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Renewable energy in chemical industrial buildings for cost performance

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Abstract

Due to their potential benefits for various industries, blockchain technologies have recently attracted a lot of attention from the scientific and business communities. Blockchain provides distributed, secure, permissioned transactional ledgers that successfully deal with these problems. This study aims to present a new conceptual framework that combines blockchain technology with building information modeling. This framework is specifically designed for smart contracts and digital transactions in the chemical industry's retrofitting of green buildings. The main goals Within this context are to improve cost-effectiveness, bolster cybersecurity measures, improve information sharing and management, expedite payment transactions, and advance sustainability. In Cilegon, Banten, Indonesia, a chemical facility was the study's location. The study also makes use of partial least squares structural equation modeling.

Keywords:
BIM;
Blockchain;
Cost performance;
Green Chemical Industry;
Renewable energy;

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INTRODUCTION

Climate change, which affects governments and private sector organizations, is a serious environmental issue [1] because of the enormous challenge that global warming presents to humanity. Creating new business ideas that give priority to environmental solutions for grammar, spelling, and punctuation issues has become imperative for all communities [2]. The industry with the most industrial impact on the environment is construction. The industry is renowned for consuming a lot of energy and resources and for harming the environment [2]. The building sector is responsible for excessive energy use and resource overuse [3][4].

The proportion of all worldwide energy-related CO2 emissions rises to 38% when building construction industry emissions are taken into account [5]. There are several advantages to the concept of "green buildings" for the environment, society, and economics. It encompasses the ideas of efficient resource use (vehicles and workplaces), and sharing of resources (energy, water, land, and environment); also, sustainable resource conservation [6] is addressed.

Few studies specifically address green buildings in the chemical industry that adhere to the new guidelines for building green structures in Indonesia set forth by the Ministry of Works and Buildings No. 1 of 2022, despite the abundance of research on the metrics used to assess the success of green buildings. This guideline states that there are three rating categories totalling 165 points [7]: Green Main House (80%-100%) (1), Middle (65%-80%) (2), and First (45%-65%) (3). Green building principles are generally more expensive to incorporate into new construction than they are to retrofit existing structures. The price of turning existing structures into green ones [8]. During the implementation process, the construction sector significantly affects the environment, leading to environmental pollution and the overconsumption of natural resources [9]. Environmental sustainability is just not taken into account in mainstream policies at this time [10]. Greenhouse Gases (GHG) can cause global warming, directly impacting climate change [11].

The creation of ecologically sustainable structures is greatly aided by the green building chemical industry, which incorporates design principles that reduce the harm that buildings do to the environment and the people who live in them [12]. Draft Organizations using affordable energy sources (such as geothermal energy and environmentally friendly materials), shared resources (such as general facilities, transportation, and workspace), and green building materials can lead to a number of social and economic advantages as well as the construction of environmentally friendly structures. Sources of land, water, energy, and wildlife conservation that are sustainable [13]. Furthermore, substantial data indicates that project cost is more important than time or quality. Notable benefits of green buildings include 20–30% energy and 30–50% water savings. Improvements in natural light and improved air quality are increasing.

Blockchain is a system that allows two or more people to share safe, irreversible information and transactions [14] by the use of full encryption. Blockchain technology is based on distributed ledger technology, which uses a shared ledger among all network users [15][16]. Transfers do not need a centralized mediator for identification and authentication since information is distributed around many independent nodes That register and verify it in the blockchain network [17]. Transactions are traceable and impenetrable since every participant has an identical copy of the data. Any modifications made to the project model can also be transparently handled [18].

A paradigm shift, Building Information Modeling (BIM), offers numerous benefits to both the general public and those employed in the building industry [19]. During construction, a superior building uses less energy, labor, and money [20]. Realistic architectural designs and construction prototypes with BIM models yield enough information to meet client needs [15, 18, 20]. BIM provides all the necessary tools and automation to achieve end-to-end communication, data interchange, and information sharing among partners [21]. One lesson to be learned from this is that although BIM might offer certain advantages to a project, it also raises project expenses and time [22][23].

The Spanish DELFOS project's research and technology development site has attempted the first combined use of Blockchain and BIM with an eye toward productivity [24]. Blockchain and BIM technology provide an increasingly private and secure environment for commercial dealings with complete process control [25]. Blockchain technology enables features including evidence of ownership, addressing rights, proof-of-provenance, recordkeeping through an immutable and traceable ledger, and reduced human errors and deviations [26]. Blockchain-based smart contracts have emerged as a cutting-edge method for enhancing specific project sustainability aspects. [27].

This research uses an Action Research methodology to address the environmental effects caused by the chemical business and change the building's classification as green [28]. A study framework was put in place to enhance the assessment of cost-effectiveness in the chemical industry based on green retrofit using Blockchain-BIM. This framework comprised variables designed to compare the respective impacts. After the data was gathered, an analysis was done to get some initial information. Following a discussion and evaluation of this preliminary data, conclusions were reached about the efficient payment procedure, and a descriptive account was given regarding how Blockchain-BIM might improve cost efficiency in the green retrofit-based business.

METHOD

To assess if current buildings adhere to green building criteria, we collected primary data for this study using an audit or verification process [29]. The degree to which Housing Regulation No. 01 of 2022 and the Technical Specifications of the Ministry of Public Works are followed is reflected in this source data. To initiate this phase, we began by making use of the secondary data that the business has available, such as information on energy generation and consumption. Additionally, the secondary data set included project records such as planning drawings, bills of quantities, and facility operation data.

We determined the most important parameters while creating the questionnaire. The signs that researchers had previously found and presented were incorporated into the questionnaire's composition. Stakeholders in the project, including those with direct and indirect engagement, will get this questionnaire. Using the SMART PLS (Partial Least Squares) 3.0 tool, we will use Structural Equation Modeling (SEM), a simulation method, to analyze the data. In order to gain a deeper understanding, we also intend to conduct interviews. Using this approach, we want to identify the primary components and significant contributing variables influencing the cost efficiency under investigation. Scientific study uses SMART PLS, a well-known and often used program, for data analysis [30]. The study methodology employed in this work is shown in

Figure 1, which was impacted by the outcomes of previous SEM-PLS testing. Model parameters, sample size, data distribution shape, missing data management, and measurement scale are among the considerations. The 80% statistical stress test's minimum sample size requirement is established by the path factor (p-min) and tolerance margin [31]. To support the statistical analysis and the practical application of the case studies research, the researcher's next step is to develop a research strategy for each stage to achieve the study objectives. Remarkably, in one specific study, only 50% of the systematic reviews included flowcharts to clarify the study evaluation process [32].

Second, the evaluation must meet a minimum Basic Rating level of 74.25 throughout this first phase. Figure 2 presents the study Flow for the GB Concept and outlines the study process.

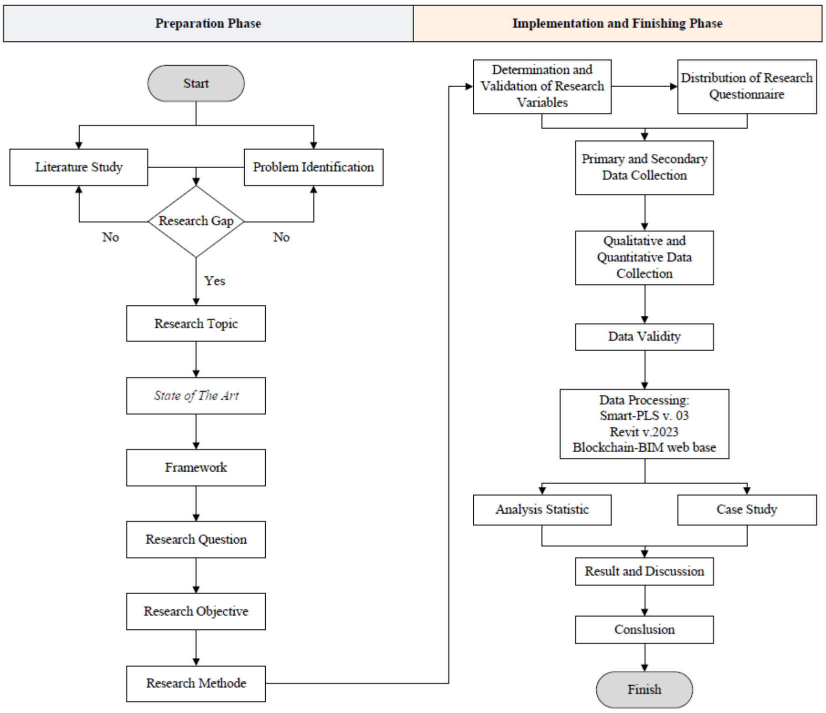


Figure 1. Research Framework.

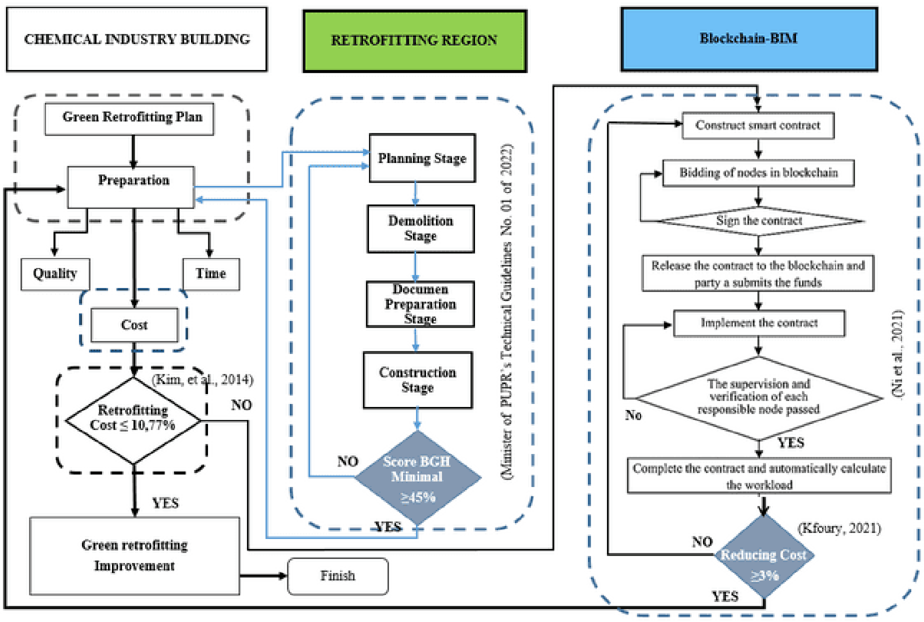


Figure 2. Investigating the Use of the GB Concept in Contemporary Shopping Center Structures

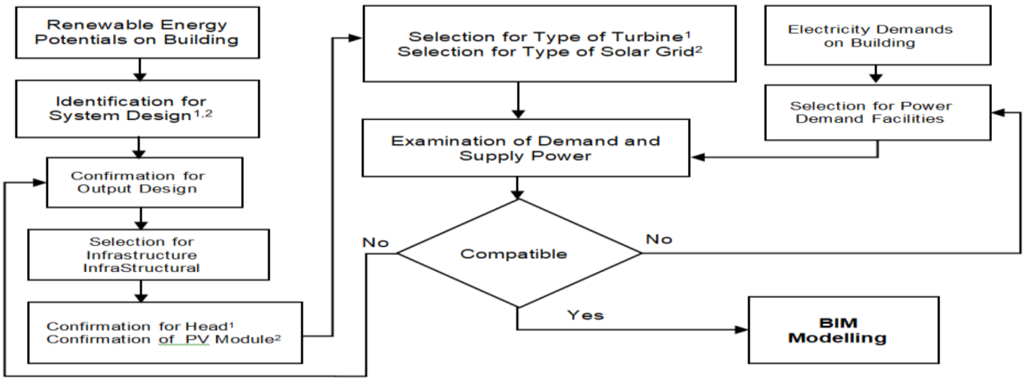


Figure 3. Identification and Analysis for the Use of Renewable Energy

Thirdly, finding substitute sources inside the research site is how the integration of renewable energy sources is carried out. The Minister of PUPR's Regulation's 2022 GB requirements and the evaluation results align with this integration. As shown in Figure 3, the Identification Analysis for Renewable Energy Implementation, the researcher recommends adding solar PV systems and natural illumination to the study site. The BIM modeling of renewable energy is considered necessary to determine the GB project's cost components.

RESULTS AND DISCUSSION

Case Study

The study was carried out at a construction site for the chemical industry in Cilegon, Banten, Indonesia. In terms of the planning stage assessment, the obtained score was 62.3 points. This implies that certain aspects of the building planning procedure must be enhanced to achieve the required minimum Basic rating level of 74.25 points.

Using the previously outlined methods, we have concluded that there is a possibility of using renewable energy sources in this building by applying green building (Figure 4). These models were designed to examine green construction regulations' financial effects.

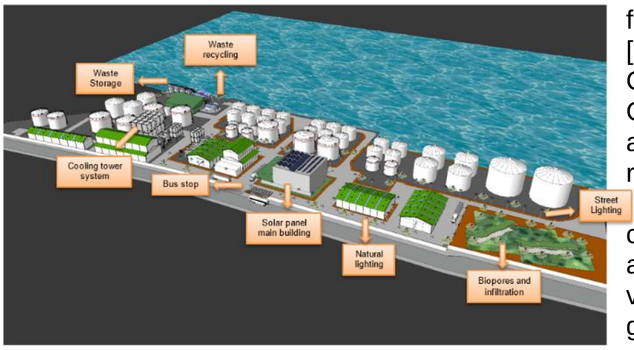


Figure 4. BIM Modelling for Renewable Energy

Smart Contracts and the Blockchain-BIM network will incorporate this modeling [33]. Using this demo system, we may evaluate the efficacy and dependability of the methodology used to build Blockchain-BIM for punctuation, grammatical, and spelling issues.

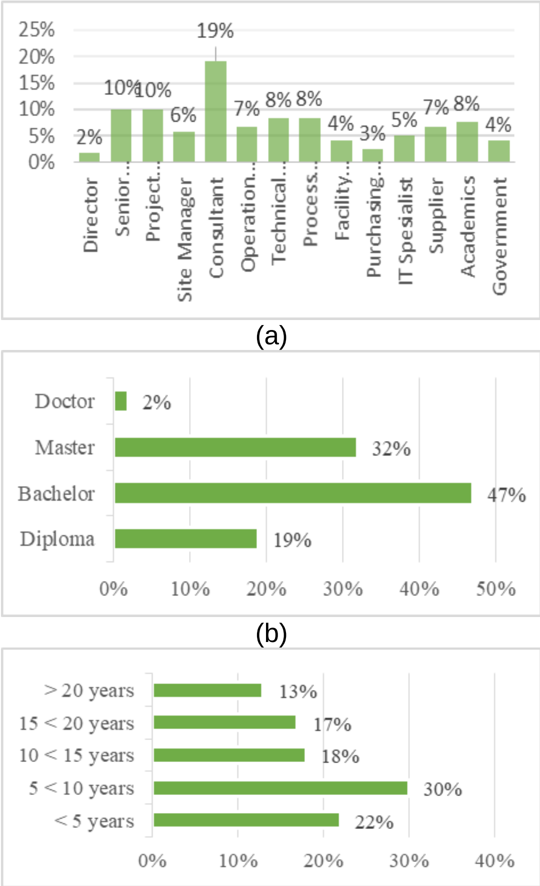
Measurement Models Evaluation (Outer Loading – PLS Algorithm)

As shown in Figure 5, 120 study questionnaires were sent, meeting the minimum criterion of 118 responders for the following statistical analysis. The information obtained from these participants is included in the respondent data.

First, the SEM-PLS application must be run in order to perform calculations. The strength of a measure's association with other measures of the same construct is examined using convergent validity analysis [34]. The methods used for this evaluation are Cronbach's Alpha and Composite Reliability. Cronbach's alpha values are used to assess the internal consistency and reliability of the scales. On the overall scale of the study, reliability scores more than 0.6 are observed for each variable [35].

A validity test is deemed valid if the Average Variance Extracted (AVE) number is greater than 0.5. When the AVE value is more than 0.5, the latent variable construct accounts for more than half of the variance in the indicators [36]. Variables are considered reliable if their Composite Reliability is better than 0.7 and their Cronbach's Alpha is larger than 0.7, in accordance with generally accepted norms for research instrument reliability [37].

The values in Table 1 lead to the following conclusions: The convergent variables are valid and satisfy the required threshold if (a) the AVE values for the latent and median variables are greater than 0.5; (b) the instrument is reliable and exceeds acceptable standards if both the Composite Reliability and Cronbach's alpha values are greater than 0.7.



(a)
(b)
(c)

Figure 5. Information from respondents: (a) occupations, (b) degrees, and (c) employment history

Table 1. Convergent validity-based concept reliability examination results

Main Factor	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
The green retrofit (X2)	0.992	0.992	0.992	0.514
The chemical industry (X1)	0.993	0.993	0.993	0.807
The external expenses (Y2)	0.900	0.904	0.952	0.909
The internal expenses(Y1)	0.901	0.904	0.931	0.773
The expenses(Y)	0.935	0.940	0.949	0.757
Blockchain-BIM (X3)	0.973	0.974	0.976	0.760
BIM Reliability (X3.1)	0.949	0.950	0.964	0.844
Auction Stage (X1.2)	0.992	0.992	0.994	0.977
Implementation Stages (X1.3)	0.992	0.992	0.993	0.938
Utilization Stages (X2.1)	0.991	0.992	0.992	0.517
Demolition Stages (X2.2)	0.871	0.883	0.912	0.721
Technology Adjustment (X3.2)	0.979	0.980	0.983	0.876
The Planning Stages (X1.1)	0.991	0.992	0.992	0.887
Operational and Maintenance Stages (X1.4)	0.995	0.995	0.996	0.977

Assessment of Measurement Models (Bootstrapping – Inner Loading)

SEM SMART-PLS software version 3.0 was used to perform the analysis. R-Square, which measures 0.825, is the total impact on the Cost (Y) variable, as Figure 6 illustrates. There is also an additional 0.824 in the modified R-Square.

This implies that 82.5% of all independent factors have a cumulative effect on the Cost (Y) variable. It may be inferred that all independent factors significantly affect the Cost (Y) variable as the corrected R-Square value is larger than 50%.

By examining the data from the questionnaire analysis, we may ascertain which of the 304 sub-factors were considered to be significant factors. The initial steps in assessing a structural model are to test the links between constructs and ascertain the prediction power of the model.

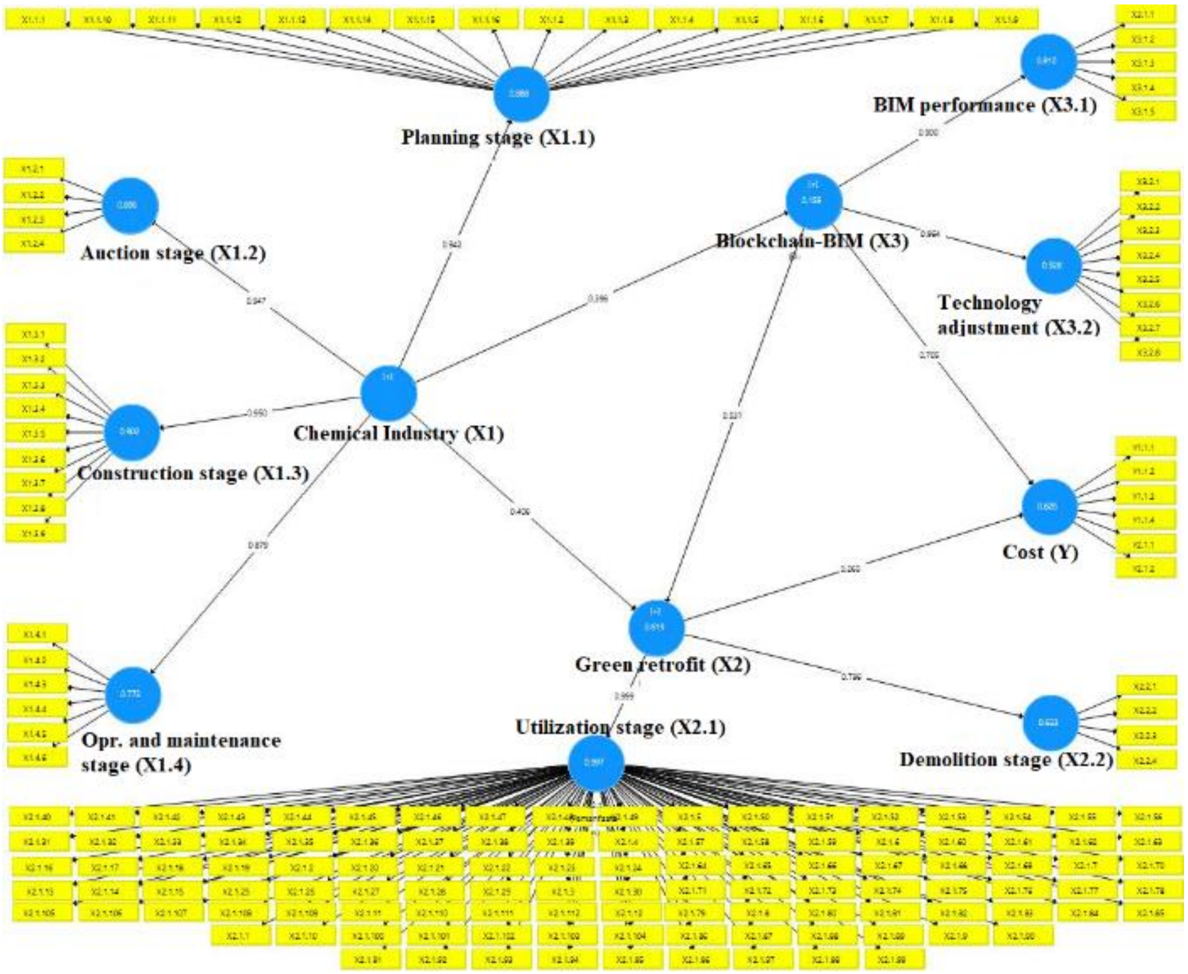


Figure 6. The partial coefficient and p-value diagram

Table 2. The subfactor with the greatest influence (significant)

No	Sub Factor		Original Sample Value	Mean	T.Statistic > 1.96 (p < 0.05)	R Square
1	Waste management	X2.1.66	0.831	0.831	32.617	
2	Blockchain Transactions	X3.2.3	0.920	0.920	32.344	
3	Demolition Material Disposal Locations	X2.2.3	0.866	0.865	27.238	
4	Planting consumption crops in at least 10% of the open space area.	X2.1.76	0.815	0.815	27.612	
5	Rainwater is absorbed by the surface by at least 30%.	X2.1.94	0.812	0.811	25.279	
6	Documents efforts to save energy	X2.1.6	0.686	0.686	12.958	0.998
7	The dependability of the drainage network regulates stagnant water	X2.1.77	0.715	0.717	15.756	
8	Using renewable electrical energy sources to power lights	X2.1.108	0.709	0.709	12.599	
9	Evaluation of water consumption utilization	X2.1.67	0.680	0.681	12.571	
10	Assessment of the application of power usage	X2.1.69	0.653	0.653	9.735	

Subsequently, other measures are employed, such as path coefficients, effect size (f2), coefficient of determination (R2), and cross-validation redundancy (Q2) [37]. When Q2 > 0, the model is considered to have strong predictive relevance; when Q2 < 0, the model is considered to have low predictive relevance.

Both strength and significance are evaluated for the estimated path coefficient values in the structural model; a T-Statistic > and a P-value < 5% 1.96 are deemed significant. Then, using the calibrated SEM model, a thorough study is carried out to look at the direct and indirect effects of specific components [38]. As shown in Table 2, the ten most significant elements are listed in descending order of impact, with the validation of green building (GB) having the greatest influence.

Building envelope energy efficiency standards are meant to provide direction to all stakeholders involved in the development process to achieve energy efficiency, construction, upkeep, and operation of structures. Proper envelope design is one of the most critical aspects in significantly lowering building energy use. Heat loss via the building envelope accounts for more than half of the energy requirement for multipurpose buildings—a frequently disregarded factor.

The successful implementation of energy conservation requires several essential elements, including planning for the adoption of state-of-the-art, energy-efficient technology, selecting machinery and infrastructure with care, and ensuring that systems operate efficiently. In actuality, energy-saving projects usually consist of three main steps: turning off lights or other appliances that draw power when not in use, unplugging devices that draw power while not in use, and adjusting air conditioning settings to better align with group initiatives to reduce greenhouse gas emissions.

Relationship Between Blockchain-BIM and Renewable Energy in Green Building

The researchers made an effort to duplicate the use of Blockchain-BIM according to the previously described protocol. The main goal of these simulations was to determine whether the front-end network could function, especially in validating smart contracts included in the Blockchain network.

Within the blockchain network, smart contracts serve as the mechanisms for executing transactions contained within a block. When a smart contract method is initiated, the corresponding transaction is executed, creating blocks. In this context, the client is required to make payments to the contractor upon the completion of each process, utilizing the funds derived from the Bill of Quantity (BOQ). Notably, a single block within the blockchain network can encompass multiple transactions, aligning with the logic of each action performed. Further elaboration on this topic will be provided in the subsequent chapter [39].

To facilitate interaction with the blockchain network, the SDK Owner is employed as a tool for connecting applications to the blockchain, particularly smart contracts. Through the utilization of these applications, users can readily and efficiently communicate and interact with the blockchain network. Figure 7 illustrates the smart contract for payment transactions within the blockchain network.

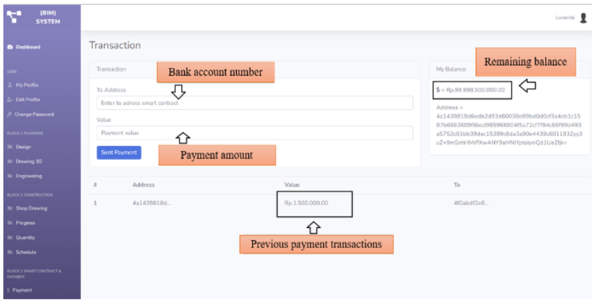


Figure 7. Block approval smart contract payment transaction

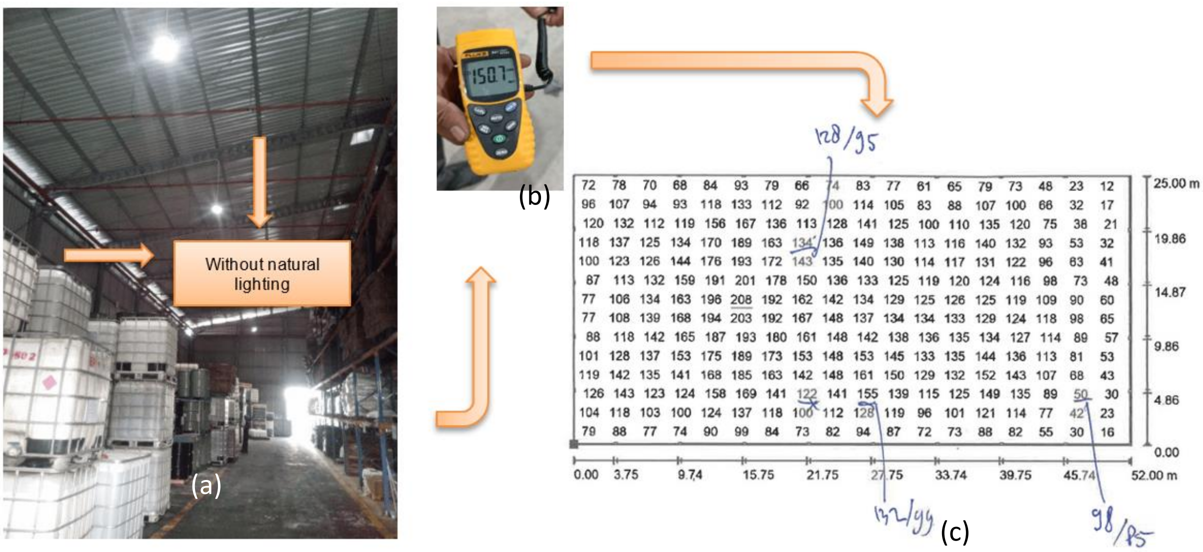


Figure 8. Check for luminization before retrofitting: (a) the state of the building in the absence of natural light; (b) the lux meter's reading; and (c) a lux values chart.

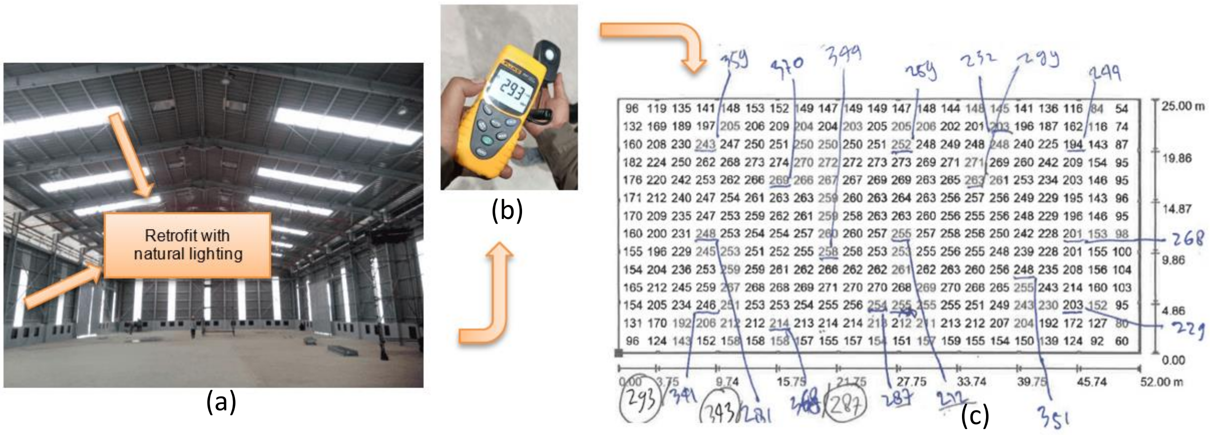


Figure 9. Following retrofitting, a lux value chart, a lux meter measurement value, and the building's state with natural illumination are used to check for lumens.

Table 3. Works Improvement cost based on green retrofitting assessment

No	Description	Initial budget plan (IDR)	Budget proposal for green building improvements (IDR)		
			Primary	Middle	Main
1	Legal, Safety, and Preliminary Work	4,539,606,575	4,539,606,575	4,539,606,575	4,539,606,575
2	Office building structure	19,395,000,000	19,395,000,000	19,395,000,000	19,395,000,000
3	Laboratory building	1,320,763,000	1,320,763,000	1,320,763,000	1,320,763,000
4	Utility facility	24,937,500,000	24,937,500,000	24,937,500,000	24,937,500,000
5	Plant producing facility	106,816,000,000	106,816,000,000	106,816,000,000	106,816,000,000
6	Infrastructure facility	10,500,000,000	10,500,000,000	10,500,000,000	10,500,000,000
7	Provision of Green Building Handbook (BGH) SOP & Governance Documents.		260,000,000	364,000,000	572,000,000
8	Planning for Renovation Work		416,000,000	468,000,000	577,200,000
9	Retrofitting works				
	- Bus stop		-	385,000,000	385,000,000
	- Solar panel		8,586,070,577	8,586,070,577	8,586,070,577
	- Replacing Sanitary Fixtures with Low Water Use		-	445,769,222	445,769,222
	- Provision of outdoor smoking areas		-	-	175,000,000
	- Temporary location for storing garbage		2,026,061,613	2,026,061,613	2,026,061,613
	- Organic waste composting machine		-	-	397,612,378
	- Inorganic waste recycling machine		-	-	357,500,000
	- Biopores and infiltration		489,750,000	489,750,000	489,750,000
	- Natural Lighting Fixtures inside the Building		995,766,611	995,766,611	995,766,611
	- Solar cells are used to power public street lighting and garden lamps		-	3,668,836,563	3,668,836,563
	- Sewage treatment plant (stp)		-	2,391,214,509	2,391,214,509
	- Improvement cooling tower system		2,928,913,800	2,928,913,800	2,928,913,800
10	Maintenance operations during use. Socialization and Empowerment at Work		1,361,881,973	1,702,352,466	2,213,058,205
11	Green Building Occupants or Users		453,960,658	453,960,658	453,960,658
TOTAL (IDR)		167,508,869,575	185,027,274,806	192,414,565,592	194,172,583,710
The distinction between the Green Building Improvement Cost Estimate (RAB) and the Non-Green Building Cost Estimate (RAB) (IDR)			17,518,405,231	24,905,696,017	26,663,714,135
Deviation (%)			10.46%	14.87%	15.92%

As seen in Figure 8 and Figure 9, The results of retrofit simulations in warehouses with the addition of conventional lighting have proven to be quite successful. According to the illumination measurement criteria, it was less than 200 lux before reset (Figure 8). The brightness value rises above 200 lux following the reset (Figure 9).

The worth of the retrofitting work for the chemical industry was ascertained by analyzing the implementation of Blockchain-Building Information Modeling (BIM) on these projects through modeling and the input of unit price parameters. The results are displayed in Table 3. Based on the analytical data displayed in Table 4, cost savings of 4.42% for Primary, 4.45% for Middle, and 4.40% for Main were discovered.

Table 4. Works improvement cost using Blockchain-BIM

No	Description	Initial budget plan (IDR)	Budget proposal for green building improvements (IDR) using Blockchain-BIM (IDR)		
			Primary	Middle	Main
1	Preliminary, legal, and safety work	4,539,606,575	4,539,606,575	4,539,606,575	4,539,606,575
2	Structure office building	19,395,000,000	19,395,000,000	19,395,000,000	19,395,000,000
3	Laboratory building	1,320,763,000	1,320,763,000	1,320,763,000	1,320,763,000
4	Utility facility	24,937,500,000	24,937,500,000	24,937,500,000	24,937,500,000
5	Plant production facility	106,816,000,000	106,816,000,000	106,816,000,000	106,816,000,000
6	Infrastructure facility	10,500,000,000	10,500,000,000	10,500,000,000	10,500,000,000
7	Provision of green building handbook (bgh) sop & governance documents.		260,000,000	364,000,000	572,000,000
8	Planning for renovation work		416,000,000	468,000,000	577,200,000
9	Retrofitting works				
	- bus stop		-	367,290,000	367,290,000
	- solar panel		8,191,111,330	8,191,111,330	8,191,111,330
	- replacement of water-efficient sanitary fixtures		-	425,263,837	425,263,837
	- Provide an outside smoking spot		-	-	166,950,000
	- temporary waste storage area		1,932,862,779	1,932,862,779	1,932,862,779
	- organic waste composting machine		-	-	379,322,209
	- inorganic waste recycling machine		-	-	341,055,000
	- provision of bio pores and infiltration		467,221,500	467,221,500	467,221,500
	- natural lighting fixtures inside the building		949,961,347	949,961,347	949,961,347
	- public street lighting and garden lamps using solar cells		-	3,500,070,081	3,500,070,081
	- sewage treatment plant (stp)		-	2,281,218,642	2,281,218,642
	- improvement cooling tower system		2,794,183,765	2,794,183,765	2,794,183,765
10	Maintenance operations during use.		1,299,235,402	1,624,044,252	2,111,257,528
11	Socialization and Empowerment at Work green building occupants/users		433,078,467	433,078,467	433,078,467
Total (IDR)		167,508,869,575	184,252,524,165	191,307,175,575	192,998,916,060
The distinction between the green building improvement cost estimate (IDR) and the non-green building cost estimate			16,743,654,590	23,798,306,000	25,490,046,485
Deviation (IDR)			774,750,641	1,107,390,017	1,173,667,650
Reduction in cost difference as a percentage (%)			4.42%	4.45%	4.40%

CONCLUSION

In this research, the authors require assistance in starting the Blockchain network's smart contract development as they have encountered technological constraints that hinder their progress. Multiple attempts to create blockchain-based applications have resulted in failures. Therefore, collaboration and cooperation with blockchain practitioners are essential for future endeavours to streamline the method and facilitate its application effectively. Promoting the adoption of Blockchain-BIM to enhance the cost efficiency of Green Building (GB) construction should focus on equipping construction engineers with the necessary skills to extract value in various building projects. However, the effective utilization of Blockchain-BIM is contingent on users' ability to adapt to the technology and their understanding of encryption technology. Future research endeavors should delve deeper into GB's intricacies and consider stakeholders' diverse needs. The innovation in this study lies in the development of a comprehensive strategy that amalgamates Blockchain-BIM to bolster GB practices, particularly in conjunction with renewable energy.

This strategy aims to enhance modeling proficiency in renewable energy integration within GB projects and bolster knowledge of digital software and Blockchain technology among stakeholders. The research findings indicate that implementing the green industry, blockchain-BIM can lead to cost savings of 4.42% for Primary-level buildings, 4.45% for Middle-level buildings, and 4.40% for Chemical Industry Buildings at the Main Level. These results confirm the hypothesis that the utilization of Blockchain-BIM may significantly increase the cost-effectiveness of chemical industry buildings within the green industry sector. Based on a review of the literature, the researchers have determined that this is the first study of its kind in the world on using Blockchain-BIM to enhance the cost-effectiveness of green retrofitting in Chemical Industrial Buildings.

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