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Analysis of Factors Causing Variation Orders and their Impact on Construction Contract Value of Main Dam Projects

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ABSTRACT

The Indonesian government has been actively engaged in extensive dam construction initiatives aimed at harnessing water resources for diverse purposes such as agricultural irrigation, clean water supply, flood control, power generation, and tourism. However, the construction of each main dam project faces challenges, particularly in the form of variation orders that lead to increases in construction costs. This research investigated the factors contributing to variation orders in main dam projects in Indonesia and assessed their impact on the overall construction costs. A comprehensive literature review was performed to identify variation order factors previously studied by researchers. Subsequently, secondary data were gathered through questionnaires administered to various stakeholders involved in main dam projects, including contractors, consultants, and owners. The analysis of questionnaire responses revealed a total of 26 indicators contributing to variation orders, which were categorized into 9 consultant-related factors, 8 owner-related factor, 6 external factors, and 3 contractor-related factors. Four indicators, including the alignment of tender drawings and field conditions, natural changes (weather/geology), changes in work items, and the complexity of dam design, were identified as having mean values greater than 4 on a 5-point Likert scale. This indicates a strong consensus among respondents that these indicators significantly contribute to variation orders. A subsequent questionnaire aimed to evaluate the impact of these 26 variation order indicators on construction cost increases. The collected data from respondents was analyzed using multiple linear regression. The results revealed that the contractor-related factor had the most substantial impact on cost increases with a coefficient of 0.14, followed by the external factor at 0.067, and the owner-related factor at 0.04.

Key word: main dam; variation order; factor; indicator; cost increases.

INTRODUCTION

Indonesian Government, under the Directorate of Water Resources within the Ministry of Public Works and People's Housing, has actively participated in main dam construction since 2015. Main Dams are crucial infrastructures, vital for citizen well-being, serving the dual purpose of water storage during the rainy season and elevation of water levels. Stored water is utilized for irrigating connected networks, supplying agricultural areas, providing clean water to surrounding regions, and facilitating hydroelectric power generation through hydropower plants (PLTA). Additionally, main dams play a pivotal role in water flow control and contribute to tourism.

Variation orders are a common aspect of the construction process, particularly in contracts based on unit prices, and their occurrence is influenced by the complexity of construction projects. Main dams, as intricate constructions, consistently encounter variation orders in Indonesian projects. A variation order encompasses any changes in a contract from approval to project completion.

The causes of variation orders vary across construction projects due to their unique characteristics. Previous research has identified four clusters of sources for variation orders: owner, consultant, contractor, and others (Desai et al., 2019), with the consultant variable significantly contributing to variation order occurrences (Adedeji et al., 2018). Given the substantial impact of variation orders, stakeholders such as owners, consultants, contractors, and others must pay careful attention to them (Oladapo, 2007).

The impacts of variation orders include cost overruns, project completion delays, a decline in work quality, and the emergence of disputes among owners, contractors, and consultants (Thakar, 2020). Due to these consequences, stakeholders must consider variation orders carefully (Oladapo, 2007).

In the specific context of main dam construction projects in Indonesia, where variation orders are prevalent, leading to an increase in contract value, this research aims to analysis the factors causing variation orders in Indonesian main dam projects and examine their correlation with construction cost overruns.

RESEARCH METHODS

This research focused on main dam construction projects in Indonesia. The respondents involved in the research were individuals who had been or were currently engaged in main dam construction projects. Respondents were selected from owners, consultants, and contractors, based on their qualifications and experience in main dam construction projects to ensure that the data obtained reflected the conditions of variation orders in main dam projects.

The research consisted of two stages of data collection, using two questionnaires. Stage 1 involved exploratory analysis to examine the factors causing variation orders. Stage 2 was the data collection process to analyze the factors causing variation orders and their impact on cost overruns. The research plan is outlined in Figure 1.

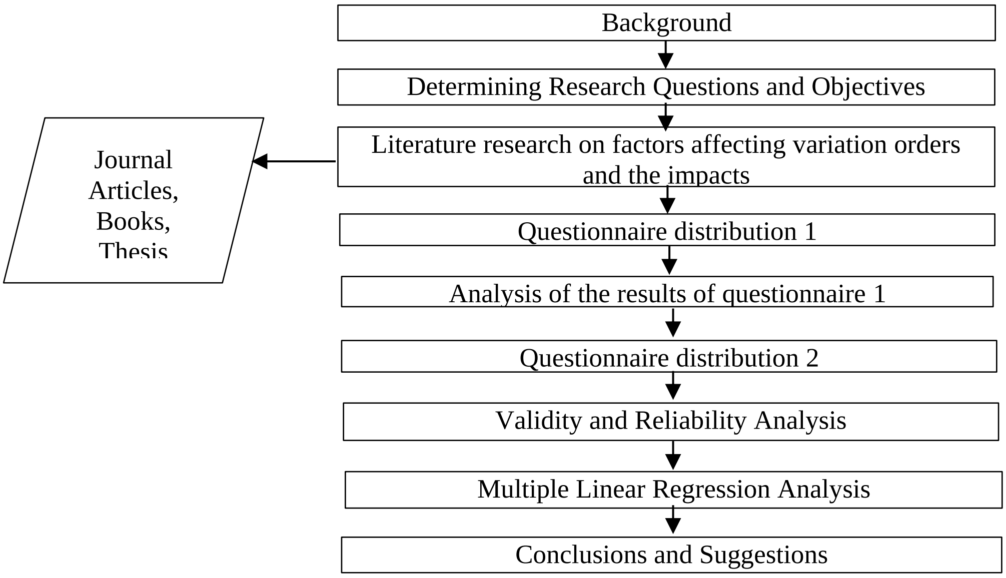

Figure 1. Research Flow Chart

Research Variables

In this research, there are four independent variables and one dependent variable described as follows

1. Variables Related to Owner (X1) : factor causing the variation order where owner is the initiator
2. Variables Related to Consultant (X2) : factor causing the variation order where consultant is the initiator
3. Variables Related to Contractor (X3) : factor causing the variation order where contractor is the initiator
4. External Variables (X4) : factor causing variation orders where the initiators are neither the owner, consultant nor contractor

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5. Cost Overruns Variables (Y) : The increase in construction costs

Variables X1, X2, X3, and X4 were extracted from existing literature and prior research, identifying a total of 33 indicators contributing to the incidence of variation orders. These 33 indicators will be investigated through a questionnaire to discern the significance of each indicator as either Relevant or irrelevant in causing variation orders. A Relevance threshold of 10% will be applied, and the assessment of Relevance will be carried out using the Binomial test. The assumptions for the test are as follows.

1. p1 : Relevant
2. p2 : Irrelevant
3. H0 : $p1 < p2$
4. H1 : $p1 > p2$

The factors that cause variation orders would be included in the questionnaire for Stage 2. In this Stage 2 questionnaire, the relationship between independent variables and dependent variables was examined using respondent data. The data collected from respondents underwent multiple linear regression analysis to comprehend the relationship between the identified independent variables and the dependent variable.

Data Analysis Method

This research utilized the statistical method of multiple linear regression analysis. The stages of analysis conducted are as follows:

1. Testing the validity and reliability of variation order factors
2. Classic assumption tests, including normality test, homoscedasticity/non-heteroskedasticity test, non-autocorrelation test, and multicollinearity test
3. Analysis of data distribution
4. Analysis of residual variability errors
5. Analysis of correlation among independent variables
6. Analysis of the multiple linear regression model

RESULTS AND DISCUSSION

In the questionnaire of the first stage, which is the exploratory research phase, aimed at analyzing the factors causing variation orders, 37 respondents participated with the following characteristics:

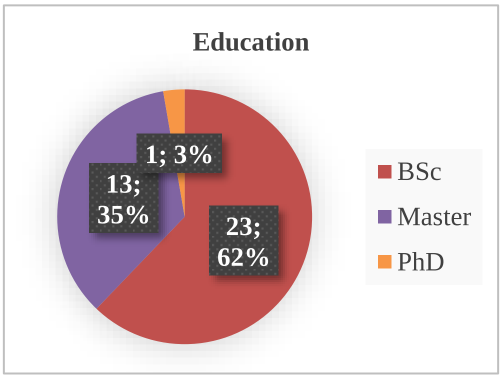

Figure 2. Respondents' Education Background

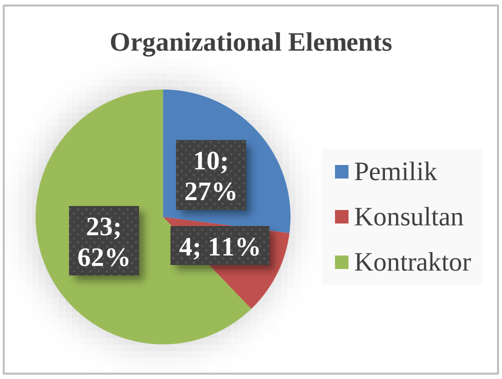

Figure 3. Organizational Elements

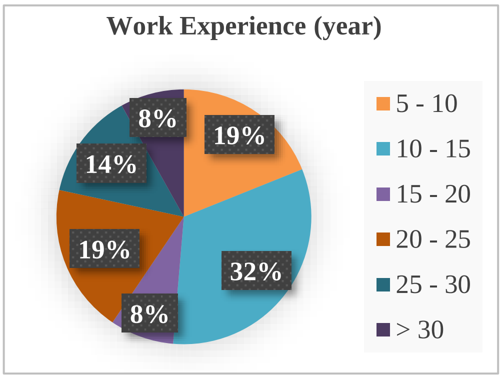

Figure 4. Work Experience

Based on the background, work experience, and organizational background of the respondents, it can be concluded that the respondents are qualified to answer the questions in the questionnaire for the first stage concerning the factors causing variation orders.

The results of the binomial test analysis on Relevance and irrelevance of the factors causing variation orders are as follows:

Table 1. The results of the Relevance among factors

No	Variation Order Factors	Relevant (p1)	Irrelevant (p2)	n	p value	α	Outcome
X1	**Project owner as the factor causing variation orders.**						
X1.1	Budget Availability	25	12	37	0.024	0.1	Relevant
X1.2	Changes in plans and scope of work	26	11	37	0.011	0.1	Relevant
X1.3	Completeness of job item specifications	26	11	37	0.011	0.1	Relevant
X1.4	Completeness of material specifications	27	10	37	0.004	0.1	Relevant
X1.5	Optimization of building/construction functions	33	4	37	0.000	0.1	Relevant
X1.6	Changes in job items	34	3	37	0.000	0.1	Relevant
X1.7	Changes in implementation schedule	31	6	37	0.000	0.1	Relevant
X1.8	Completeness of contract documents	27	10	37	0.004	0.1	Relevant
X1.9	Project objectives	9	28	37	0.500	0.1	Irrelevant
X2	**Project consultant as the factor causing variation orders.**						
X2.1	Compatibility between tender drawings and field conditions	36	1	37	0.000	0.1	Relevant
X2.2	Design quality	32	5	37	0.000	0.1	Relevant
X2.3	Comprehensive level of Detailed Engineering Design (DED) and Estimation suitability	34	3	37	0.000	0.1	Relevant
X2.4	Completeness of tender drawings	35	2	37	0.000	0.1	Relevant
X2.5	Design changes	32	5	37	0.000	0.1	Relevant

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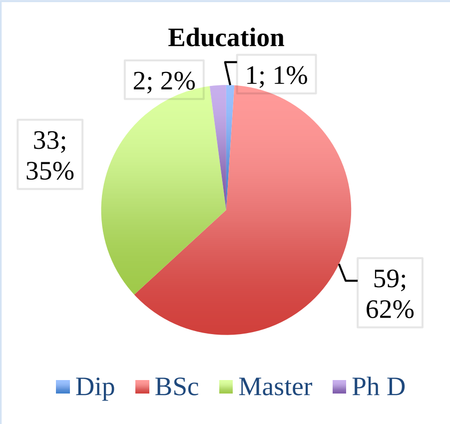
No	Variation Order Factors	Relevant (p1)	Irrelevant (p2)	n	p value	α	Outcome
X2.6	Complexity of main dam design	35	2	37	0.000	0.1	Relevant
X2.7	Consultant's experience	26	11	37	0.011	0.1	Relevant
X2.8	Accuracy of soil investigation/geotechnical conditions	34	3	37	0.000	0.1	Relevant
X2.9	Availability of materials according to specifications	32	5	37	0.000	0.1	Relevant
X3	**Project contractor as the factor causing variation orders.**						
X3.1	Contractor's financial capability	17	20	37	0.371	0.1	Irrelevant
X3.2	Changes in work schedule	29	8	37	0.001	0.1	Relevant
X3.3	Contractor's execution speed	14	23	37	0.950	0.1	Irrelevant
X3.4	Contractor's accuracy in the implementation process	16	21	37	0.255	0.1	Irrelevant
X3.5	Contractor's experience in main dam construction	11	26	37	0.496	0.1	Irrelevant
X3.6	Material changes	31	6	37	0.000	0.1	Relevant
X3.7	Changes in work methods	30	7	37	0.000	0.1	Relevant
X3.8	Availability of tools and resources	18	19	37	0.500	0.1	Irrelevant
X4	**External factors as the factors causing variation orders.**						
X4.1	Government economic conditions	35	2	37	0.000	0.1	Relevant
X4.2	Natural changes (weather/geology)	35	2	37	0.000	0.1	Relevant
X4.3	Changes in legislation or government policies	34	3	37	0.000	0.1	Relevant
X4.4	Safety, health, and environmental aspects in work methods	30	7	37	0.000	0.1	Relevant
X4.5	Occurrence of conflicts at the job site	32	5	37	0.000	0.1	Relevant
X4.6	Political pressure	22	15	37	0.161	0.1	Irrelevant
X4.7	Land acquisition	34	3	37	0.000	0.1	Relevant

Results from the data analysis of Stage 1 questionnaires identified the Relevant causing variation orders. In the Stage 2 questionnaire, these indicators will be considered as independent variables, with the dependent variable being cost overruns. The Stage 2 questionnaire was administered to 95 respondents, and the characteristics of the Stage 2 respondents are as follows:



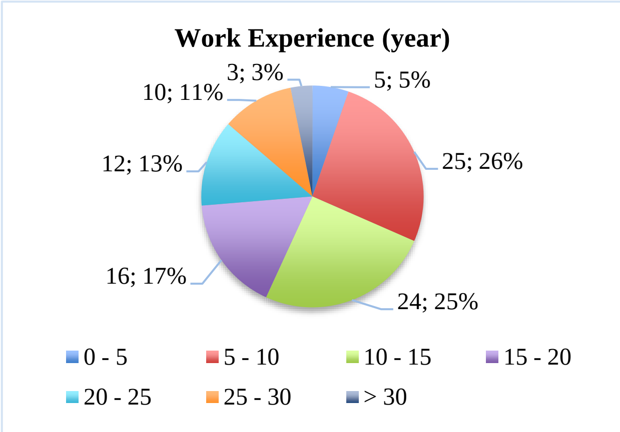


Figure 5. Work Experience in Stage 2

Figure 6. Education Background in Stage 2

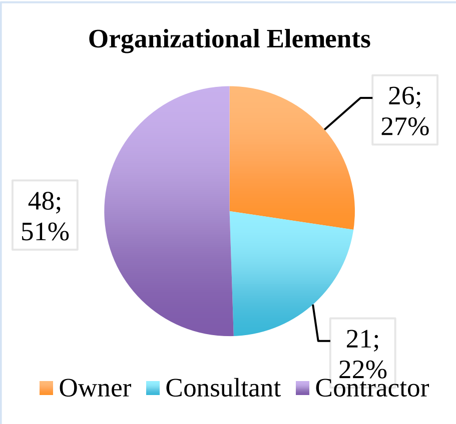


Figure 7. Organizational Elements in Stage 2

Analyzing the characteristics of Stage 2 respondents revealed a notable emphasis on strong educational backgrounds, with 62% holding a Bachelor of Science (BSc) degree and 35% possessing a Master's degree. Regarding professional experience, a significant 97% of respondents boasted over 5 years of work experience, and all participants played pivotal roles in main dam construction projects. Consequently, it can be inferred that the respondents possessed the requisite expertise to effectively respond to the questionnaire.

To facilitate additional scrutiny, this research employed mean values for each variable and factor, as delineated in Tables 2 and 3, based on the available data.

Table 2. Mean Scores of the Variables

Variable	Min	Max	Mode	Mean	Std
Owner	1	5	4	3.612	1.252
Consultant	1	5	4	3.713	1.238
Contractor	1	5	4	3.874	1.037
External Factor	1	5	4	3.842	1.136
Cost Overruns	1	5	5	4.000	1.120

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Table 3. Mean Score of Each Factor

Indicator	Frequency					Statistical Measures					
	STS	TS	N	S	SS	sum	min	max	mode	mean	std
X1.1	9	7	12	34	33	95	1	5	4	3.789	1.262
X1.2	9	10	9	40	27	95	1	5	4	3.695	1.255
X1.3	11	21	9	26	28	95	1	5	5	3.411	1.410
X1.4	13	23	9	30	20	95	1	5	4	3.221	1.385
X1.5	3	7	10	49	26	95	1	5	4	3.926	0.981
X1.6	3	5	10	45	32	95	1	5	4	4.032	0.973
X1.7	6	10	22	40	17	95	1	5	4	3.547	1.099
X1.8	10	25	11	27	22	95	1	5	4	3.274	1.356
X2.1	3	2	2	44	44	95	1	5	5	4.305	0.876
X2.2	10	12	15	33	25	95	1	5	4	3.537	1.295
X2.3	8	15	6	31	35	95	1	5	5	3.737	1.331
X2.4	5	13	5	39	33	95	1	5	4	3.863	1.190
X2.5	4	5	16	43	27	95	1	5	4	3.884	1.020
X2.6	1	9	11	41	33	95	1	5	4	4.011	0.973
X2.7	7	20	15	32	21	95	1	5	4	3.421	1.251
X2.8	9	17	6	36	27	95	1	5	4	3.579	1.326
X2.9	17	20	13	28	17	95	1	5	4	3.084	1.397
X3.1	2	9	12	39	33	95	1	5	4	3.968	1.026
X3.2	1	11	17	39	27	95	1	5	4	3.842	1.003
X3.3	3	11	15	38	28	95	1	5	4	3.811	1.085
X4.1	2	9	16	30	38	95	1	5	5	3.979	1.072
X4.2	2	8	8	42	35	95	1	5	4	4.053	0.993
X4.3	5	14	23	28	25	95	1	5	4	3.568	1.182
X4.4	2	11	12	40	30	95	1	5	4	3.895	1.047
X4.4	7	10	19	34	25	95	1	5	4	3.632	1.194
X4.5	5	13	8	27	42	95	1	5	5	3.926	1.248
Y1.1	4	8	11	33	39	95	1	5	5	4.000	1.120

From Table 3, it was determined that the mean value exceeds 3, indicating approval by respondents for all indicators identified as causes of variation orders. Additionally, four indicators contributing to variation orders received values exceeding 4, signifying strong agreement among respondents regarding the significant impact of these factors on variation order occurrences. The four indicators are as follows: X2.1 "alignment between tender drawings and on-site conditions," with a mean value of 4.302, indicating strong consensus that factor X2.1 is a substantial cause of variation orders. This finding aligns with previous research (Zentenno et al., 2018), (Thakar, 2020).

Validity Testing and Reliability of Variation Order Factors

The results of the analysis of respondent data, as presented in Table 4, lead to the conclusion that all factors are valid. Furthermore, according to Table 5, all variables were considered reliable.

Table 4. Data Validity

Indicator	Statistics		Conclusion
	r	sign	
Project Owner			
X1.1	.205*	0.047	valid
X1.2	.644**	0.000	valid
X1.3	.753**	0.000	valid
X1.4	.788**	0.000	valid
X1.5	.411**	0.000	valid
X1.6	.547**	0.000	valid
X1.7	.608**	0.000	valid
X1.8	.724**	0.000	Valid

Indicator	Statistics		Conclusion
	r	**sign**	
Consultant			
X2.1	.669**	0.000	valid
X2.2	.680**	0.000	valid
X2.3	.826**	0.000	valid
X2.4	.733**	0.000	valid
X2.5	.321**	0.002	valid
X2.6	.637**	0.000	valid
X2.7	.456**	0.000	valid
X2.8	.797**	0.000	valid
X2.9	.620**	0.000	valid
Contractor			
X3.1	.768**	0.000	valid
X3.2	.805**	0.000	valid
X3.3	.780**	0.000	valid
External Factors			
X4.1	.784**	0.000	valid
X4.2	.709**	0.000	valid
X4.3	.767**	0.000	valid
X4.4	.406**	0.000	valid
X4.5	.689**	0.000	valid
X4.6	.679**	0.000	valid

Table 5. Data Reliability

Variables	Cronbach's Alpha	N of Items	CR Benchmark	Conclusion
Owner	0.735	8	0.6	reliable
Consultant	0.818	9	0.6	reliable
Contractor	0.786	3	0.6	reliable
External	0. 686	6	0.6	Reliable

Data Distribution Analysis

To assess the normality of data distribution in this research, a normality test was conducted using the P-P Plot and Kolmogorov-Smirnov test for each model. The normality assessment entailed checking if residuals clustered around the y=x line (450) on the P-P Plot and examining the significance (probability) value from the Kolmogorov-Smirnov test. The null hypothesis assumed that the data followed a normal distribution, while the alternative hypothesis suggested otherwise.

$H_0 : \varepsilon_i \sim N(0; \sigma^2)$ or ε_i shows normal distribution

$H_0 : \varepsilon_i \sim N(0; \sigma^2)$ or ε_i shows abnormal distribution

Decision Making Criteria: H_0 is rejected if if $P_{value} \leq \alpha$

The results of the normality test on the questionnaire data in this research, illustrated in Figure 8's P-P Plot of residuals with a reference line y = x (450), indicate that the data is observed to follow a normal distribution.

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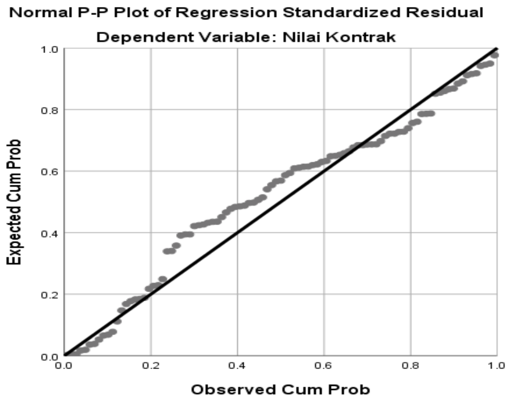

Figure 8. P – P Plot of the Data

Table 6. One – Sample Kolmogorov – Smirnov Test Data

		Unstandardized Residual
N		95
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.89845350
Test Statistic		.125
Asymp. Sig. (2-tailed)		.001[c]
Monte Carlo Sig. (2tailed)	Sig.	.094[d]

a. *Test distribution is Normal*.

A well-constructed regression model should not display heteroskedasticity. As depicted in Figure 9, the scatterplot of residuals reveals a random pattern without noticeable clustering around a specific point. The Glejser test results in Table 7 indicate that none of the independent variables significantly affect their absolute residuals, as evident from the significance values (sig) being greater than 0.05. Consequently, it is concluded that there is no heteroskedasticity in the research data.

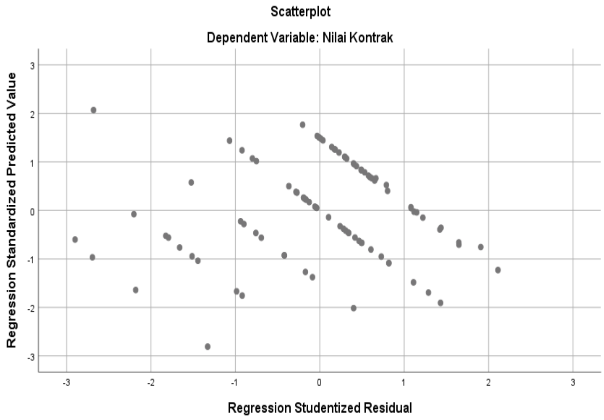

Figure 9. Scatterplot from the Heteroscedasticity Test

Table 7. Glejzer Test

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Owner	.019	.014	.615	1.295	.199
	Consultant	-.015	.013	-.560	-1.094	.277
	Contractor	.026	.028	.340	.922	.359
	External	.012	.016	.323	.753	.453

a. Dependent Variable:

The results of the multicollinearity test reveal that all Variance Inflation Factor (VIF) values for independent variables are below 10. and the tolerance values for variables are greater than 0.1. These findings, presented in Table 8, suggest the absence of multicollinearity in the model.

Table 8. Multicollinearity Test

Model	**Collinearity Statistics**	
	Tolerance	**VIF**
Owner	.570	1.756
Consultant	.499	2.005
Contractor	.816	1.225
External	.694	1.440

Based on the results of the coefficient of determination test, as presented in Table 9, the Adjusted R Square value is determined to be 0.328. This indicates that the independent variables (owner, contractor, and external factors) collectively influence the dependent variable (contract value) by approximately 33.5%. The remaining 66.5% of the variability in the dependent variable is influenced by other variables not included in the model.

Table 9. Coefficient of Determination Test

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.597[a]	.356	.335	.91369	1.682

a. Predictors: (Constant), External, Contractor, Owner
b. Dependent Variable: Cost Overruns

Table 10 describes the results of the F-test, with a significance value of 0.000 < 0.05, indicating that the model is fit and each independent variable has a linear relationship with the dependent variable.

Table 10. F Test

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	42.031	3	14.010	16.782	.000[b]
	Residual	75.969	91	.835		
	Total	118.000	94			

a. *Dependent Variable*: Cost Overruns
b. *Predictors: (Constant)*, External, Contractor, Owner

The results of the Partial Test (T-test) in Table 11 yield the linear regression equation as follows: Cost Overruns = -0.330 + 0.040 x Owner + 0.140 x Contractor + 0.067 x External.

From this regression equation, it is determined that the Contractor variable has the most significant influence on Cost Overruns, with a coefficient of 0.14.

Table 11. T Test

Coefficients[a]							
Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig. 2 tail**	**Sig. 1 tail**
		B	**Std. Error**	**Beta**			
1	(Constant)	-.330	.622		-.531	.597	0.298
	Owner	.040	.018	.208	2.229	.028	0.014
	Contractor	.140	.043	.305	3.290	.001	0.000
	External	.067	.023	.271	2.868	.005	0.002

a. *Dependent Variable*: Cost Overruns

CONCLUSION

The research identified 26 indicators contributing to the occurrence of variation orders in main dam projects, categorized into 8 indicators from owners, 9 from consultants, 3 from contractors, and 6 from external sources. All 26 indicators have a mean greater than 3 on a 5-point scale. Notably, 4 indicators, namely the alignment of tender drawings and on-site conditions, natural changes (weather/geology), changes in work items, and the complexity of main dam design, have means greater than 4. Respondents strongly agree that these indicators significantly contribute to variation orders in main dam projects in Indonesia. The multivariate analysis resulted in a multiple linear regression equation as follows: Cost overruns = - 0.330 + 0.040 x owner + 0.140 x contractor + 0.067 x external. From the equation, the contractor factor with a coefficient of 0.14 has the most substantial impact on cost overrun, followed by the external factor with 0.067 and the owner variable with 0.040. This suggests that variation orders initiated by contractors have the most significant impact. Therefore, it is crucial to control variation orders proposed by contractors, as changes due to design directly lead to contractors proposing changes based on method changes or material changes, resulting in changes in unit prices and subsequently impacting construction costs.

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