Analysis of the Relationship Between WBS, SOP, BIM, LS, and IS for Dam Maintenance

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Abstract

Dams are critical national infrastructure assets that the Indonesian government has developed extensively over the past decade to improve water security and mitigate the impacts of drought and extreme weather events. This large-scale development has created increasing demands for effective and sustainable dam maintenance. At present, dam maintenance activities have not been systematically implemented using a Work Breakdown Structure (WBS)-based approach. Ideally, maintenance performance should be optimized by first identifying the complete scope of maintenance components and then developing maintenance guidelines and Standard Operating Procedures (SOPs) for each identified component. These WBS-based maintenance procedures and guidelines can subsequently be integrated into a maintenance management model using Building Information Modeling (BIM). To support real-time monitoring and inspection, laser scanning (LS) technology can be integrated with BIM and information systems (IS). This study forms part of the development of an electronic dam maintenance (e-maintenance) system by examining the relationships among the key components of the proposed framework, namely WBS, Standard Operating Procedures (SOPs), BIM, laser scanning (LS), and information systems (IS), and their influence on improving dam maintenance performance. Multiple regression analysis, followed by expert validation, was employed to evaluate the significance of these variables in the proposed dam maintenance system. The results indicate strong relationships among the variables, with correlation coefficients ranging from 0.714 to 0.822. Among the variables, WBS exhibited the strongest influence on dam maintenance performance, with the highest standardized regression coefficient (b = 0.237), whereas the remaining variables produced coefficients ranging from 0.048 to 0.173.

INTRODUCTION

In recent years, the Indonesian Government has constructed numerous dams to improve water security, mitigate the impacts of drought and extreme weather events, and meet increasing water demands. As critical national infrastructure assets, dams require effective long-term operation and maintenance (O&M). According to data from the Ministry of Public Works and Public Housing (Kementerian Pekerjaan Umum dan Perumahan Rakyat [PUPR]), more than 50 new dams were constructed between 2015 and 2024 across Indonesia. This expansion has substantially increased the need for systematic and sustainable dam maintenance. Lessons learned from several dam failures in Indonesia indicate that failures are caused not only by natural hazards but also by deteriorating structural conditions, internal defects such as cracking and seepage, malfunctioning supporting infrastructure, sedimentation, and inadequate maintenance management (Rosytha & Suryana, 2023). The inability to perform routine maintenance and timely repairs threatens not only dam functionality but also the economic and social well-being of communities that depend on this critical infrastructure (Rocque Jr., 2001).

Within the context of operation and maintenance (O&M), maintenance performance can be improved by clearly identifying the complete scope of work and its individual components. A Work Breakdown Structure (WBS) provides a hierarchical, deliverable-oriented framework for defining maintenance activities and organizing work into manageable components (Swarabramesta et al., 2025). According to (Elsye et al., 2018), a WBS is a structured project management tool that decomposes a project into smaller elements, enabling more effective control of scope, schedule, and cost. A WBS also clarifies project deliverables and the activities required to achieve them (Burghate, 2018). Although WBS has been widely applied during the planning and construction phases of dam projects, its application to dam maintenance remains limited.

Based on the work packages defined in the WBS, implementation guidelines and Standard Operating Procedures (SOPs) can be developed. SOPs provide standardized written procedures for performing routine maintenance activities consistently and effectively (Faisal & Alwi, 2017). Developing WBS-based SOPs for dam maintenance is essential for ensuring standardized work processes, consistent quality, and improved maintenance outcomes. Currently, most dams in Indonesia have maintenance SOPs established by the Balai Besar Wilayah Sungai (BBWS), a technical implementing agency under PUPR. These SOPs generally cover organizational responsibilities, maintenance planning, inspection and maintenance procedures, and reporting requirements. However, existing SOPs have not yet been systematically developed based on detailed WBS work packages.

Information technology also plays a critical role in improving dam maintenance performance. One of the most widely adopted technologies is Building Information Modeling (BIM), which provides an integrated digital platform for planning, managing, and exchanging information throughout the project life cycle (Wangchuk et al., 2024). BIM supports information management from planning and design through operation and eventual decommissioning, enabling more efficient collection, storage, and retrieval of project information (Li et al., 2022). In addition to geometric representations, BIM stores semantic information, including material properties, functional attributes, construction details, maintenance records, and scheduling information. Consequently, BIM has become increasingly valuable not only during design and construction but also during facility operation and maintenance (Zhou et al., 2023).

Furthermore, integrating laser scanning (LS) technology with BIM can enhance dam inspection by improving the identification of structural defects and accelerating field monitoring, thereby supporting more effective maintenance management.

This study examined the relationships among the variables that form the proposed dam maintenance system. The dependent variable (Y) was dam maintenance performance, whereas the independent variables (X) consisted of Work Breakdown Structure (WBS; X1), Standard Operating Procedures (SOPs; X2), Building Information Modeling (BIM; X3), laser scanning (LS; X4), and information systems (IS; X5). These variables were analyzed to evaluate both their interrelationships and their influence on dam maintenance performance.

Based on the literature review, a conceptual framework was developed (Figure 1) to illustrate the proposed e-maintenance system for dams. The framework suggests that improvements in dam maintenance performance depend on the integration of WBS-based SOPs, BIM, LS, and IS within a comprehensive maintenance management system. Detailed maintenance activities defined through the WBS, standardized through SOPs, and integrated with BIM and LS provide accurate and reliable information that supports an effective information system and improves maintenance efficiency and decision-making.

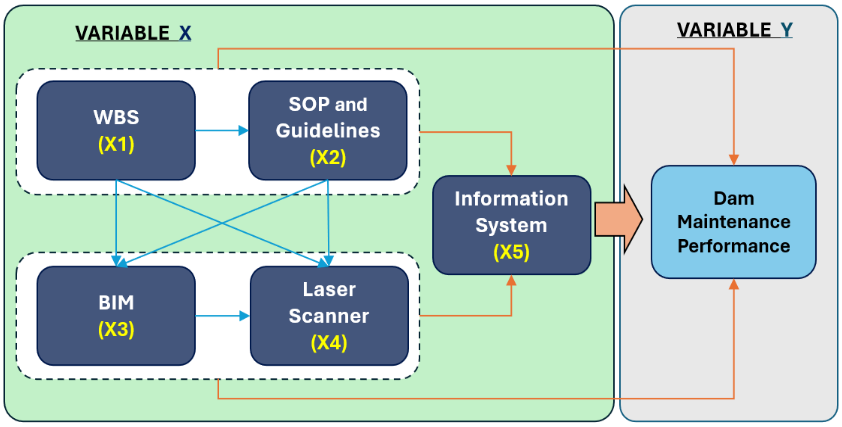

Figure 1. The conceptual framework of E-maintenance System for Dam

Following the development of the conceptual framework, hypotheses describing the relationships among the variables were formulated (Figure 2). The proposed relationships were derived from previous studies examining project management, digital construction technologies, information systems, and infrastructure maintenance.

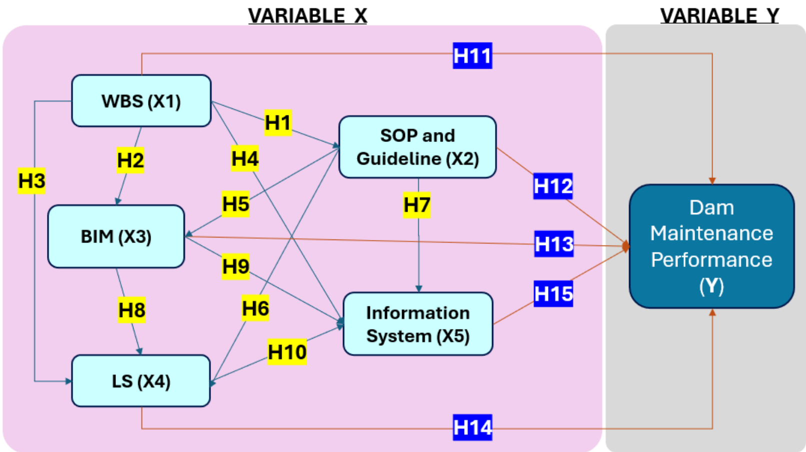

Figure 2. Relationship and Hypotheses (H) of variables

The relationships involving WBS were developed based on evidence that WBS provides the structural foundation for maintenance procedures and information management. WBS supports the development of SOPs by defining detailed maintenance activities (Faisal & Alwi, 2017; Riantini et al., 2020; Widharani et al., 2024), facilitates BIM implementation by linking maintenance tasks with digital building objects (Lee et al., 2018; Riantini et al., 2020), supports LS applications through structured component identification (Tang et al., 2010; Wang & Cho, 2015), contributes to IS by providing organized maintenance data (Anwar et al., 2024;

Riantini et al., 2020), and improves dam maintenance performance through systematic maintenance planning (Pradika et al., 2020).

The relationships involving SOPs indicate that standardized maintenance procedures support BIM implementation (Chen et al., 2020; Rakyat, 2018), facilitate the effective application of LS technologies (Wang & Cho, 2015), improve the quality of information managed within IS (Riantini et al., 2020), and contribute directly to improved dam maintenance performance through standardized maintenance practices (Riantini et al., 2020).

The relationships involving BIM indicate that BIM integrated with LS enhances structural condition assessment and defect detection. (Aziz et al., 2016; Bilqis & Latief, 2023), functions as a central information repository supporting IS (Heleno, 2021), and improves dam maintenance performance by enabling more effective maintenance planning and management. The relationships involving LS indicate that LS supports IS through accurate spatial data acquisition and processing and improves dam maintenance performance by enabling more precise and efficient structural inspections.

Finally, the relationship between IS and dam maintenance performance indicates that accurate and integrated information systems support more effective maintenance planning, monitoring, and decision-making, thereby improving overall maintenance performance (Riantini et al., 2020).

The novelty of this research lies in the development of an integrated quantitative model that simultaneously examines the relationships among WBS, SOPs, BIM, LS, and IS and evaluates their influence on dam maintenance performance. Unlike previous studies that investigated individual technologies or limited combinations of variables, this study employed multiple regression analysis validated by expert judgment to quantify the relative contribution of each variable. The proposed model provides empirical evidence of the interrelationships among these variables and offers a comprehensive framework for developing integrated dam maintenance systems.

The dependent variable examined in this study was dam maintenance performance. Based on the literature review, the proposed framework introduces a refined and integrated e-maintenance information system for dam maintenance in Indonesia by combining WBS, SOPs, BIM, LS, and IS into a unified maintenance management approach. This integrated framework has the potential to improve the effectiveness and efficiency of dam maintenance and provides a practical model for broader implementation in dam infrastructure management throughout Indonesia.

METHOD

This study employed a mixed-methods approach that combined qualitative and quantitative methods (Creswell & Creswell, 2018). The qualitative component included archival analysis and survey strategies (adapted from Yin (2003), as presented in Table 1) to obtain preliminary insights, while the quantitative component was used to analyze survey data. This approach provided a more comprehensive understanding of the relationships among the study variables.

Table 1. Relevant Situations for Different Research Strategies

Strategy	Form of Research Questions	Requires Control of Behavioral Events?	Focuses on Contemporary Events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many/much	No	Yes
Archival Analysis	Who, what, where, how many/much	No	Yes/No
History	How, why	No	No
Case Study	How, why	No	Yes

Source: COSMOS, cited in Yin (2003)

The initial phase of the research involved reviewing technical documents, applicable regulations, scientific publications, and relevant case studies, together with consultations with practitioners involved in dam operation and maintenance. The findings from the literature review were used to develop the survey questionnaire.

The questionnaire was designed to examine the relationships among the study variables and was administered to approximately 70–100 respondents. Participants evaluated the influence of each variable (X1–X5 and Y) using a five-point Likert scale. The validity of the measurement instrument was assessed using IBM SPSS Statistics through item-total correlation analysis to ensure the validity of the questionnaire items.

The validated questionnaire was subsequently assessed for reliability using Cronbach's alpha. After the reliability of the measurement instrument was confirmed, intercorrelation analysis was performed using Spearman's rank correlation coefficient to examine the relationships among the study variables. Multiple linear regression analysis was then conducted to evaluate the influence of the independent variables on the dependent variable and to develop the proposed regression model.

RESULTS AND DISCUSSION

From the questions that have been compiled in the questionnaire, which were then answered by 73 respondents using the Likert scale (Yin, 2018), can be seen in table 2 below. The validity test was then conducted, which confirmed that all questions in the questionnaire were valid (table 3), where all r-value > 0,2303 (r-table). Validity testing is conducted to assess the validity of each factor identified in the questionnaire. An instrument is considered valid if the questions it constructs are able to measure aspects that align with the questionnaire's objectives.

Table 2. Questionnaire filling excerpt

Respondent	X1	X2	X3	X4	X5	Y
R1	5	5	5	5	2	4
R2	2	2	3	3	3	4
R3	4	4	3	3	3	4
R4	5	4	5	5	4	5
R5	4	4	4	4	4	4
	…	…	…	…	…	…
R73	4	4	4	3	4	5

**Shortened from 73 respondents*

Table 3. Validity test results

Variables	Statistic	X1	X2	X3	X4	X5	Y	Status
X1	Pearson Correlation	1	.277*	.273*	.381**	.353**	.707**	**VALID**
	Sig. (2-tailed)	–	.014	.014	.001	.002	.000	
	N	73	73	73	73	73	73	
X2	Pearson Correlation	.277*	1	.301**	.284*	.276*	.704**	**VALID**
	Sig. (2-tailed)	.014	–	.007	.012	.018	.000	
	N	73	73	73	73	73	73	
X3	Pearson Correlation	.273*	.301**	1	.185	.195	.638**	**VALID**
	Sig. (2-tailed)	.014	.007	–	.104	.097	.000	
	N	73	73	73	73	73	73	
X4	Pearson Correlation	.381**	.284*	.185	1	.273*	.694**	**VALID**
	Sig. (2-tailed)	.001	.012	.104	–	.013	.000	
	N	73	73	73	73	73	73	
X5	Pearson Correlation	.353**	.276*	.195	.273*	1	.662**	**VALID**
	Sig. (2-tailed)	.002	.018	.097	.013	–	.000	
	N	73	73	73	73	73	73	
Y	Pearson Correlation	.707**	.704**	.638**	.694**	.662**	1	**VALID**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	–	
	N	73	73	73	73	73	73	

Notes:
Correlation is significant at the 0.05 level (2-tailed).
Correlation is significant at the 0.01 level (2-tailed).

Next, a reliability test was conducted for each variable using Cronbach's Alpha. Reliability testing aims to assess the consistency and stability of measurement results when the instrument is reused as a measurement tool for respondents. The results of a reliability test indicate the extent to which a research instrument is reliable, based on its accuracy and precision in producing valid measurement data. The reliability test results are shown in table 4 below. From these results, it can be said that all instruments are reliable.

Table 4. Reliability test results

Variabel	N of Items	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	Reliability Level	Internal Consistency
X1	12	0,8652	0,8671	**Very Reliable**	**Good**
X2	18	0,7251	0,7289	**Reliable**	Acceptable
X3	9	0,9124	0,9156	**Very Reliable**	**Excellent**
X4	7	0,8114	0,8206	**Very Reliable**	Good
X5	5	0,9347	0,9362	**Very Reliable**	**Excellent**
Y	4	0,6091	0,6102	**Reliable**	Questionable

After being declared reliable, a correlation test was conducted. Correlation test aims to assess the extent to which independent variables relate to dependent variables. In this study, the *Spearman* correlation method was used because the data analyzed was ordinal and to more accurately measure the relationship between variables. Table 5 below shows the correlation test results for all variables.

Table 5. Correlations test results

Variables	X1	X2	X3	X4	X5	Y
X1	1	.811**	.877**	.767**	.805**	.822**
X2	.811**	1	.724**	.826**	.801**	.806**
X3	.877**	.724**	1	.724**	.724**	.778**
X4	.767**	.826**	.724**	1	.805**	.729**
X5	.805**	.801**	.724**	.805**	1	.714**
Y	.822**	.806**	.778**	.729**	.714**	1

Notes:
Correlation Method: Spearman's rho
Sample Size (N): 73
Significance (2-tailed): p = 0.000 for all variable pairs.
*** Correlation is significant at the 0.01 level (2-tailed).*

The results of the *Spearman* external correlation test concluded that all X variables have good external validity against the Y variable (Dam Maintenance Performance). This is proven by the correlation value of each X variable to Y which is quite high in the range between 0.714 to 0.822 with a significance value of 0.000 (<0.05).

In the final stage of testing, regression testing (*Coefficients*[a]) is conducted to construct a model of the relationship between one dependent variable and one or more independent variables. The regression equation used in this analysis is formulated as follows:

$$Y = a + b_1 X_1 + b_2 X_2 + \ ..... + b_n X_n + e$$

where:

- Y = Dependent variable
- a = Constanta (intercept)
- X_n = Independent variables
- $b_n X_n$ = Regression coefficient for independent variables
- e = Error or *residue*.

The regression analysis (*Coefficients*[a]) results can be seen in table 6, where produce a regression equation as follows:

$$\boldsymbol{Y} = 3.480 + 0.237\,\boldsymbol{X1} + 0.173\,\boldsymbol{X2} + 0.109\,\boldsymbol{X3} + 0.082\,\boldsymbol{X4} + 0.048\,\boldsymbol{X5}$$

Table 6. Regression testing (*Coefficients*[a]) results

Model	Variabel	Unstandardized Coefficients (B)	Std. Error	Standardized Coefficients (Beta)	T	Sig.
1	(Constant)	3.480	3.413	–	1.392	0.196
1	X1	0.237	0.083	0.460	2.871	0.005
1	X2	0.173	0.085	0.316	2.066	0.108
1	X3	0.109	0.086	0.172	1.261	0.211
1	X4	0.082	0.045	0.224	1.831	0.071
1	X5	0.048	0.089	0.108	0.536	0.596

The results of the regression analysis show that the R value is 0.876, which indicates a fairly strong positive correlation between the independent variable and the dependent variable. Based on the results of the determination coefficient (R^2) test, the Adjusted *R-Square* result is

0.631 (table 7), which means that 63.1% of the distribution of the dependent variable can be explained by the independent variable. The remaining 36.9% cannot be explained by the independent variable or can be explained by variables outside the independent variable (error component). Therefore, it can be concluded that the Adjusted R-Square above 0.5 meets the requirements. The Standard Error of the Estimate (SEE) of 0.670 indicates the level of deviation or error between the value predicted by the model and the actual observed value.

Table 7. Regression model summary results

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.876[a]	0.631	0.523	0.670

a. Predictors: *(Constant), X5, X4, X3, X2, X1.*

After conducting the regression analysis, the results (final equation) and its explanation will then be validated by three experts on the field of dam maintenance management, with more than 10 years of experience and a minimum of master's education. This validation process is carried out to ensure that the resulting model is not only statistically significant but also has practical value and is acceptable within the conceptual framework. The validation indicates that according to the experts, all inter-variable relationship hypotheses are significant, showing the contribution of each X variable to Y variable, and strengthening the statement is in accordance with the literature review. The following table 8 shows the validity statements and responses from the experts.

Table 8. Expert validation and responses

Expert	Validity statement	Responses
E1	*Significant and Valid*	The explanations regarding the intercept and coefficients are quite comprehensive. The description of the relationship between the independent variables (WBS, SOP, BIM, LS, and SI) and Dam Maintenance Performance provides a fairly in-depth understanding of the contribution of each variable.
E2	*Significant and Valid*	From the equation (regression results) it is known that each independent variable (X) still has a positive contribution to the dependent variable Y even though the magnitude of the influence varies.
E3	*Significant and Valid*	This analysis can serve as a basis for further decision-making regarding dam maintenance. The use of technologies such as BIM and laser scanners requires further discussion and validation.

Based on the analysis and results that have been processed and validated by experts, it is found that experts agree with the initial insights generated from literature study and archives analysis. The hypotheses have also been proven by the scores of the relationship between variables from the results of the tests carried out (figure 3).

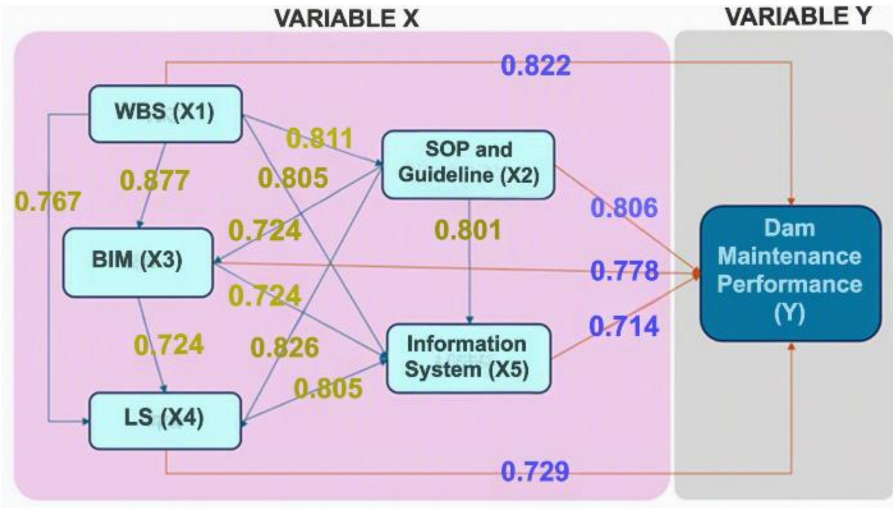

Figure 3. Relationship score between variables

From the results of the correlation test, it has been proven that all X variables not only have good internal validity between X variables, but also have good external validity against Y variable (Dam Maintenance Performance), where the hypothesis of the relationship between variables is strengthened by the relationship score resulting from the correlation test (figure 3), with following description:

The relationship between WBS (X1) with SOP (X2), BIM (X3), and SI (X5) has score range between 0.805 to 0.877 which indicates a very strong relationship (> 0.800), while relationship between WBS (X1) with LS (X4) has score 0.724 (strong relationship). WBS also has a very strong relationship with the Y (Dam Maintenance Performance) with score 0.822.

The relationship between SOP (X2) with LS (X4) and SI (X5) has score range between 0.801 to 0.826 which indicates a very strong relationship (> 0.800), while relationship between SOP (X2) with BIM (X3) has score 0.724, just indicates a strong relationship. Relationship between the SOP and Y score is 0.806 stated that SOP has a very strong relationship with the Dam Maintenance Performance.

The relationship between BIM (X3) with LS (X4) and SI (X5) has a same score 0.724 which indicates a strong relationship (0.600 - 0.800), almost the same as the relationship score between BIM and Y (Dam Maintenance Performance) which is 0.778.

The relationship between LS (X4) with SI (X5) has score 0.805 which indicates a very strong relationship (> 0.800), while relationship between LS with Y has score only 0.729 (strong relationship).

The relationship between SI (X5) with the Dam Maintenance Performance (Variable Y) has score 0.714 which indicates a strong relationship.

Of all the X variables, only WBS (X1) and SOP (X2) have stronger relationship with dam maintenance performance (Y), this is based on the fact that implementing procedures and guidelines through the development of rules and guidelines can accommodate all the details of dam maintenance activities. The BIM (X3), LS (X4), and IS (X5) relationship with the Y are not stronger than X1 and X2, but still have strong influences on optimizing dam maintenance performance. The relationship between the independent variables X shows significant relationships, especially between X1 and X3 (WBS and BIM), with a value reaching 0.877. It can be said that WBS and BIM support each other significantly.

As a final result, the regression model in this study produced the following equation:

$$\boldsymbol{Y} = 3.480 + 0.237\,\boldsymbol{X1} + 0.173\,\boldsymbol{X2} + 0.109\,\boldsymbol{X3} + 0.082\,\boldsymbol{X4} + 0.048\,\boldsymbol{X5}$$

where:

- Y is Dam Maintenance Performance
- X1 is Work Breakdown Structure (WBS)
- X2 is Standard Operating Procedure (SOP)
- X3 is Building Information Modeling (BIM)
- X4 is Laser Scanner (LS), and
- X5 is Information System (IS).

The explanation of the model equation is as follows:

Constant (a); the constant or intercept value of 3.480 indicates that if the values of the independent variables X1 to X5 are equal to '0' (zero), then the value of variable Y will be 3.480. This means that when there is no influence from any variable X, variable Y has an initial value of 3.480. In the context of this research, without the implementation of WBS, SOP, BIM, Laser Scanner, and Information System, Dam Maintenance Performance (Y) is estimated to have a value of 3.480 (*on the scale used by the model*).

The X1 coefficient has a value of 0.237. This indicates that every 1-unit increase in variable X1 will increase the dependent variable Y by 0.237 (*scale model*), assuming the other independent variables are held constant. A positive sign indicates a directional influence between the independent and dependent variables.

The X2 coefficient, with a value of 0.173, indicates that every 1-unit increase in variable X2 will increase the dependent variable Y by 0.173, assuming the other independent variables are held constant. A positive sign indicates a directional influence between the independent and dependent variables.

The X3 coefficient has a value of 0.109. This indicates that every 1-unit increase in variable X3 will increase the dependent variable Y by 0.109 units, assuming the other independent variables are held constant. A positive sign indicates a directional influence between the independent and dependent variables.

The X4 coefficient, with a value of 0.082, indicates that every 1-unit increase in variable X4 will increase the dependent variable Y by 0.082, assuming the other independent variables are held constant. A positive sign indicates a directional influence between the independent and dependent variables.

The X5 coefficient, with a value of 0.048, indicates that every 1-unit increase in variable X5 will increase the dependent variable Y by 0.048 units, assuming the other independent variables are held constant. A positive sign indicates a directional influence between the independent and dependent variables. Although its coefficient is the smallest compared to the others (SOP, BIM, and LS), Information Systems (IS) still contribute positively to maintenance performance.

Based on the regression analysis results (*coefficient*[a]) and explanation above, it is known that of the five independent variables tested, only X1 (WBS) has the most significant influence on the dependent variable (Y), with a regression coefficient of 0.237 and a significance level of 0.005 (<0.05). This indicates that X1 (WBS) is the primary factor contributing positively to explaining the dependent variable compared to other X variables. Variables X2, X3, X4, and

X5 do not have a significant influence on the dependent variable Y, with significance levels ranging from 0.071 to 0.596 (all above 0.05). These results also indicate that variable X5 (Information Systems) has the smallest influence, with a coefficient of 0.048 and a significance level of 0.596, but still contribute positively to maintenance performance.

In the validation stage, experts provided input regarding the intercept values and coefficients of the independent variables (X1 to X5) that reflect the level of influence of each variable on Dam Maintenance Performance (variable Y). This evaluation included an assessment of the suitability of the regression model to actual conditions in the field to ensure that the analysis results can be practically applied and have a real impact on improving dam maintenance performance.

CONCLUSION

This study forms part of the development of an e-maintenance system for dams, in which the key components of the proposed dam maintenance framework—Work Breakdown Structure (WBS), Standard Operating Procedures (SOPs), Building Information Modeling (BIM), laser scanning (LS), and information systems (IS)—were analyzed to examine their interrelationships and their influence on dam maintenance performance. The study identified the significance of these variables in establishing an integrated dam maintenance system and evaluated their contributions to maintenance performance. The results indicate strong relationships among the variables, with correlation coefficients ranging from 0.714 to 0.822. Among the variables, WBS exhibited the strongest influence, with the highest regression coefficient (0.237), whereas the remaining variables produced coefficients ranging from 0.048 to 0.173 in explaining dam maintenance performance. These findings provide a foundation for future decision-making related to dam maintenance management.

The strong relationship between WBS and BIM demonstrates that dam maintenance systems can be developed in a more structured and integrated manner, with BIM serving as an effective platform for improving the efficiency, accuracy, and sustainability of maintenance management. The proposed WBS provides a robust foundation for systematic maintenance implementation, while the validation results indicate that most maintenance components can be effectively integrated into a digital BIM environment. Nevertheless, further BIM development should focus on improving the representation of maintenance elements that are not yet fully accommodated within the current model and on ensuring alignment between digital technologies and operational requirements in the field. The application of BIM and laser scanning technologies also requires further evaluation and validation under practical operating conditions.

Based on expert feedback, this study recommends several directions for future research, including strengthening the integration of BIM, LS, and IS; developing real-time monitoring capabilities for critical dam components with higher data accuracy; and expanding the scope and diversity of maintenance data. These improvements are expected to enhance the proposed e-maintenance information system, making it more comprehensive, reliable, and effective in supporting dam maintenance management.

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