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Analysis of Building Information Modeling (BIM) 4D-5D Method to Minimize the Occurrence of Variation Orders in Design and Build Contract Models

Mulyo[1], and Mawardi Amin[2]

Master of Civil Engineering[1], and Professor[2]

Mercubuana University, Jakarta, Indonesia

Jl. Raya Meruya Selatan, Kecamatan Kembangan

Jakarta Barat, Indonesia 11650

ABSTRACT

Reducing VO in the Design and Build contract model requires increased coordination, communication, and change management between the design team, project implementers, and service providers. This study aims to analyze the effect of BIM 4D and BIM 5D on the Order of Variations in the Design and Building contract model, as well as the effect of their combinations. This study examines the effectiveness of applying the 4D and 5D BIM methods to mitigate work changes in projects. Data was collected through questionnaires and analyzed with SPSS for Windows. The results showed that the BIM 4D variable had a significant effect on the use of Variation Order to reduce post-construction changes. The X1 BIM 4D coefficient (β1) is 0.937 indicating that an increase in X1 BIM 4D by 1 increases the Y1 Variation Order by 0.937. Regression analysis showed a tcount of 4.343 which is significant at the 0.05 level (p<0.05). The 5D BIM variable has a significant effect on Variation Order in reducing post-construction-growth changes. The coefficient value of β2 X2 BIM 5D is 0.120 and is positive, which means that every 1-time increase in X2 BIM 5D will increase Y1 Financial Performance by 0.120. The results of the regression analysis showed a tcount value of 3.764 and a significance of 0.041. The results of data processing show an F-count value of 83.893 and a significance of 0.000. H0 and Ha are accepted. BIM 4D and BIM 5D have a significant effect on Variation Order as a tool for minimizing post-construction growth changes. The application of 4D and 5D BIM technologies helps mitigate construction project risks through simulating project steps, training project teams, visualizing changes/requests using BIM, and storing material specification information in BIM models. BIM technology reduces risks and increases the effectiveness of construction projects.

Key words: BIM 4D and 5D, Design and Build, Variation Orders.

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1. INTRODUCTION

In recent times, Design-Build contracts have gained popularity as they allow for the transfer of risks to the service provider, who is responsible for both construction and design aspects. This contract type offers advantages, such as the project owner entering into a single contract for both design and project execution with a single contractor [1]. In the midst of intense competition in the construction industry, contractors must adapt to changing systems [2].

The Design-Build contract type often faces the challenge of changes occurring during the construction contract period, resulting from various parties involved in the project's execution. This can lead to changes in initial planning, resulting in design changes or specification alterations, commonly known as variation orders [3]. During any construction project, change orders are unavoidable. However, the magnitude of these changes is a primary concern for project owners, as they can negatively impact project costs, schedules, quality, and the morale of project participants. As such, it is an important area of interest for owners, designers, and contractors [5].

Building Information Modeling (BIM) has proven beneficial in construction delivery processes. BIM achieves these results by enabling information interoperability related to buildings or facilities throughout their lifecycle, from conceptual design to facility management, and particularly addressing contractual challenges for BIM-based construction projects [6].

Due to its novelty and the involvement of numerous stakeholders, BIM application in projects and the construction industry has become increasingly complex. BIM is now enshrined in government regulations, such as Government Regulation (PP) Number 16 of 2021 in Attachment II, Roman numeral three, outlining Building Implementation and Supervision Standards, letter A, Construction Implementation Standards, point two, specifically stating that for technology-intensive buildings, Building Information Modeling (BIM) up to at least the fifth dimension must be used, involving at least medium-class service providers that include quantity surveyors and construction surveyors. In the case of capital-intensive buildings, BIM must be used up to the eighth dimension and carried out by major-class service providers involving quantity surveyors, project management, and construction management, (PP) Number 16 of 2021).

According to [7], BIM undoubtedly brings many benefits to the industry, including single but multiple use entries, design efficiency, collaboration, flexibility, consistent design basis, three-dimensional modeling and conflict resolution, visualization of solutions and alternative options, and energy analysis capabilities. However, BIM has raised legal and contractual questions.

Variation orders frequently occur during the execution of building and civil construction projects. These orders represent enhancements to the existing design in a contract. In brief, variation orders can be defined as modifications to the original contract. As the project progresses, the impact of scope changes becomes more pronounced [8].

The Building Information Modeling (BIM) 4D-5D method has been utilized in the construction industry to enhance project management efficiency and accuracy. However, within the Design and Build contract model, issues with Variation Orders still persist, leading to unwanted project delays and additional costs. To address this problem, an analysis of the 4D-5D BIM method is needed to minimize the occurrence of Variation Orders in the Design and Build contract model. This analysis aims to identify potential shortcomings and develop appropriate strategies to mitigate the risk of Variation Orders.

Four fundamental stages are related to the process of change orders, including a request for change by an initiator (either the contractor or architect-engineer) to obtain approval from the project owner or architect-engineer. During the request for approval from the initiator, discussions occur with the contractor, and the proposal variation order document is reviewed to understand the impact of changes on contract time and cost. The contractor submits a signed proposal for the change order to the project owner, indicating all additional costs and requested time extensions. The project owner accepts the signed proposal and issues orders for the specified work to proceed.

To minimize the occurrence of Variation Orders in the Design and Build contract model, further efforts are required to enhance coordination, communication, and change management among the design team, project implementers, and service providers. Additionally, comprehensive design drafting, meticulous cost monitoring, and effective management of material specifications and availability are crucial steps in reducing the risk of unwanted changes in construction projects.

2. METHODS

2.1. Research Concept

This study is a quantitative descriptive research. According to the descriptive method, it is used to analyze data by describing or depicting the collected data as they are, without intending to draw universally applicable conclusions or generalizations [9]. Meanwhile, quantitative research is a research method based on a positivist philosophy, used to investigate a specific population or sample, with sampling techniques typically conducted randomly. Data collection involves using research instruments, and data analysis is quantitative or statistical in nature, with the aim of testing predetermined hypotheses [9].

2.2. Research Stages

Validity is a measure that demonstrates validity. An instrument is said to be valid if it can accurately measure what is intended and reveal data from the studied variables. According to [10], valid means that the instrument can be

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used to measure what should be measured. The data analysis method employed is Correlation Analysis using SPSS (Statistical Package for the Social Sciences). Statistics is a discipline related to numbers, thus statistics is often associated with quantitative (numeric) data, and one of the tools used is the SPSS software. To understand the workings of the SPSS software, the connection between computer operation and SPSS in processing data is explained

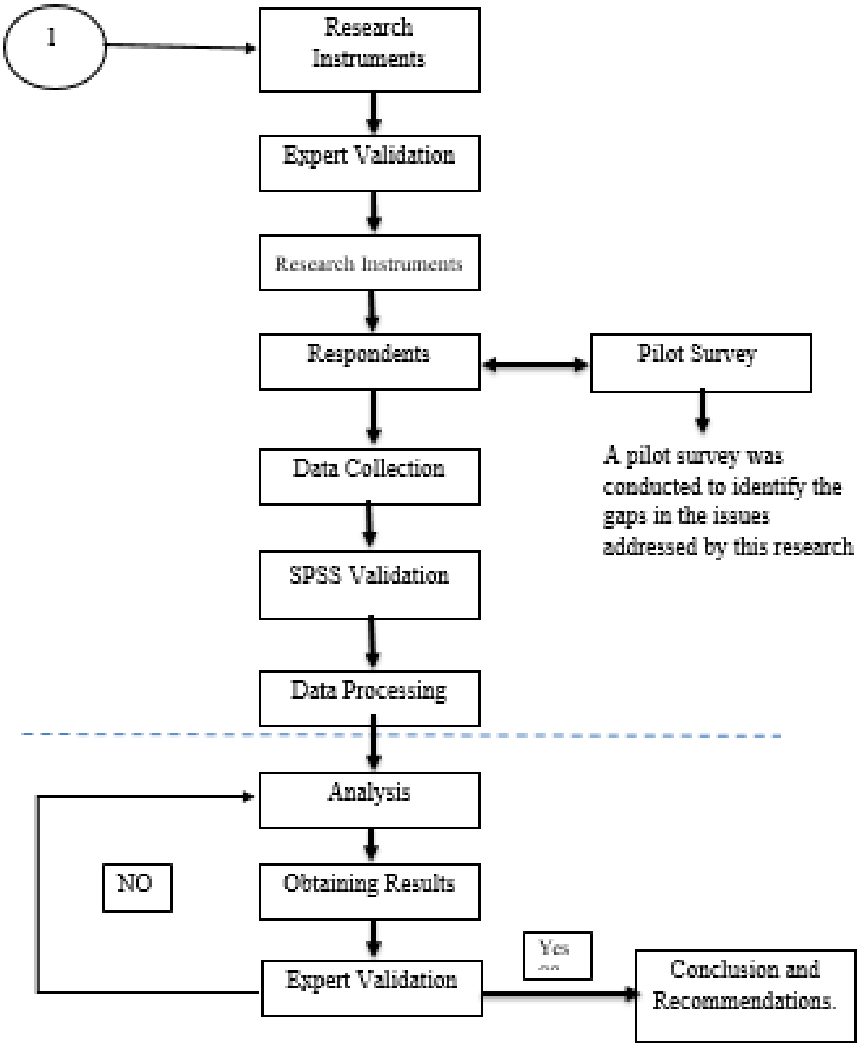

Figure 1. Framework of Research

3. RESULTS AND DISCUSSIONS

The variables obtained from the previous study through the analysis of the Building Information Modeling 4D-5D method, aiming to minimize the occurrence of variation orders in the design and build contract model, resulted in 3 (three) variables with 40 (forty) indicators. These variables were validated by 5 (five) experts. The validated variables were then transformed into a questionnaire for further research and distributed among the respondents.

Validity Test

To test the validity of an instrument using SPSS on the sample, the validity can be examined by correlating each item in the instrument with the total score of the instrument. The validity testing is conducted to determine whether the questionnaire for each variable is valid or not. The validity test conducted in this research is presented below.

DOI : 10.31695/IJERAT.2023.9.12.2

Table 1. Validity Test on Variables

Indicator	R Calculated	R Table	Description
X1 BIM 4D			
X1.1	0,657	0,2542	Valid
X1.2	0,337	0,2542	Valid
X1.3	0,336	0,2542	Valid
X1.4	0,508	0,2542	Valid
X1.5	0,379	0,2542	Valid
X1.6	0,415	0,2542	Valid
X1.7	0,382	0,2542	Valid
X1.8	0,414	0,2542	Valid
X1.9	0,372	0,2542	Valid
X1.10	0,726	0,2542	Valid
X2 BIM 5D			
X2.1	0,507	0,2542	Valid
X2.2	0,456	0,2542	Valid
X2.3	0,58	0,2542	Valid
X2.4	0,416	0,2542	Valid
X2.5	0,373	0,2542	Valid
X2.6	0,383	0,2542	Valid
X2.7	0,338	0,2542	Valid
X2.8	0,405	0,2542	Valid
X2.9	0,420	0,2542	Valid
X2.10	0,344	0,2542	Valid
X2.11	0,369	0,2542	Valid
X2.12	0,66	0,2542	Valid
X2.13	0,441	0,2542	Valid
X2.14	0,379	0,2542	Valid

DOI : 10.31695/IJERAT.2023.9.12.2

Y1 Variation Order			
Y1.1	0,349	0,2542	Valid
Y1.2	0,604	0,2542	Valid
Y1.3	0,328	0,2542	Valid
Y1.4	0,321	0,2542	Valid
Y1.5	0,419	0,2542	Valid
Y1.6	0,327	0,2542	Valid
Y1.7	0,341	0,2542	Valid
Y1.8	0,368	0,2542	Valid
Y1.9	0,386	0,2542	Valid
Y1.10	0,37	0,2542	Valid
Y1.11	0,684	0,2542	Valid
Y1.12	0,377	0,2542	Valid
Y1.13	0,455	0,2542	Valid
Y1.14	0,455	0,2542	Valid
Y1.15	0,314	0,2542	Valid
Y1.16	0,335	0,2542	Valid

Based on the above output, it can be concluded that the calculated Pearson correlation (r) values for all questionnaire items are greater than the tabled critical value (r-table), indicating the validity of all frequency-based questionnaire items. From the validity testing results shown in the table above, a total of 24 questionnaires were completed by 30 respondents in this study. One way to determine which questionnaires are valid and which are not is to find out the r-table value first. The formula for the r-table is df = N-2, so for 60-2 = 58 degrees of freedom, the r-table value is 0.2542. From the validity calculation results in the table above, it can observed that for 40 questionnaires, the calculated r-values are greater than the r-table value, indicating their validity. All 40 statements in the questionnaire are considered valid since their calculated r-values exceed the r-table value of 0.2542.

Reliability Test

In this study, a reliability test must be conducted to measure the consistency of the questionnaire used to assess the influence of variable X on variable Y1. Before performing the reliability test, a decision-making basis should be established, which is an alpha value of 0.60. A variable is considered reliable if its value is greater than >0.60; if it is smaller, then the researched variable cannot be deemed reliable. Based on the output table above, there is a total of 40 items representing the number of questions across 3 variables: X1 BIM 4D with a Cronbach's alpha value of 0.663, X2 BIM 5D with a Cronbach's alpha value of 0.682, and Y1 Variation Order with a Cronbach's alpha value of 0.648. According to the aforementioned decision-making basis, all questionnaire items are considered reliable since their Cronbach's alpha values are greater than 0.60..

DOI : 10.31695/IJERAT.2023.9.12.2

Table 2. Reliability Test on Variables

Variable	Cronbach's Alpha
X1 BIM 4D	0,663
X2 BIM 5D	0,682
Y1 Variation Order	0,648

Normality Test

The normality test aims to examine whether in the regression model, the disturbance or residual variable has a normal distribution. To determine whether a data is normally distributed or not, the normality test can be conducted using the one-sample Kolmogorov-Smirnov test on the equation's residuals. The testing criteria are as follows: if the probability value > 0.05, then the data is normally distributed, and if the probability value < 0.05, then the data is not normally distributed.

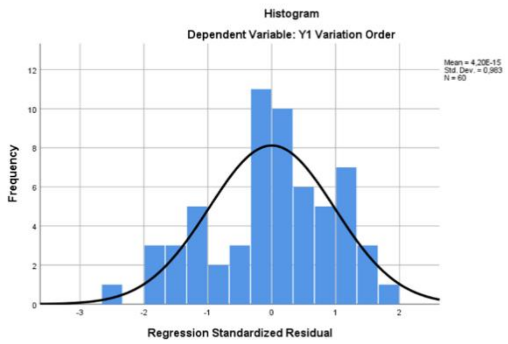

Figure 2. Normality Test Histogram

Table 3. Normality Test

One-Sample Kolmogorov-Smirnov Test		
Unstandardized Residual		
N		60
Normal Parameters[a,b]	Mean	0,0000000
	Std. Deviation	4,43065484
Most Extreme Differences	Absolute	0,065
	Positive	0,065
	Negative	-0,052
Test Statistic		0,065
Asymp. Sig. (2-tailed)		,200[c,d]

DOI : 10.31695/IJERAT.2023.9.12.2

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

Based on Table 3, it can be observed that the Kolmogorov-Smirnov Z value is 0.065 and the significance is 0.200 (0.200 > 0.05), indicating that the residual data is normally distributed. This result with a value greater than 0.05 implies that the residual data is normally distributed and therefore suitable for use.

Hypothesis Testing

Multiple Linear Regression & t-test

The data analysis method used in this study is the multiple linear regression model. Multiple linear regression analysis is used to determine the influence between two or more independent variables and the dependent variable. The calculation of the multiple linear regression model is performed using SPSS for Windows Release 25.0. The obtained analysis results are as follows.

Table 4. Results of Multiple Linear Regression & t-test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	17,920	3,773		4,750	0,000
	X1 BIM 4D	0,937	0,216	0,742	4,343	0,000
	X2 BIM 5D	0,120	0,158	0,131	3,764	0,048

a. Dependent Variable: Y1 Variation Order

Based on the results of the multiple linear regression test presented in Table 4 above, the regression equation obtained is as follows:

Y1 = 17.920 + 0.937 X1 + 0.120 X2 + ε

The equation can be explained as follows: The constant value of 17.920 indicates that when the values of X1 BIM 4D and X2 BIM 5D are both 0, the Y1 Variation Order as a tool to minimize post-construction changes has a performance level of 17.920.

DOI : 10.31695/IJERAT.2023.9.12.2

1. The coefficient value of X1 BIM 4D (β1) is 0.937 with a positive value. This means that for every 1-unit increase in X1 BIM 4D (β1), the Y1 Variation Order as a tool to minimize post-construction changes will increase by 0.937, assuming the other variables are constant. Based on the first hypothesis proposed by the researcher, it is shown that the BIM 4D variable has an influence on Variation Order as a tool to minimize post-construction changes. It is also explained in the regression analysis result that the X1 BIM 4D variable has a t-test value of 4.343, which is greater than the t-table value of 1.67065, and the significance value is 0.00, which is smaller than the significance level of 0.05 (0.00 < 0.05). Therefore, it can be concluded that the hypothesis is accepted.
2. The coefficient value of X2 BIM 5D (β2) is 0.120 with a positive value. This means that for every 1-unit increase in X2 BIM 5D (β2), the Y1 Variation Order as a tool to minimize post-construction changes will increase by 0.120, assuming the other variables are constant. Based on the second hypothesis proposed by the researcher, it is shown that the BIM 5D variable has an influence on Variation Order as a tool to minimize post-construction changes. It is also explained in the regression analysis result that the X2 BIM 5D variable has a t-test value of 3.764, which is greater than the t-table value of 1.67065, and the significance value is 0.041, which is smaller than the significance level of 0.05 (0.041 < 0.05). Therefore, it can be concluded that the hypothesis is accepted.

F-Test

The F-test is used to determine the influence of both BIM 4D and BIM 5D on Variation Order as a tool to minimize post-construction changes simultaneously or together. The acceptance criteria for the hypothesis are that if the significance value (sig.) is ≤ 0.05, then the hypothesis is accepted; if sig. > 0.05, then the hypothesis is rejected. To obtain the result in the F-test using the formula (n-k)(k-1), the obtained F-table value is 3.16. The results of the F-test are presented in Table 5 below:

Tabel 5. Uji F

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	340,109	2	170,054	83,893	,000[b]
	Residual	115,541	57	2,027		
	Total	455,650	59			

a. Dependent Variable: Y1 Variation Order

b. Predictors: (Constant), X2 BIM 5D, X1 BIM 4D

The results of data analysis can be observed in the above Table 5, which indicates that the calculated F value of 83.893 > F table 3.16 and the significance value of 0.000 < 0.05. This means that the null hypothesis (H0) is accepted and the alternative hypothesis (Ha) is accepted. Therefore, it can be stated that BIM 4D and BIM 5D significantly influence Variation Order as a tool to minimize post-construction changes.

The Coefficient of Determination

The Coefficient of Determination (R Square) aims to measure the percentage of influence of independent variables on the dependent variable in a regression model, expressed in percentage terms. The results of the coefficient of determination test in this research are as follows::

DOI : 10.31695/IJERAT.2023.9.12.2

Table 6. Coefficient of Determination

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics
					R Square Change
1	,864[a]	0,746	0,738	1,424	0,746

a. Predictors: (Constant), X2 BIM 5D, X1 BIM 4D

b. Dependent Variable: Y1 Variation Order

Based on the SPSS output table "Model Summary" above, the coefficient of determination, also known as R Square, is found to be 0.746 or 74.6%. This value indicates that the variables BIM 4D & BIM 5D collectively (simultaneously) influence the Variation Order variable as a tool to minimize post-construction changes by 74.6%. The remaining portion (100% - 74.6% = 25.4%) is influenced by other variables not included in this regression equation or variables that were not studied.

Effectiveness of Applying BIM 4D & BIM 5D in Mitigation

BIM (Building Information Modeling) 4D and BIM 5D are technologies that can aid in mitigating job changes during the project phases. BIM 4D involves using BIM models to generate graphics that depict project progress over time, while BIM 5D involves integrating cost and time aspects into the BIM model. The implementation of BIM 4D and BIM 5D can enhance the effectiveness of mitigating job changes during the project phases. The risk mitigation measures are presented in Table 7.

Table 7. Effectiveness of 4D & 5D BIM Implementation in Mitigation

Risk	Mitigation
Simulation and project steps	Develop a detailed project plan with a clear schedule approved by all relevant parties.
Learn to schedule	Provide training to the entire project team on the use of BIM 4D & BIM 5D and how to implement this technology in the project schedule.
Visual validation for payments	Use BIM 4D & BIM 5D technology to ensure construction aligns with drawings and specifications.
Approvals	Implement a clear and documented approval system for design changes and scope alterations.
Real-time concept modeling and cost planning	Use BIM 5D technology to create real-time cost estimates and concept modeling.

DOI : 10.31695/IJERAT.2023.9.12.2

Quantity extraction to support detailed cost estimation	Use BIM 5D technology to calculate and manage the quantities of materials needed in the project.
Manufacturer model trade verification	Use BIM 4D & BIM 5D technology to verify that manufacturer models align with actual construction.
Value engineering	Use BIM 5D technology to analyze cost-efficient alternative designs.
Prefabrication solutions	Use BIM 4D & BIM 5D technology to plan and construct prefabricated elements on time.
Design changes	Implement a clear approval and coordination system for design changes, including using BIM 4D & BIM 5D technology to visualize these changes.
Scope changes	Implement a clear approval and coordination system for scope changes, including using BIM 4D & BIM 5D technology to visualize these changes.
Delays assessment	Use BIM 4D & BIM 5D technology to assess the impact of delays on the project schedule.
Varied requests	Implement a clear approval and coordination system for varied requests, including using BIM 4D & BIM 5D technology to visualize these changes.
Imperfect designs	Use BIM 4D & BIM 5D technology to identify potential issues in designs and apply improvements before construction starts.
Material specification changes	Store material specification information in the BIM model. Create an updated material database. Use change management tools to systematically update material specifications.
Incomplete specifications	Ensure all specification information is input into the BIM model. Use change management tools to systematically update specifications. Have clear procedures for addressing missing or incomplete specifications.

Table 7. on How 4D & 5D BIM Implementation Can Aid in Risk Mitigation in Construction Projects The implementation of 4D and 5D Building Information Modeling (BIM) technologies plays a crucial role in mitigating risks within construction projects. Various risk mitigation strategies can be executed through the utilization of BIM technology. These strategies include simulating and planning project steps meticulously to formulate detailed project plans with clear schedules that are agreed upon by all relevant parties. This approach aids in risk evaluation and offers

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effective and efficient solutions. Furthermore, providing comprehensive training to the entire project team on the application of 4D and 5D BIM technologies, as well as the methods for integrating these technologies into project schedules, is of paramount importance. This ensures that the entire team comprehends the workings of BIM technology, enhancing its efficacy and diminishing the potential for errors.

Additionally, leveraging 4D and 5D BIM technology to visualize design changes, alterations in scope of work, and diverse requests also contributes to risk mitigation within construction projects. Establishing a clear approval and coordination system and employing BIM technology allows all stakeholders to easily grasp occurring changes and take necessary actions to minimize risks. Lastly, storing material specifications within the BIM model and maintaining an updated material database aids in risk mitigation within construction projects. By having comprehensive and current material specification information, errors in procurement can be avoided, and the quality of materials used in construction can be assured. Consequently, the utilization of 4D and 5D BIM technology contributes to risk reduction and enhances effectiveness in construction project execution.

4. CONCLUSIONS

Based on the analysis and discussion, the conclusions are as follows:

1. The coefficient value of X1 for 4D BIM (β1) is 0.937 with a positive value. This indicates that for every 1-unit increase in 4D BIM (β1), the Variation Order (Y1) as a tool to minimize post-construction changes will increase by 0.937, assuming that other variables are constant. The first hypothesis proposed by the researcher suggests that the 4D BIM variable affects the Variation Order as a tool to minimize post-construction changes. The regression analysis results also show that the X1 variable for 4D BIM has a t-value of 4.343, which is greater than the t-table value of 1.67065, and a significance value of 0.00, which is smaller than the significance level of 0.05 ($0.00 < 0.05$). Therefore, it can be concluded that the hypothesis is accepted.
2. The coefficient value of X2 for 5D BIM (β2) is 0.120 with a positive value. This indicates that for every 1-unit increase in 5D BIM (β2), the Financial Performance (Y2) will increase by 0.120, assuming that other variables are constant. The first hypothesis proposed by the researcher suggests that the 5D BIM variable affects the Financial Performance. The regression analysis results also show that the X2 variable for 5D BIM has a t-value of 3.764, which is greater than the t-table value of 1.67065, and a significance value of 0.041, which is smaller than the significance level of 0.05 ($0.041 < 0.05$). Therefore, it can be concluded that the hypothesis is accepted.
3. The data processing results show that the calculated F value of 83.893 > the tabulated F value of 3.16, and the significance value of $0.000 < 0.05$. This means that H0 is accepted and Ha is accepted. Thus, it can be stated that 4D and 5D BIM significantly influence the Variation Order as a tool to minimize post-construction changes.
4. The use of 4D and 5D BIM enables detailed project step simulations. Detailed project plans with clear schedules approved by relevant parties help identify risks and implement effective and efficient preventive measures. Intensive training for the entire project team on the use and implementation of 4D and 5D BIM in project schedules is essential. This ensures that the entire team understands the technology, enhances effective usage, and reduces the risk of human errors. Using BIM to visualize design changes, scope of work modifications, and diverse requests aids in risk reduction. An integrated approval and coordination system facilitates the understanding of changes and required mitigation steps by all relevant parties.

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