and Blockchain-BIM

Researchers have tried to simulate the application of blockchain-BIM by following the process described on the previous page. In the simulations carried out, researchers only ensure that the network on the back end can be implemented, especially to validate smart contracts embedded in the blockchain network.

An Integrated Development Environment (IDE) is needed for blockchain simulation, where the Visual Studio Code software is a program that can build software code efficiently. In these applications, blockchain increased productivity for GB by combining capabilities such as editing, building, testing, and packaging software in an easy-to-use application. This IDE has quite complete and capable features such as debugging, extension, marketplace, IntelliSense, and Github integration, and this application supports almost all programming languages such as Node.js, JavaScript, and Typescript [68], which are scripts needed in building a smart contract network. The IBM Blockchain Accelerator helps start-ups rapidly develop blockchain business networks. Besides that, IBM Blockchain provides a way to improve process efficiency by creating intelligent workflows and data collection, especially for cross-agency data exchange [69].

The simulation model created a smart-contract network for the micro-hydro work. In the simulation of this model (Figure 8), the progress of the micro-hydro work can be entirely accepted. In modeling, the first step is to determine the user: Client (User 1), Contractor A (User 2), and Contractor B (User 3). Then the network was created with several essential functions for the tender procurement process of micro-hydro installation work. In this case, five functions were created to meet the configuration of the desired network stage. Job data is stored in the "microhydroExist" function, containing the volume and price that the researcher has set. The bidding process uses the "createMicrohydro" function, and the selection of tender winners can use the "verifyMicrohydro" function.

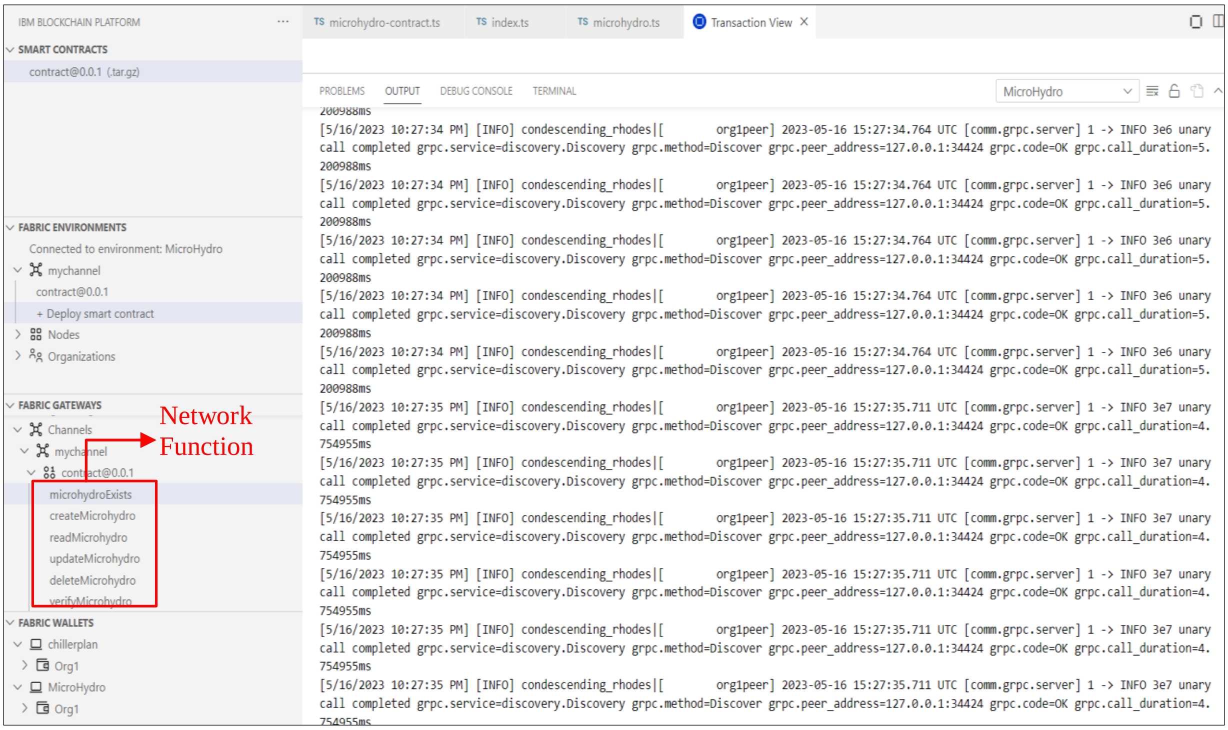


Figure 8. Micro-Hydro Transaction Network Function on IBM-Blockchain Platform, by Visual Code Studio

All the improvement work in Table 6 is produced from the BG assessment, where the target to go to the green building with a minimum point of 74.25 can be achieved, as mentioned in the research implementation path. Then, related to renewable energy, the researcher improved the Renewable Energy item in the Modern Shopping Center Building with Blockchain-BIM simulation and the choice of technology. Previously, researchers summarized the costs from the effects of BIM modeling, which consisted of thirteen work items, to achieve the GB requirement.

Table 6. Budget Plan Base on Green Building per Item Assessments

No	Work Improvement Base on GB Assessment	Detail of Work	Budget Cost Become Green Building Level		
			Basic	**Intermediate**	**Main**
1	Rain Water management ≥ 2 Hours	Detention Pond & Water Filter Pump	N/A	10,301	10,301
2	OTTV max. 35 Watts/m^2 (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 Natural Sources	Lighting on Skylights	25,423	25,423	25,423
7	Sensors CO2 and CO for Ventilation Parking	Ventilation for Basement Parking	18,096	18,096	18,096
8	Utilization Rain Water	Rain Water Filtration	N/A	9,660	9,660
9	Sanitary with Saving Water	Water Fixtures Unit	21,676	38,530	40,987
10	Electricity with Renewable Energy	**Solar PV (Op. 1)**	1,317,936	1,317,936	1,317,936
		Micro Hydro (Op. 2)	249,787	249,787	249,787
11	Rubbish Shelter	Garbage Building	N/A	21,215	21,215
12	Facility Processing 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**

The final result of increasing cost performance for the entire work is described in Figure 9 for all ratings, where the blockchain-BIM method is applied. From the chart above, the increase in cost performance of GB with the implementation of solar PV gets a better value than micro-hydro, but the initial cost is higher. That is different from the implementation of micro-hydro, which requires better initial costs but is low in increasing the cost of GB performance.

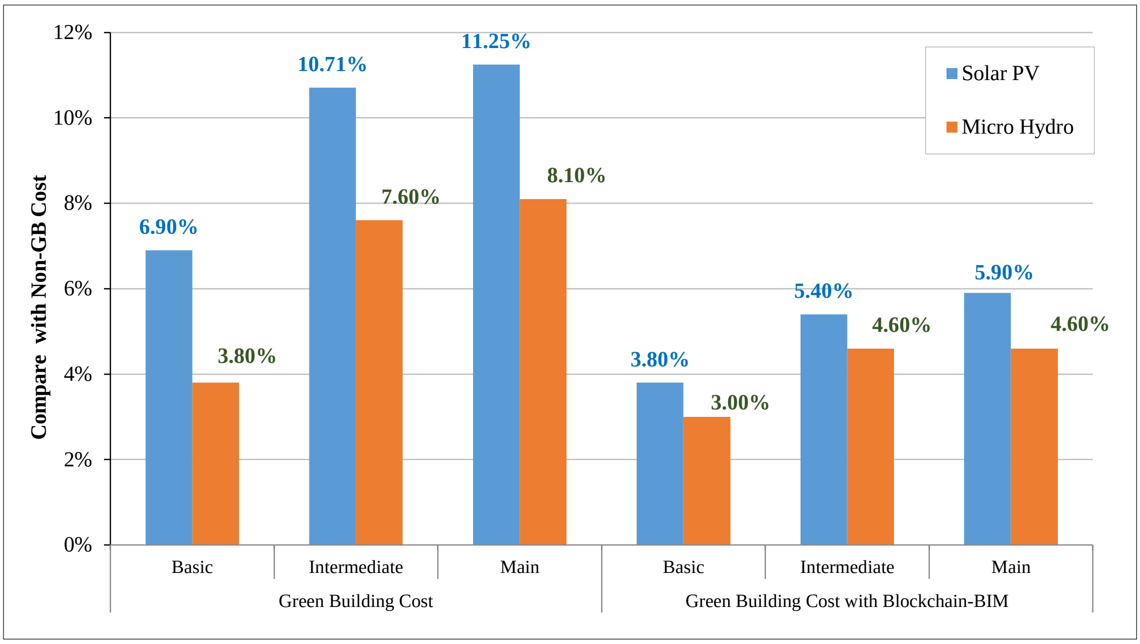


Figure 9. GB cost performance with renewable energy implementation

From the cost component itself, it can be explained briefly that it consists of several works, and solar PV installation work is the biggest contributor to the implementation of renewable energy in GB. Another option is to apply a micro-hydro plant to reduce the initial costs, but the efficiency needs to be considered against the demand and the electrical energy generated in this building.

Then, based on the prerequisites for kW/TR from fulfilling the requirements for GB and working on improving the chiller plant, the efficiency value for centrifugal-type chiller machines is a minimum of 0.67 for capacities above 300 TR. Third, the building façade work is closely related to the building envelope and is the most significant component in calculating the OTTV and WWR according to the GB requirements. To meet the criteria for the OTTV value according to the GB requirements, the researcher analyzed it by replacing the glass model with a lower shading coefficient value. Work on upgrading the STP, which means that in addition to STP processed water that must meet the standards issued by the Environment Agency and refers to the requirements for GB, the STP processed water must be reused as proper water without any side effects either chemical or biological to the surrounding environment. Other works include building a monitoring system, rainwater filtration, grouping lighting in the skylight area, providing garbage buildings, water fixtures with efficiency types, a detention pond, and ventilation for basement parking.

The results of cost performance from several studies on the cost of green buildings reviewed from the aspect of components show, for example, that building energy costs 48% and building water and sewerage costs about 2% of the total project cost [70]. The other researcher in Indonesia mentions that platinum-certified green buildings have the highest premium cost score, with building envelopes (23.89%), regional materials (15.92%), and legal logging materials (13.86%). Then, for gold-certified green buildings, the focus is on energy, intelligent lighting control system features (72.05%), and the building envelope (20.54%) [71]. Then, researchers by Hwang et al. [14] identified that green building technology costs are high, with 10% of commercial building projects experiencing the highest premium cost, which is influenced by project type and size. Therefore, this research shows that the energy sector greatly affects the cost component of green building. For the costs in the energy sector to be more affordable, the approach of renewable energy by providing the choice of applied technology and the selection of the right method for improving the cost of green energy will provide the benefit of a choice of cost that is suitable for the stakeholders.

6. Conclusion

Our discussion mainly focuses on renewable energy, environmental sustainability, and cost performance; therefore, the economic aspects of using Blockchain-BIM to increase cost performance in GB require further analysis and discussion. The flow of implementation in building cost performance GB for Modern Shopping Center Buildings based on blockchain-BIM has proven effective in increasing the cost performance of GB. 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 modern shopping center buildings by 3.8% in the Basic Rating. At the same time, for the Intermediate and Main Ratings, it is 2.1% higher where 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, for the Intermediate and Main Ratings, it is less than 0.8% higher. The selection of renewable energy technologies has a vital role in initiating the cost aspects of GB. It 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 and 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 need help to start making intelligent application contracts on the blockchain network because the limitations will affect their technology. Researchers have several times experienced failure in making applications based on blockchains. So that in the future, studies need to be done and work needs to be done with practitioners in blockchain so that this method can be easily assembled and applied.

Adopting Blockchain-BIM to increase the cost performance of GB needs to be pushed with facilitating skills for construction engineers in getting value for other buildings. Whatever, the effective use of Blockchain-BIM depends on the user adapting the technology as well as their knowledge base about encryption technology. Future analysis should take more into account the complexities of GB and the needs of various stakeholders. The novelty of this research depends on the contribution of a set strategy that combines blockchain-BIM deep increase practices for GB with renewable energy by the stakeholders. This is especially true for strengthening modeling skills for renewable energy on GB, but also for controlling knowledge of device digital software in its blockchain technology.

7. Declarations

7.1. Author Contributions

Conceptualization, P.P. and A.E.H.; methodology, A.E.H.; software, P.P.; validation, P.P., A.E.H., B.D.K. and R.P.; formal analysis, A.E.H.; investigation, P.P.; data curation, P.P.; writing—original draft preparation, P.P., R.P., R.S.P., and K.K.; writing—review and editing, P.P., A.E.H., and B.D.K.; visualization, P.P.; supervision, P.P., A.E.H.; project administration, P.P. and E.J.A. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

Data sharing is not applicable to this article.

7.3. Funding

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7.4. Conflicts of Interest

The authors declare no conflict of interest.

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