

Improving Project Performance Based on Building Information Modelling 6D & LCCA in High-Rise Office Building

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ABSTRACT

Of the total 5.9 million existing buildings, the Office occupies the 2nd position of the most types of buildings with 16% of the Total Total. The least used aspect of BIM (Building Information Modeling) is the ability to obtain building energy models using the 6D BIM methodology. This digital information model is to simulate building energy and improve building energy systems. In this way, 6D BIM simulation allows us to make building design and operational decisions. In the case of increased energy, which leads to greater quality and comfort in the sustainable use of buildings. This issue has a special relationship in public buildings. Where energy efficiency and comfort are two fundamental criteria that are highly valued by society. Once the building's energy model is prepared, it will study and identify possible ones to improve energy efficiency, as well as analyze the incorporation of other, more efficient forms of renewable energy such as the use of natural light. From this research, "10 factors that affect cost performance in Office Building Projects" Maintenance costs, Use of Photovoltaic Solar Panel Material, Model Obyektifiability, Office Equipment (TV, Computer, Printer etc.), Use of refrigerant without ODP, Use of Elevators, Initial cost of retrofit, Material Façade, environmentally friendly materials.

Key word: building information modelling; BIM 6D; life cycle cost analysis; cost performance.

INTRODUCTION

Based on data recorded in the world, it can be seen that energy use in each country, especially in office buildings with detailed data, namely Switzerland with energy use of 26%, Singapore with 43%, and the highest is Indonesia with energy use of 55%. (Pahnael, 2020), (Kiamili, 2020) & (Santiago et al, 2020). Green Building (ecological building) is a concern for environmental sustainability in the field of construction. Based on the index issued by the Environmental Performance Index (EPI) in 2020, Indonesia's ranking is in the position of 116 out of 180 countries. Therefore, Indonesia is recommended to implement the construction of Green building-based buildings. (EPI,2020). The application of Green Building has been implemented in building construction projects in Indonesia. The application carried out in Badung Regency, Bali amounted to 65.14% (Sudiarta, 2015). The application of green construction in construction buildings in Makassar reached 72.22% (M.A. Abdurrahman et al, 2021). Most of the contractors have been involved in the implementation of Green Construction (environmentally friendly construction) of 68.75%. However, the knowledge of construction actors regarding the standard criteria of Green Building is still low, it is proven that less than 50% of contractors know the standard criteria and the benefits of implementing Green Construction (Novandira, 2020). To respond to the phenomenon that occurs, the Indonesian government has implemented the Green Building concept. However, until now there have only been 48 Green Building certified buildings in Indonesia, 15 of which are new construction, 8 existing buildings, 2 interiors, and 23 design approvals. (GBCI,2020). LCCA (*Lifecycle Cost Analysis*) is a technical and economical method of optimizing whose primary purpose is to identify and select solutions that generate the highest revenue over the life of their service or, in other words, have the lowest life cycle costs (Marana et al, 2017). Life cycle cost analysis using Internal Rate of Return (IRR) and *Net Present Value* (NPV) approaches confirms that the development of the *Sunda Strait Bridge* (SSB) project with additional functions increases the Internal Rate of Return for the entire project by 7.56% which will provide a positive NPV value (Husin et al, 2015)The achievement of green building reduction in 2020 has only reached 0.93%. The problem that arises in the application of green building is the increase in the general cost of

projects by 4.5% – 7% (Bong-Gang, 2018). Handling the increased costs in the Green Building project can be reduced by the cost of investing in residual materials. By carrying out an intensive 3R (reduce, reuse, recycle) obtained by 3.7% of the estimated material costs (kustiani, 2020). BIM As Analysis Tools Means that BIM can also function as a device capable of analyzing Energy, Thermal Comfort and Lighting in Buildings (Arayici, 2015). Meanwhile, Indonesia is a developing country located in Southeast Asia and participates in efforts to implement BIM (Zhabrinna, Davies, Abdillah Pratama, & Yusuf, 2018). 6D BIM Has The Potential To Generate Energy Output Quickly Allowing Design Teams To Analyze And Compare The Most Cost-Effective And Energy Efficient Options. Through the concept of the relationship between factors in the object of the Main Building of the Office Building, the concept of green, BIM 6D and Life Cycle Cost Analysis can be examined the influence on improving cost performance in the Main Building of the Office Building. Such complex relationship models and concepts can use analytical models. The purpose of the study is to determine the influence and relationship between the use and development of methods that analyze influential factors on 6D BIM-based cost performance and Life Cycle Cost Analysis on Office Building Buildings.

RESEARCH METHODS

Several solutions to the software to this problem, one of the most famous programs is SPSS (Naidenov, 2015). Data analysis with simulation tools (e.g. SPSS with version 21) also includes interviews and surveys, which have recently proven to be dominated by several variables and components that affect the economy that the authors want to study. SPSS statistical values have limitations regarding internal file structure, data type, data processing, and matching file size, and also make it very easy to simplify programming (Subramani, 2016). Determining the Number of Respondents

Use the following equation to determine the minimum number of respondents:

Known:

$Z = 1.96$ from the Z distribution table

$P = 0.50$ degrees of variation between members of the population

$\epsilon = 0.05$ Sample value of a limited population

$N = 43.0$ Number of variable components

$n =$ Minimum number of respondents

$$m = \frac{Z^2 \times P \times (1 - P)}{\epsilon^2} = \frac{0,9600}{0,0025} = 384,16$$

$$n = \frac{m}{1 + \left[\frac{(m - 1)}{N} \right]} = \frac{384,16}{11,94} = 32,99$$

So that the number of respondents is at least 33 people whose data is normally distributed. Determining the population of data in addition to based on the literacy of journals, e-books and related books is also based on the validity of experts, so that the population is right on target. The data entered after being collected is examined and then determined grouping based on, education, job title, experience, and projects worked on. This is important so that the target of the questionnaire is indeed right on target so that the data is valid and reliable.

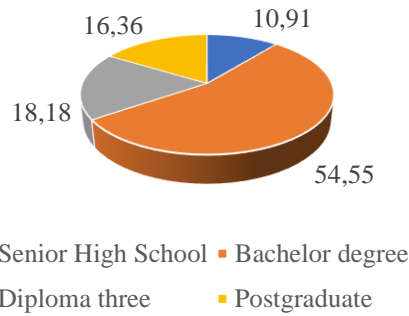


Figure 1. Respondent's Education Level

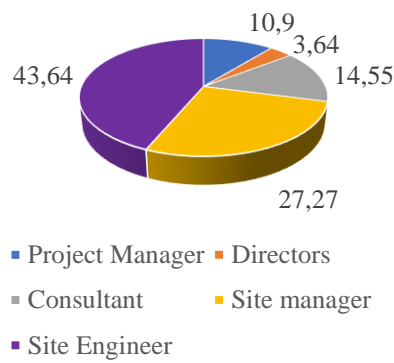


Figure 2. Respondent's Employment Level

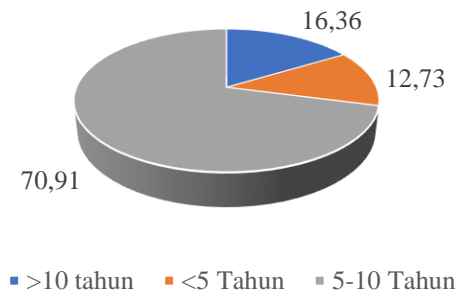


Figure 3. Respondents' Experience

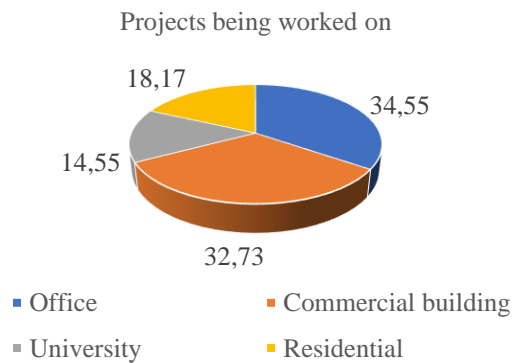


Figure 4. Projects worked on by respondents

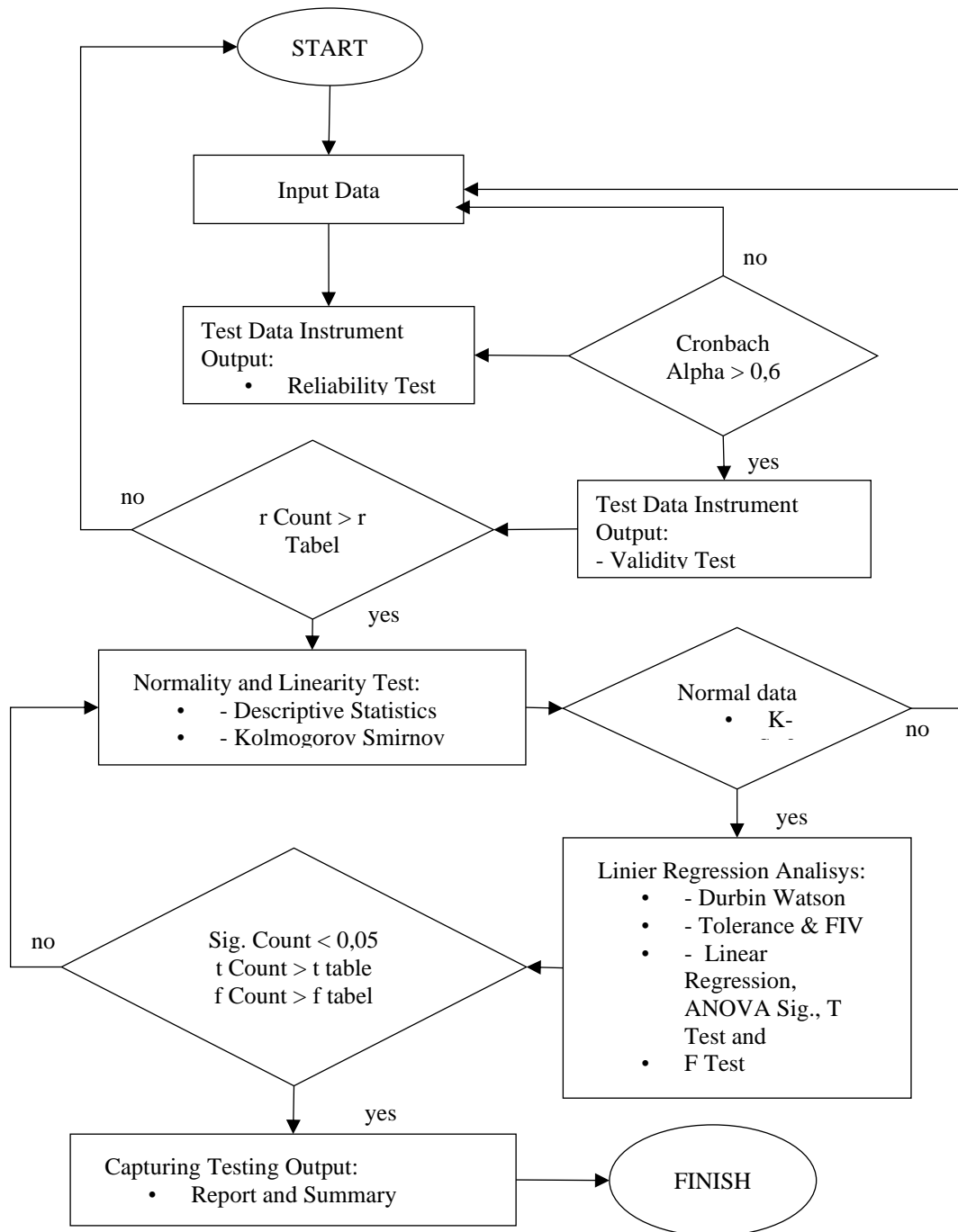


Figure 5. Flow chart data Analysis

RESULT AND DISCUSSION

The questionnaire data collected by the researchers in this research and will be processed and analyzed using SPSS. This method seems to dominate the use of multiple path and regression analysis that has been used frequently so far. This is because this analysis is more comprehensive because each value in each question of each latent variable or factor or in this method is referred to as an observed variable or sub-factor of a latent variable can be analyzed comprehensively.

a. Validity Test

The validity test is used with the aim of measuring the validity or not of the research instrument by providing information from the variables tested correctly (Dewi,2018). The validity test can be accepted or said to be valid if the Convergence Validity value is greater than 0.5 and the average value of the variation in the extract is greater than 0.5, The RTABEL value used as the basis for determining the *validity standard* value is $DF = 55 - 2 = 53$ with a signification rate of 95% obtained an RTABEL value of 0.266, For all question items greater than the standard validity value, then all question items are valid. All question items also have a significance value of < 0.05 , which means that the item is significant.

b. Reality Test

The reliability test is a test that aims to measure the consistency of respondents' answers to question items in the questionnaire. In this study, instrument reliability tests were carried out on all variables used, namely questionnaires X1, X2, X3, and Y using the calculation of Cronbach's Alpha values. A questionnaire is said to be reliable if the value of Cronbach's Alpha produced is > 0.60 .

Table 1. Results Reliability Test

	Scale Mean if Item Deleted	Cronbach's Alpha if Item Deleted	Cronbach's Alpha	Status
X1.1	39,38	,876	0,6	Reliabel
X1.2	39,27	,849	0,6	Reliabel
X1.3	39,42	,853	0,6	Reliabel
X1.4	39,31	,855	0,6	Reliabel
X1.5	39,25	,864	0,6	Reliabel
X1.6	39,29	,849	0,6	Reliabel
X1.7	39,56	,864	0,6	Reliabel
X1.8	39,35	,860	0,6	Reliabel
X1.9	39,58	,858	0,6	Reliabel
X1.10	39,62	,861	0,6	Reliabel
X2.1	43,36	,813	0,6	Reliabel
X2.2	43,33	,809	0,6	Reliabel
X2.3	43,18	,804	0,6	Reliabel
X2.4	43,15	,816	0,6	Reliabel
X2.5	43,29	,814	0,6	Reliabel
X2.6	43,04	,807	0,6	Reliabel
X2.7	43,44	,827	0,6	Reliabel
X2.8	43,25	,851	0,6	Reliabel
X2.9	43,29	,817	0,6	Reliabel
X2.10	43,16	,808	0,6	Reliabel
X3.1	41,93	,855	0,6	Reliabel
X3.2	41,60	,833	0,6	Reliabel
X3.3	41,87	,852	0,6	Reliabel
X3.4	41,55	,838	0,6	Reliabel
X3.5	41,82	,852	0,6	Reliabel
X3.6	42,20	,844	0,6	Reliabel
X3.7	42,00	,827	0,6	Reliabel
X3.8	42,29	,821	0,6	Reliabel
X3.9	42,05	,822	0,6	Reliabel

X3.10	42,25	,824	0,6	Reliabel
Y.1	23,24	,841	0,6	Reliabel
Y.2	23,38	,813	0,6	Reliabel
Y.3	23,16	,813	0,6	Reliabel
Y.4	23,35	,765	0,6	Reliabel
Y.5	23,47	,793	0,6	Reliabel
Y.6	23,31	,759	0,6	Reliabel

The results of the Reability Test in the table can be concluded that:

All question items have a calculation value of Cronbach's Alpha > 0.60. Thus, the questionnaires on the variables X1,X2,X3 and Y are reliable.

c. Normality Test

The normality testaims to find out whether the data is normally distributed or not. The normality of the data in this study was carried out by testing outlier and kolmogorov smirnov..

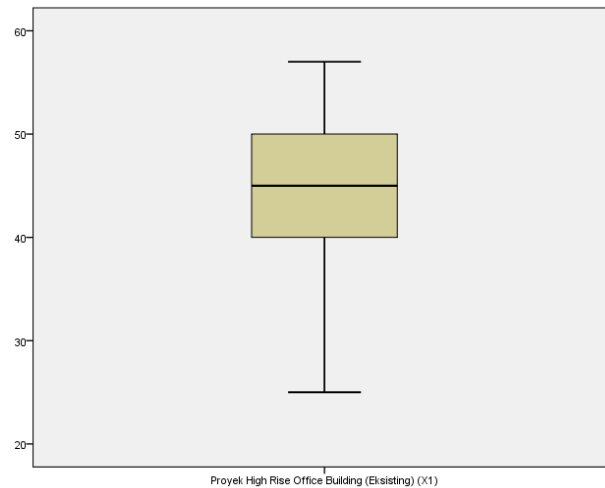


Figure 6. Normality Test X1

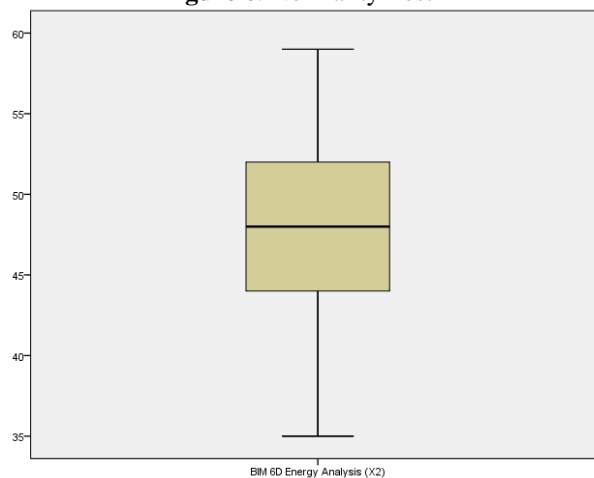


Figure 7. Normality Test X2

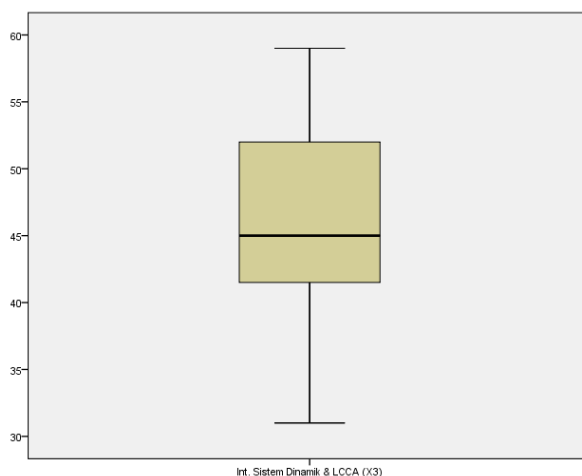


Figure 8. Normality Test X3

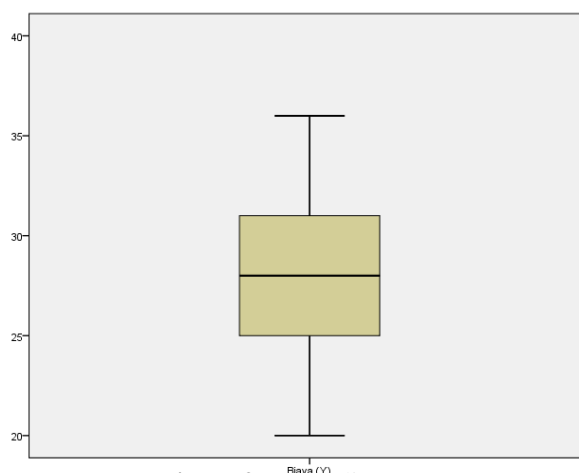


Figure 9. Normality Test Y

The results of the Normality Test in the table can be concluded that the Figure above shows a clean image graph and there are no respondent numbers marked with months or stars marked. Thus the data X1, X2, X3 and Y are normally distributed.

d. Kolmogorov Smirnov test

The kolmogorov Smirnov test (KS) of this study aims to prove free samples come from the same population

Table 2. Results Kolmogorov Test

		Project High Rise Office Building (Eksisting) (X1)	BIM 6D Energy Analysis (X2)	LCCA (X3)	Cost (Y)
N		55	55	55	55
Normal Parameters ^{a,b}	Mean	43,78	48,05	46,62	27,98
	Std. Deviation	7,831	5,599	6,699	3,894
	Absolute	,097	,071	,107	,094

Most Extreme Differences	Positive	,061	,071	,105	,088
	Negative	-,097	-,068	-,107	-,094
Test Statistic		,097	,071	,107	,094
Asymp. Sig. (2-tailed)		.200 ^{c,d}	.200 ^{c,d}	.174 ^c	.200 ^{c,d}

The results of the Kolmogorov Test in the table can be concluded that:

In the picture above, it shows the significance (Asymp. Sig. (2-tailed)) for all variables above 0.05. Thus, the variables X1, X2, X3, and Y meet the assumption of normality because they have a significance value of > 0.05 .

E. Multicholinerity Test

The multicholinerity test is used to test the correlation between regression models or the strength or not of relationships between independent variables. Basically, a good regression model should show the absence of a correlation between independent variables or symptoms of multicholinerity.

Table 3. Results Multicholinerity Test

Model	Collinearity Statistics	
	Tolerance	VIF
(Constant)		
1 Proyek High Rise Office Building (Eksisting) (X1)	,403	2,478
BIM 6D Energy Analysis (X2)	,585	1,711
LCCA (X3)	,356	2,810

The SPSS output of the multicholinerity test as shown in table 3 the variables X1, X2, and X3 have tolerance values of more than 0.1 each. The VIF values for all variables X1, X2, and X3 are less than 10. Thus, because the tolerance value > 0.1 and the VIF value < 10 , there are no symptoms of muticolinerity.

f. Heterochedasticity Test

A good regression model is a model that does not experience symptoms of heterochedasticity. If heterochedasticity occurs, it results in doubts about the regression analysis that has been performed. This heterochedasticity test aims to test the occurrence of differences in variance from residual values in one observation period to another. The heterochedasticity test in this study was using the Glejser SPSS model and the SPSS Scatterplots image.

Table 4. Results Heterochedasticity Test

Model	t	Sig.
(Constant)	1,524	,134
1 Proyek High Rise Office Building (Eksisting) (X1)	-,089	,930

BIM 6D Energy Analysis (X2)	-,672	,505
LCCA (X3)	,382	,704

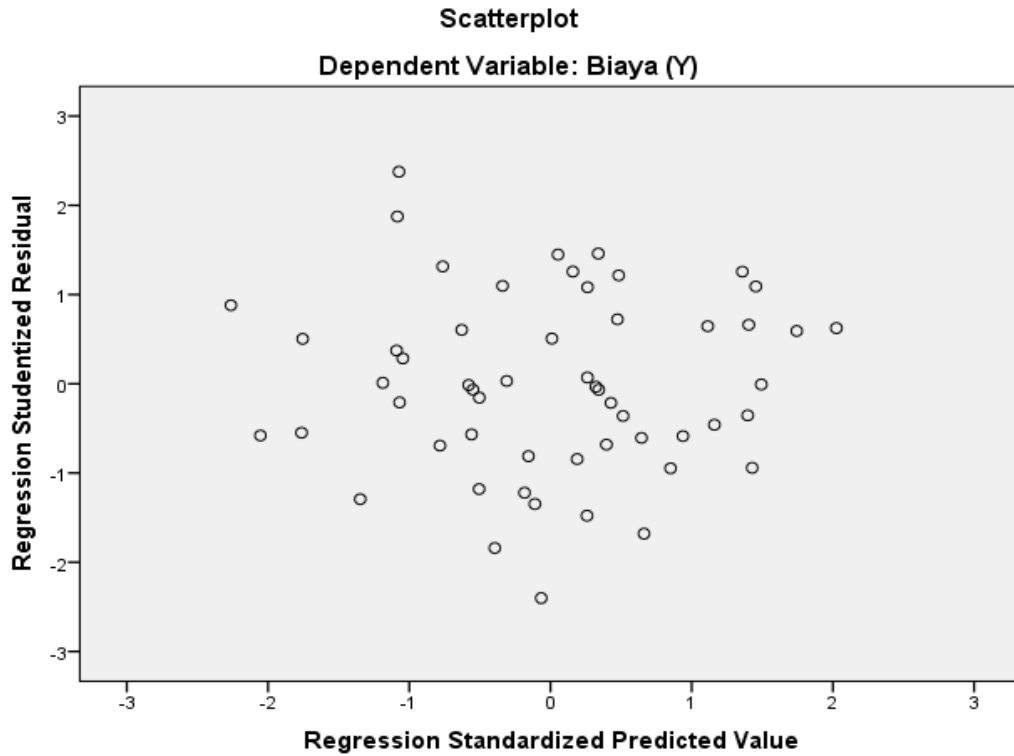


Figure 10. Scatterplot output analysis

Analysis of the scatterplot output in figure 10 is:

The point -tick of the spreader data above and below or around the number 0, Point – dots do not accumulate just above or below, Point spread – the data points do not form a wavy pattern of widening then narrowing and widening back, Point deployment – data points are not patterned Thus it can be concluded that there are no symptoms of heteroscedasticity, so that a good regression model and idela can be fulfilled.

g. T Test

The t test is performed to determine the effect of partial free variables on bound variables. As for the results of the t test

Table 5. Results T Test

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	,618	2,424		,255	,800
Proyek High Rise Office Building (Eksisting) (X1)	,130	,055	,262	2,372	,022
BIM 6D Energy Analysis (X2)	,230	,064	,331	3,612	,001

LCCA (X3)	,227	,068	,391	3,324	,002
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The result of the t test analysis in table 5 is $Y=0.618+0.130X1+0.230X2+0.227X3$

The explanation of the results of equation 1 is as follows;

The value of the regression coefficient X1 shows a positive value of 0.130. This value means that if the value of the highrise office building (X1) project increases by 1 (one) unit, then the cost (Y) will increase by 0.130 X1. The value of the regression coefficient X2 shows a positive value of 0.230. This value means that if the BIM 6D energy analysis (X2) value increases by 1 (one) unit, then the cost (Y) will increase by 0.230 X2. The value of the regression coefficient X3 shows a positive value of 0.227. This value means that if the LCCA (X3) value increases by 1 (one) unit, then the cost (Y) will increase by 0.227 X3.

Find the *mean* and ranking by running SP SS, namely: Click *Analyze > Scale > Reliability Analysis>Items* (Var X1.1,X1.n; X2.1,X2.n; X3.1,X3.n and Y1,Yn to items) > *Statistic > Ceklis item and mean >Continue > OK*

Table 6. Table mean and ranking

Rank	Sub factor	Mean
1	X3.4	5,07
2	X2.6	5,02
3	X3.2	5,02
4	X2.4	4,91
5	X2.10	4,89
6	X2.3	4,87
7	X2.8	4,80
8	X3.5	4,80
9	X2.5	4,76
10	X2.9	4,76

CONCLUSION

The results showed that in office buildings using the 6D BIM method and lifecycle cost analysis had a significant effect on improving cost performance and obtained the most influential factors were maintenance costs, use of Photovoltaic Solar Panel Material, Model Obyektifiability, Office Equipment (TV, Computer, Printer etc.), Use of refrigen without ODP, Use of Elevators, Initial cost of retrofit, Material Façade, environmentally friendly material. Using SPSS analysis has proven to be more effective in obtaining correlation relationships to develop theories in research.

REFERENCES

- T. C. Marrana, J. D. Silvestre, J. De Brito, and R. Gomes, "Lifecycle Cost Analysis of Flat Roofs of Buildings," *J. Constr. Eng. Manag.*, vol. 143, no. 6, 2017.
- A. E. Husin, M. A. Berawi, S. Dikun, T. Ilyas, and A. R. B. Berawi, "Forecasting demand on mega infrastructure projects: Increasing financial feasibility," *Int. J. Technol.*, vol. 6, no. 1, pp. 73–83, 2015.
- Kiamili, C., Hollberg, A., & Habert, G. (2020). Detailed assessment of embodied carbon of HVAC systems for a new office building based on BIM. *Sustainability (Switzerland)*, 12(8). <https://doi.org/10.3390/SU12083372>
- A. Naidenov and A. Naidenov, "Using SPSS for Process Quality Control – A Critical Review Using SPSS for Process Quality Control – A Critical Review," no. February 2014, 2015.

- T. Subramani and S. R. Rajiv, "Productivity Of Industry Using SPSS," vol. 5, no. 5, pp. 239–250, 2016.
- Dewi, D. A. N. N. (2018). Modul Uji Validitas Dan Hormonal. Universits Diponegoro, October.
- Bon-Gang, H. (2018). Cost Premium, Performance and Improvement of Green Construction Projects. Performance and Improvement of Green Construction Projects, 103–118. <https://doi.org/10.1016/b978-0-12-815483-0.00008-9>
- Arayici, Y. (2015). Building information modeling. In Building Information Modeling. Attia, S., Beltrán, L., De Herde, A., & Hensen, J. (2009). "Architect friendly": A comparison of ten different building performance simulation tools. IBPSA 2009 - International Building Performance Simulation Association 2009, 204–211.
- Pahnael, J. R. N., Soekiman, A., & Wimala, M. (2020). Penerapan Kebijakan Insentif Green Building Di Kota Bandung. *Jurnal Infrastruktur*, 6(1), 1–13. <https://doi.org/10.35814/infrastruktur.v6i1.1315>
- Sahlol, D. G., Elbeltagi, E., Elzoughiby, M., & Abd Elrahman, M. (2021). Sustainable building materials assessment and selection using system dynamics. *Journal of Building Engineering*, 35, 101978. <https://doi.org/10.1016/j.jobe.2020.101978>
- Environmental Performance Index (EPI), 2020. Dipetik pada Januari 2021, dari <https://epi.yale.edu>
- Jungsik, C., Hansaem, K., & Inhan, K. (2015). Open BIM-based quantity take-off system for schematic estimation of building frame in early design stage. *Journal of Computational Design and Engineering*, 2, 16–25. <https://doi.org/10.1016/j.jcde.2014.11.002>
- GBCI, (2020) EDGE Indonesia Dipetik pada Januari 2021, dari [GBCI:http://www.gbcindonesia.org/edge/edge-indonesia](http://www.gbcindonesia.org/edge/edge-indonesia)
- Husin, A. E., Setyawan, T. L., Meidiyanto, H., Kussumardianadewi, B. D., & Eddy Husin, M. K. (2019). Key success factors implementing BIM based quantity take-off in fit-out office work using relative importance index. *International Journal of Engineering and Advanced Technology*, 8(6), 986–990. <https://doi.org/10.35940/ijeat.F82650.88619>
- Kustiani, I., Widyawati, R., & Warena, R. D. (2020). *Seminar Nasional Ilmu Teknik dan Aplikasi Industri Analisis Pengelolaan Limbah Konstruksi dengan Skema Stepwise Incentive System dalam Rangka Penerapan Lean Construction pada Proyek Konstruksi di Lingkungan Universitas Lampung*. 3.
- Konstantinidou, C. A., Lang, W., Papadopoulos, A. M., & Santamouris, M. (2019). Life cycle and life cycle cost implications of integrated phase change materials in office buildings. *International Journal of Energy Research*, 43(1), 150–166. <https://doi.org/10.1002/er.4238>
- Francisco Javier Montiel-Santiago., Manuel Jesús Hermoso-Orzáez., Julio Terrados-Cepeda. (2020) Sustainability and Energy Efficiency: BIM 6D. Study of the BIM Methodology Applied to Hospital Buildings. Value of Interior Lighting and Daylight in Energy Simulation.