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Cost performance improvement in the Green Transit Oriented Development (TOD) area based on Blockchain-Building Information Modelling (BIM)

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ABSTRACT

The emission and mitigation of greenhouse gases transforms the status of urban environ ments. However, a policy accounting for all the aspects associated with transport is lacking. Prob lems related to transport include a greater reliance on cars, increased congestion, and environmental impacts. The absence of an efficient public transport system is a notable cause of the prompt escala tion of diverse problems, for example, increases in the number of personal automobiles causes con gestion on the road, resulting in air pollution, ubiquitous greenhouse effects and noise pollution, which ultimately affect human health. Over the past two decades, a growing number of communities have pursued light rail transit (LRT) and Transit-Oriented Developments (TODs) as part of an integrated transportation and land use strategy to revitalize and/or regenerate the built environment of worldwide cities. Green TOD focuses on combining TOD with green neighborhood to generate larger ecological and environmental benefits. In their research, Cervero and Sullivan suggested that the combination should be realized in the following aspects: (1) higher densities, (2) mixed land use, (3) reduced. The integration of Blockchain with BIM for data provenance uses a distributed network for storing provenance data over a decentralized and fault-tolerant ledger with the results of this research, there is expected to be shared awareness and concern about implementing green neighborhood and green space as an initiative to present a more energy-efficient transit oriented, save operating costs, and provide comfort to customers.

Keywords: green neighborhood; transit-oriented development (TOD); blockchain; BIM.

INTRODUCTION

Nowadays, cities face various problems, including increasing population growth. In 2018, more than 50% of the world's population lived in urban areas, which is predicted to reach 68% by 2050. It is estimated that there will be an increase in population by 70% of the world population today in 2050, and around 66% of the increase in population will occur in urban areas. Jakarta, a metropolitan city with an area of 4384 km2 and a population density of 13,000 people/km2, whose population has reached 10.56 million people with a population growth rate of 0.92%, has a complex issue, one of which is sprawl, where the rapid growth of the city restructures the shape of the city to be scattered and in-creases individual dependence on motor vehicles. The urban sprawl phenomenon as a form of urban growth has a tendency to extend the urban areas to their peripheries, which growth also affects the demand for supporting infrastructures such as roads, clean water networks, wastewater networks, and facilities such as schools, commercial, residential, and recreational areas (Irsal & Hasibuan, 2023)

Green transit-oriented development (TOD) is an evolution of the TOD theory, influenced by sustainable development and green urbanism. This advancement expands the environmental and ecological dimensions of conventional TOD. However, relevant research has only just started, particularly in combination with high-density cities in Asia (Niu et al., 2021).

The development of a transportation system and a policy for public transport is beneficial for the environment. Additionally, the level of convenience and public health are major concerns. Eco-friendly transportation is an important aspect of the development of any community and in recent years transit-oriented development (TOD) has gained increasing significance. Transit-oriented

development aims to achieve the production of practical, blended-use, pedestrian-friendly urban neighborhoods that incorporate travel, lodging, schools, parks, and other social and monetary enhancements, benefitting various associated groups accordingly (Ali et al., 2021).

RESEARCH METHODS

The construction industry is known for its complex information environment, siloed workflows, and lack of coordination between multiple stakeholders. This resulted in a blaming culture and repeated legal disputes. With the use of Building Information Modelling (BIM), there has been a trend toward increased coordination and integration of data from several fields. BIM facilitates effective data management and communication, eliminating traditional barriers and enhancing project outcomes. Data and information come in various formats and are generated and maintained by different groups of users and communities, including local organizations and government authorities. Coordinating the sharing of this data across different disciplines such as architecture, structural engineering etc. for project tasks can be challenging, as it requires overcoming the difficulties of interoperating and integrating diverse and distributed resources (Celik, Petri, & Rezgui, 2023)

In this paper, it is combined two sources of evidence to deliver the paper objectives (i) secondary sources of evidence resulting from an in depth literature survey exploring existing BIM-Blockchain solutions and subsequent integration for construction applications and (ii) primary sources of evidence from a real construction case study involving the construction of a highway bridge.

By extracting evidence from the literature survey complemented with requirements from the case study, a new Blockchain provenance framework was proposed to ensure reliable BIM data exchanges and collaboration across project disciplines. The objectives were primarily focused on developing a capability to support distributed BIM data sharing for construction projects based on a scalable and secured provenance model that can incentivise collaboration between stakeholders (Celik, Petri, & Barati, 2023). The above objectives were achieved using the following methodological steps and the research framework as shown in Figure 1, and Figure 2.

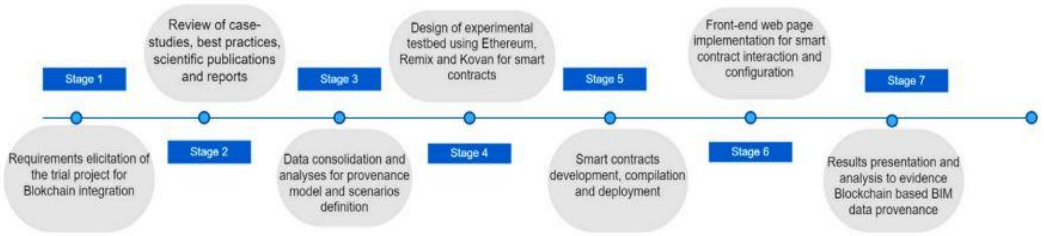

Figure 1. Methodological steps

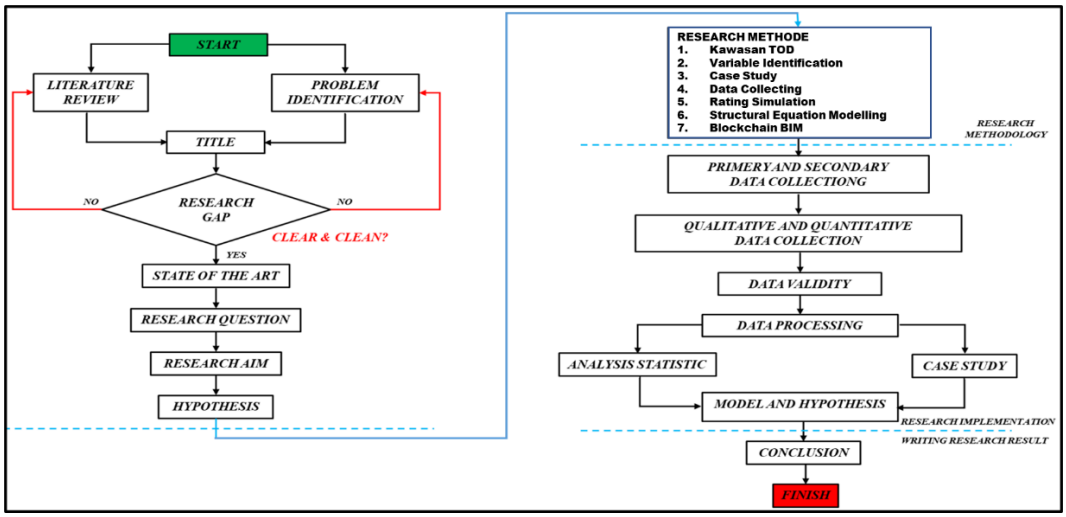

Figure 2. Research Framework

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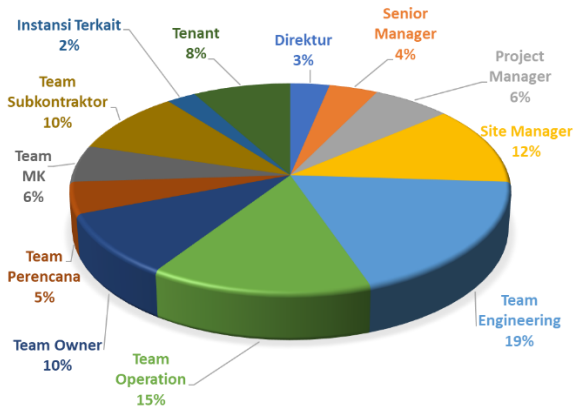
RESULT AND DISCUSSION

It is located in Ciracas, East Jakarta, to be more specific. This research was conducted in the light rapid transit city area of Ciracas. There is a transit-oriented development concept in this region that could be turned into a green TOD in the LRT.

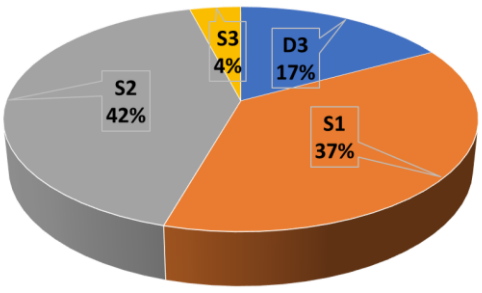
In implementing the Transit Oriented Development Green Area system, special rules are required to improve cost performance so that it can include the cost performance of Transit Oriented Development Green Areas that are financially profitable using the Blockchain-Building Information Modeling (BIM) method. The implementation of the Blockchain-Building Information Modeling (BIM) technology in conjunction with cost innovation to implement Transit Oriented Development Green Areas can enhance operational cost performance.

The dominating elements from various variables and sub-factors that influence cost performance will be determined by data analysis and the use of a simulation tool, specifically Structural Equation Modeling (SEM) PLS (Partial Least Square) 3.0, along with interviews. These are the items that the author wishes to look at. SEM PLS is software that is widely used as a popular analytical tool in scientific research. The number of respondents is counted at the start of the research to identify any contributing factors. In addition to evaluative knowledge, expert validity is used to determine the data population, ensuring that the population is accurate. Following collection, the data will be examined and classified according to employment experience, location, and educational attainment. This is crucial to ensure that the questionnaire's goal is met and the data is reliable.

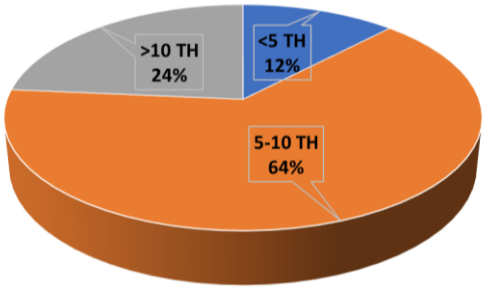
Following a job position-based determination of the respondents, the findings were obtained. Subsequently, the response data is derived from the experience and education levels, so providing the results. Fig.3 shows the respondent data, (a) position, (b) education, (c) work experience.



(a)



(b)



(c)

Figure 3. Shows the respondent data, (a) position, (b) education, (c) work experience

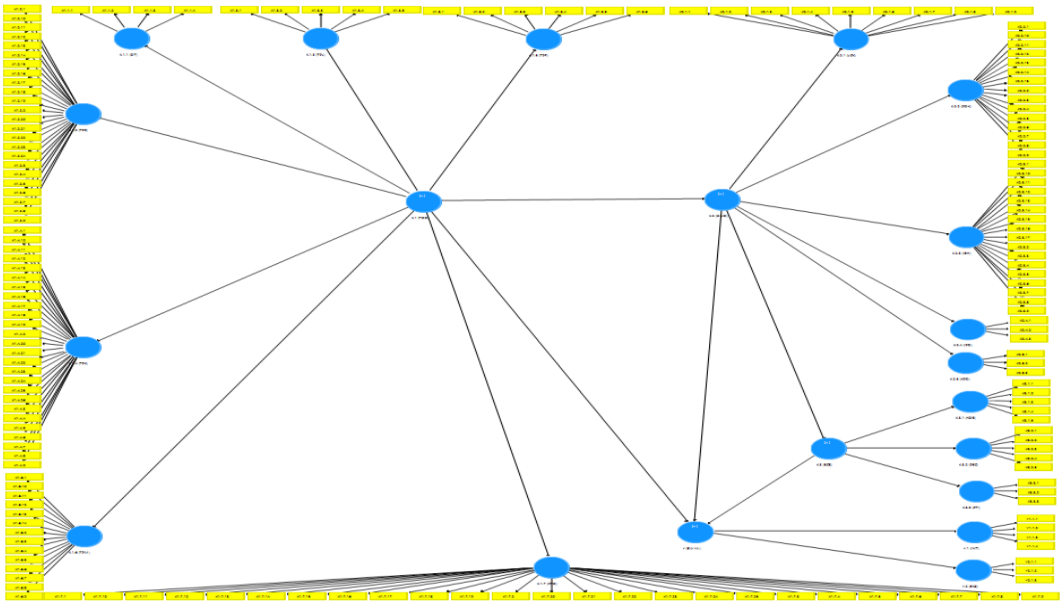


Figure 4. the research's path shape

The following stage after gathering all the data is to process it using SEM-PLS. This gives the research's path shape, which is depicted in the Fig. 4, the Table 1 below provides an explanation of the link between the variables in the path above.

Table 1. Provides an explanation of the link between the variables

Variable Manifest/Indicator	Variable Laten	Variable Intervening/Median
X1.1.1-X1.1.14, X1.2.1-X1.2.24, X1.3.1-X1.3.5, X1.4.1-X1.4.26, X1.5.1-X1.5.6, X1.6.1-X1.6.14, X1.7.1-X1.7.25	Tender Documents, Planning Stage, Tender Stage, Implementation Stage, Utilization Stage, Maintenance Stage, Characteristics of Transit Oriented Development	Transi Oriented Development (X1)
X2.1.1-X2.1.9, X2.2.1-X2.2.15, X2.3.1-X2.3.17, X2.4.1-X2.4.3, X2.5.1-X2.5.3	Smart Locations and Linkages, Regional Patterns and Design, Green Infrastructure and Buildings, Innovation and Design Process, Regional Priority Credit	Green New (X2)

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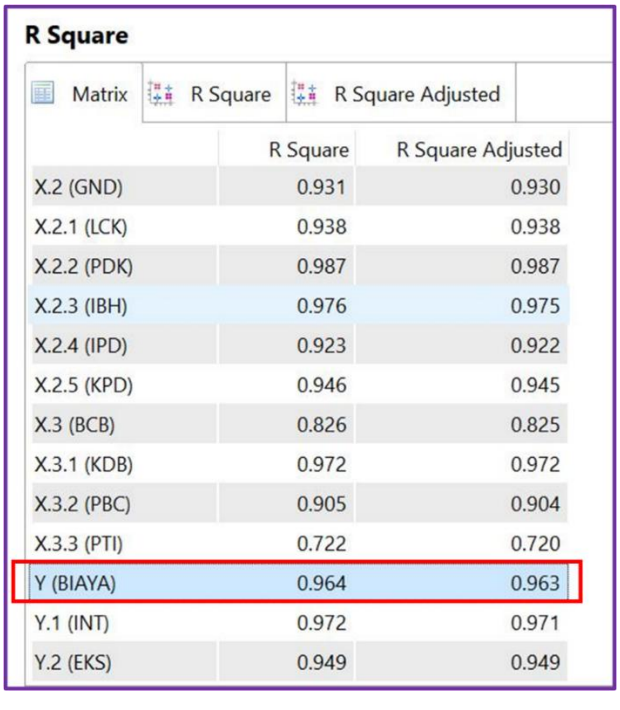
Variable Manifest/Indicator	Variable Laten	Variable Intervening/Median
X3.1.1-X3.1.5, X3.2.1-X3.2.5, X3.3.1-X3.3.3	Reliability In BIM, Blockchain Use, Technology Adaptation	Blockchain-BIM (X3)
Y1.1.1-Y1.1.4, Y1.2.1-Y1.2.3	Internal Cost, Eksternal Cost	Biaya (Y)

Following data processing, the SEM - Outer Loading (Validity Test) results show that the test is valid if the output is Outer Loading > 0.5 Average Variance Extracted (AVE > 0.5) (Wong K.K., 2013, Sarstedt dkk., 2017) state that the AVE value should be at least 0.5. When the construct has an AVE value of 0.5 or above, it can account for at least 50% of the variation in the items. A latent variable or construct's ability to explain the variation of its indicators increases with its AVE (Ugiana Gio, 2022). If the composite reliability is above 0.7, the SEM - OUTER LOADING (REABILITY TEST) will display a satisfactory result. Aside from that, if Cronbach's Alpha is greater than 0.7, it will display a respectable number. For the Y (Cost) value, the SEM Outer Loading (R Square) is 0.96. the model association is strong, moderate, and weak, respectively, with R2 values of 0.75, 0.50, and 0.25. according to (Sarstedt et.al, 2017). The Fig. 5 below displays these values.



	R Square	R Square Adjusted
X.2 (GND)	0.931	0.930
X.2.1 (LCK)	0.938	0.938
X.2.2 (PDK)	0.987	0.987
X.2.3 (IBH)	0.976	0.975
X.2.4 (IPD)	0.923	0.922
X.2.5 (KPD)	0.946	0.945
X.3 (BCB)	0.826	0.825
X.3.1 (KDB)	0.972	0.972
X.3.2 (PBC)	0.905	0.904
X.3.3 (PTI)	0.722	0.720
Y (BIAYA)	0.964	0.963
Y.1 (INT)	0.972	0.971
Y.2 (EKS)	0.949	0.949

Figure 5. Displays R Square values

Next, search for the link between SEM and Path Coefficient (T Statistics & P-Value). It is considered significant when the T-statistic (>1.96) and P-value (<0.05) are both below 0.05. The Fig. 6 below provides evidence of this.

Specific Indirect Effects

Mean, STDEV, T-Values, P-... | Confidence Intervals | Confidence Intervals Bias ... | Samples | Copy to Clipboard: | Excel Format | R Format

	Original Sample (O)	Sample Mean (M)	Standard Deviation ...	T Statistics (|...	P Values
X.2 (GND) -> X.3 (BCB) -> X.3.2 (PBC)	0.865	0.863	0.020	42.540	0.000
X.1 (TOD) -> X.2 (GND) -> X.3 (BCB) -> X.3.2 (PBC)	0.834	0.833	0.024	35.298	0.000
X.2 (GND) -> X.3 (BCB) -> X.3.3 (PTI)	0.772	0.771	0.033	23.374	0.000
X.1 (TOD) -> X.2 (GND) -> X.3 (BCB) -> X.3.3 (PTI)	0.745	0.744	0.036	20.956	0.000
X.1 (TOD) -> X.2 (GND) -> Y (BIAYA)	0.516	0.520	0.071	7.229	0.000
X.2 (GND) -> X.3 (BCB) -> Y (BIAYA)	-0.387	-0.381	0.069	5.592	0.000
X.1 (TOD) -> X.2 (GND) -> X.3 (BCB) -> Y (BIAYA)	-0.374	-0.367	0.067	5.552	0.000
X.1 (TOD) -> Y (BIAYA) -> Y.1 (INT)	0.844	0.833	0.126	6.694	0.000
X.2 (GND) -> Y (BIAYA) -> Y.1 (INT)	0.527	0.531	0.074	7.154	0.000
X.1 (TOD) -> X.2 (GND) -> Y (BIAYA) -> Y.1 (INT)	0.509	0.512	0.070	7.252	0.000
X.3 (BCB) -> Y (BIAYA) -> Y.1 (INT)	-0.420	-0.413	0.074	5.650	0.000
X.2 (GND) -> X.3 (BCB) -> Y (BIAYA) -> Y.1 (INT)	-0.382	-0.375	0.068	5.580	0.000
X.1 (TOD) -> X.2 (GND) -> X.3 (BCB) -> Y (BIAYA) -> Y.1 (INT)	-0.368	-0.362	0.067	5.538	0.000

Figure 6. The link between SEM and Path Coefficient (T Statistics & P-Value)

After knowing the relationship between variables, it can be concluded that there are 10 main factors and 10 main factors that influence this research shown in Table 2 and Table 3 below.

Table 3. The 10 main factors

No	Main Factor	R Square
1	Neighborhood Pattern & Design (X2.2)	0.987
2	Green Infrastruktur & Building (X2.3)	0.976
3	Implementation Phase (X1.4)	0.973
4	BIM Reliability (X3.1)	0.972
5	Internal Cost (Y1)	0.972
6	TOD characteristics (X1.7)	0.963
7	Maintenance Phase (X1.6)	0.95
8	External Cost (Y2)	0.949
9	Utilization Phase (X1.5)	0.948
10	Smart Location & Linkage (X2.1)	0.938

Table 4. Main factors that influence this research

No	Sub Factor		Nilai Original Sample	Mean	T.Statistic > 1.96(p < 0.05)	Terhadap R Square
1	Transit Fcilities	X2.2.13	0.967	0.967	31.586	
2	Accsess Public	X2.2.3	0.966	0.966	31.349	
3	Contractor Appointment	X1.3.5	0.928	0.925	56.298	
4	Material costs	Y1.1	0.897	0.898	57.566	0.998
5	Verifikasi Blockchain	X3.2.1	0.884	0.883	41.207	
6	Construction Feasibility Test	X1.4.9	0.871	0.871	35.12	

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No	Sub Factor		Nilai Original Sample	Mean	T.Statistic > 1.96(p < 0.05)	Terhadap R Square
7	Construction Feasibility Test	X2.1.9	0.871	0.87	25.544	
8	Blockchain Transparency	X3.2.2	0.865	0.861	35.086	
9	Cost of Goods Fluctuations	Y2.1	0.73	0.727	19.557	
10	Renewable Energy Production	X2.3.11	0.715	0.713	17.533	

After obtaining the results using SEM-PLS, analysis was then carried out to determine the ranking in the LEED assessment. The results are obtained in the following figure 7 below.

NO	PERFORMANCE ASSESSMENT PARAMETERS	POIN	(EKSISTING) ASSESMENT	(BASIC) ACHIEVEMENT TARGETS	(SILVER) ACHIEVEMENT TARGETS	(GOLD) ACHIEVEMENT TARGETS	(PLATINUM) ACHIEVEMENT TARGETS
TAHAP GREEN SERTIFICATE OF LEED ND-PLAN		110					
A.	INTEGRATIVE PROCESS	28	12	14	15	18	19
B.	NEIGHBORHOOD PATTERN & DESIGN	41	10	18	23	30	35
C.	GREEN INFRASTRUKTUR & BUILDING	31	6	10	15	15	24
D.	INNOVATION & DESGN PROCESS	6	0	2	2	4	4
E	KREDIT PRIORITAS DAERAH	4	0	0	0	0	0
	TOTAL LEED ND-PLAN	110	28	44	55	67	82
	RANGE POIN			40-49 Point	50-59 Point	60-79 Point	≥ 80 Point

Figure 7. The ranking in the LEED assessment with the results

The investment value of the green area work for the Transit Oriented Development is determined by modeling and entering unit price parameters as part of an analysis of the application of Blockchain-Building Information Modeling (BIM) on green area works. The results are displayed in the following figure 8 below.

NO	ITEM PEKERJAAN	RENCANA ANGGARAN BIAYA AWAL (NON GREEN)	RENCANA ANGGARAN BIAYA PENINGKATAN GREEN				BLOCKCHAIN BIM COST REDUCTION			
			Basic	Silver	Gold	Platinum	Basic	Silver	Gold	Platinum
1	Pekerjaan Preliminary	36,019,684,155	36,019,684,155	36,019,684,155	36,019,684,155	36,019,684,155	35,047,152,683	34,975,113,314	34,748,189,304	34,748,189,304
2	Pekerjaan *Substructure*	110,173,923,863	110,173,923,863	110,173,923,863	110,173,923,863	110,173,923,863	106,428,010,452	105,579,671,238	105,546,619,061	105,293,219,036
3	Pekerjaan *Uperstructure*	79,779,744,296	79,779,744,296	79,779,744,296	79,779,744,296	79,779,744,296	78,000,655,998	77,936,832,203	77,649,625,124	77,362,418,044
4	Pekerjaan Arsitektur	130,211,740,822	130,211,740,822	133,444,498,233	133,444,498,233	133,444,498,233	125,393,906,412	128,507,051,798	128,413,640,649	128,413,640,649
5	Pekerjaan MEP	162,764,676,028	191,168,750,105	191,168,750,105	191,168,750,105	191,168,750,105	186,389,531,352	184,955,765,726	183,713,168,851	183,464,649,476
6	Pekerjaan Perencanaan Pengubahsuaian	10,347,440,875	16,470,090,644	17,339,590,644	19,183,753,794	21,304,753,794	16,025,398,196	16,831,540,638	18,518,077,537	20,518,608,379
7	Pekerjaan Kawasan Hijau Baru									
	a. Fasilitas Sepeda	-	-	-	314,929,410	1,057,967,361	-	-	311,559,665	1,025,910,950
	b. Fasilitas Pejalan Kaki	-	2,720,799,580	2,720,799,580	2,720,799,580	2,720,799,580	2,653,051,670	2,643,800,952	2,635,638,553	2,623,667,035
	c. Fasilitas Transit	-	-	-	-	345,788,542	-	-	-	337,731,669
	d. Area *Community Space*	-	412,558,909	618,838,363	618,838,363	618,838,363	401,419,818	600,892,051	599,221,187	596,993,369
	e. Penanaman Vegetasi	-	811,614,400	1,264,985,900	1,447,805,400	1,447,805,400	801,063,413	1,237,282,709	1,396,118,747	1,392,354,453
	f. Pekerjaan Kolam Penampungan Air Hujan	-	353,904,821	353,904,821	353,904,821	353,904,821	342,933,772	340,810,343	339,713,238	337,908,323
	g. Pekerjaan Lampu Penerangan Jalan	-	-	-	-	728,694,300	-	-	-	704,064,433
	TOTAL (Rp)	529,297,210,039	568,122,811,594	572,884,719,959	575,226,632,020	579,165,152,813	551,483,123,766	553,608,760,971	553,871,571,916	556,819,355,120
SELISIH RAB PENINGKATAN BGH - RAB OUTPUT BLOCKCHAIN-BIM (Rp)			38,825,601,555	43,587,509,920	45,929,421,980	49,867,942,773	22,185,913,727	24,311,550,932	24,574,361,877	27,522,145,081
SELISIH %			7.34%	8.23%	8.68%	9.42%	4.19%	4.59%	4.64%	5.20%
SELISIH RAB PENINGKATAN BGH - RAB OUTPUT BLOCKCHAIN-BIM (Rp)							3.14%	3.64%	4.03%	4.22%

Figure 8. The investment value of the green area work for the Transit Oriented Development (TOD)

From the results of this analysis, investment cost savings were obtained of 3.14% for Basic Certificates, 3.64% for Silver Certificates, 4.03% for Gold Certificates, 4.22% for Platinum Certificates.

CONCLUSION

The research carried out was Blockchain-Based Cost Performance Improvement - Building Information Modeling (BIM) in Green Transit Oriented Development Areas, resulting in

conclusions. Ten influencing factors—Transit Facilities, Public Access, Walkable Streets, Bicycle Facilities, Reduced Parking Footprint, Rainwater Management, Renewable Energy Production, Light Pollution Reduction, Local Food Production, and Steep Slope Protection—are identified as having a significant impact on the implementation of Green Retrofitting Industrial Areas using the Blockchain-BIM Method on cost performance (by SEM PLS Tools) this can be obtained also analysis of paths that have a significant effect. With the goal to increase the cost performance of the Green New concept, a solution for implementing the green TOD Zone concept may be obtained by utilizing the Blockchain-BIM approach in the Green New Implementation flow diagram, which has shown to be effective. In order to increase the cost performance of the green new, a solution for implementing the green TOD Zone concept may be obtained by utilizing the Blockchain-BIM approach in the Green New Implementation flow diagram, which has been shown to be effective. The notion that the Blockchain-BIM approach can enhance the cost performance of green new Transit Oriented Development regions when implemented has been proven true based on the analysis results.

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