JRSSEM 2025, Vol. 04, No. 11, September
E-ISSN: 2807 - 6311, P-ISSN: 2807 - 6494

Analysis of Delay Factors in EPC Power Plant Projects (Case Study: PLTMG Project in Sumbawa)

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Abstract.
Construction projects often face the risk of delays, which can affect cost, quality, and schedule performance. This research aims to analyze the factors causing delays in the Engineering, Procurement, and Construction (EPC) Gas Engine Power Plant (*PLTMG*) project in Sumbawa and to formulate improvement recommendations. The research employs the Partial Least Squares – Structural Equation Modeling (PLS-SEM) method with 67 respondents consisting of the project owner, contractor, and supervision consultant. The research variables include design, financial, resources, contractor, material, external, and owner as independent variables and time overrun as the dependent variable. The results show that the external factor has a positive and significant influence on project delays ($\beta = 0.534$; $p = 0.000$), which includes regulatory changes, extreme weather, permit delays, and socio-cultural influences. The owner factor shows a nearly significant effect ($p = 0.092$), while design, financial, contractor, material, and resource factors have no significant impact. The research model demonstrates good predictive capability ($R^2 = 0.696$; $Q^2 = 0.516$). Improvement recommendations focus on mitigating external factors, including establishing a legal team to monitor regulations, developing a flexible work schedule adapted to weather conditions, expediting permits through a dedicated liaison officer, and enhancing communication with the local community. These findings are expected to serve as a reference for stakeholders in managing delay risks in similar construction projects.

Keywords: project delay, EPC, PLTMG, PLS-SEM, external factors.

INTRODUCTION

The construction sector plays an important role in infrastructure development that supports a country's economic growth (Maciulyte-Sniukiene & Butkus, 2022). One of the important sectors is the development of Engineering, Procurement, and Construction (EPC) projects, which involve the integration of planning, procurement, and construction implementation as a whole (Ahmad et al., 2023). EPC projects have complex characteristics, especially because they involve a wide range of disciplines, a large number of stakeholders, and complex supply chain management. In this context, the success of the project is greatly influenced by the control of time, cost, and quality (Fertilia et al., 2018).

EPC projects often face significant challenges, especially in terms of implementation time. Project complexity, inter-activity dependence, and the large number of parties involved often cause delays. Factors such as uncertainty in design, changes in material prices, and inaccuracies in time and budget planning are some of the common causes of EPC project delays. Additionally, the challenges of risk management and strict cost controls often complicate the execution of this type of project.

One of the main challenges in EPC projects is the delay in project completion. This delay not only has an impact on increasing costs and loss of revenue for the contractor, but can also interfere with the operations of the project owner and the interests of the wider community. This happens in various sectors, one of which is strategic infrastructure projects such as the Gas Engine Power Plant (*PLTMG*). In Indonesia, *PLTMG* plays an important role in supporting the fulfillment of energy needs, especially in remote areas such as Sumbawa, which still face limited access to electricity.

Previous research on project delays in the construction sector has identified various contributing factors. For example, Assaf & Al-Hejji (2006) conducted a study on large construction projects and found that delays are often caused by factors such as slow decision-making, changes in design, and poor contract management. Similarly, Chan & Kumaraswamy (1997) highlighted that delays in Hong Kong construction projects were primarily due to resource shortages and ineffective project planning. In the context of EPC projects, Fertilia et al. (2018) emphasized the importance of integrated planning based on PMBOK guidelines to improve time performance. More recently, Maktoumi et al. (2020) used PLS-SEM to identify critical delay factors in Oman's construction sector, noting that external factors such as regulatory changes and weather conditions significantly impact project timelines. However, there remains a gap in studies specifically addressing EPC power plant projects in Indonesia, particularly in remote regions like Sumbawa, where unique local challenges may exacerbate delays.

The Gas Engine Power Plant (*PLTMG*) project in Sumbawa is part of the government's strategic program in supporting the fulfillment of national electrical energy needs. This *PLTMG* is designed to improve energy access, reduce the electrification gap, and support emission reduction targets through the use of cleaner and more efficient energy sources. The project has a contract duration of 15 months, starting in December 2023 and planned to be completed in March 2025. In the management of EPC-type projects, correction and monitoring steps are continuously carried out through monthly coordination meetings. The meetings aim to compare the planned progress with the monthly realization, ensuring that each step taken is in line with the goals that have been set.

In accordance with the S-curve above and the Project Progress Report (LKP), there is a significant difference between the plan that has been set and the actual realization in the field. Since the beginning of 2024, actual progress has begun to show a lagging trend compared to the cumulative plan. The deviation began to be seen more clearly in March 2024 and continued to increase until it reached its peak in October 2024, which was -44.30%. In November 2024, the achievement of actual/planned progress was 65.18%/87.66%, showing a deviation of -22.48%, and in December 2024, it was 73.21%/94.75%, with a deviation of -21.54%. This reflects the existence of significant obstacles in the implementation of work, both in terms of design (Engineering), material procurement (Procurement), and construction (Construction).

In more detail, regarding the achievement of monthly progress in accordance with the S-curve, it can be said that at the Engineering stage, progress should have been completed in March 2024, but until December 2024, the progress achieved was only 85.68%. This shows a deviation of -14.32%, which is caused by delays in the provision of technical documents, such as working drawings and specifications. This delay has a direct impact on the smooth procurement process of materials and equipment, which is highly dependent on the availability of these documents. Additionally, these deviations trigger delays in coordination between teams, such as design, procurement, and field teams, which ultimately impact the overall project schedule. With this condition, it is important to improve document management so as not to hinder subsequent processes.

At the Procurement stage, the plan to procure goods that must be achieved in December 2024 is 81.21%, but the realization achieved is only 67.76%, so there is a deviation of -13.45%. Obstacles in the procurement process can be caused by several factors, such as delays in receiving Engineering documents, difficulties in negotiating with suppliers, and logistical obstacles that result in delays in the delivery of goods. In addition, the mismatch of the specifications of the goods with the needs of the project also contributed to these delays. As such, there need to be more intensive efforts in managing relationships with suppliers and ensuring all relevant documents are available on time to support smooth procurement.

At the Construction stage, the progress plan that should be achieved in December 2024 is 13.50%, but the actual is only 5.41%, which shows a deviation of -8.09%. This indicates a potential significant delay in the completion of the overall construction stage. Some of the factors that cause this include delays in material procurement, lack of adequate labor or equipment, and technical or weather constraints. In addition, problems in planning and coordination between the implementation teams, such as delays in preliminary work, also add to the complexity of this situation. The problems that arise from these three stages reflect the real challenges faced in the *PLTMG* EPC project in Sumbawa. If left unaddressed, these issues can lead to cost overruns and the risk of project failure, which impact losses for contractors and project owners. Therefore, an in-depth evaluation of the factors causing the delay is essential to prevent the recurrence of similar problems in the future.

In an effort to improve the problem, the author will analyze the factors causing the delay of the EPC project and find the right solution for the improvement that will be carried out with a case study on the *PLTMG* project in Sumbawa and pour it into a paper entitled "Analysis of Factors Causing Delays in the EPC Project of Power Plants (Case Study: *PLTMG* Project in Sumbawa)."

Based on the background that has been described, the formulation of the problem in this study includes the identification of the main factors that cause delays in the implementation of EPC projects, especially in the EPC Project of *PLTMG* in Sumbawa, as well as recommendations for improvements that can be applied to minimize delays in future EPC projects. The purpose of this study is to identify the main factors causing EPC project delays with a case study of the *PLTMG* EPC project in Sumbawa and to develop recommendations for solutions that can be implemented to improve project management and prevent future EPC project delays. The expected benefits of this research include theoretical contributions that can enrich knowledge in the field of project management, especially in overcoming EPC project delays, as well as providing a reference for future research. On the practical side, the results of this research are expected to be used by construction companies engaged in the EPC sector as a basis for improving project management systems, especially in planning and controlling costs, quality, and time, as well as coordination between teams. In addition, this research is also expected to provide practical solutions in the form of alternative project delay solutions that can be applied to similar projects, as well as a reference for *PLTMG* EPC project owners in improving project management performance.

MATERIALS AND METHODS

Research Methods

The method used in this study is a quantitative method with the Partial Least Squares – Structural Equation Modelling (PLS-SEM) approach. PLS-SEM is considered appropriate because it can examine the relationships between complex variables and involves many variables and indicators. In addition, this method can be used in studies with a small sample size, and if the sample size is large, the accuracy will be better (Hair et al., 2017). Through the PLS-SEM approach, researchers can identify the dominant factors that contribute to delays in projects.

Several studies using the PLS-SEM method include Maktoumi et al. (2020), which identified the causes of construction project delays in Oman. Meanwhile, another study by Chandragiri (2021) revealed that labor factors and imprecise schedule planning also affect the delay in project completion.

Population and Sample

Population includes all individuals or objects that are the target of the study. According to Sugiyono (2017), population is a generalized area consisting of objects or subjects with certain characteristics and qualities that are determined by researchers to be studied and conclusions drawn. Samples are part of a population that is carefully selected to represent the entire population. Therefore, the sample used should reflect the population as a whole. In this study, the sample is key informants from Project Owners, Contractors, and *KSK* implementing *PLTMG* projects in Sumbawa.

According to Hair et al. (2017), the minimum number of samples in the PLS-SEM method can be less than 100, for both formative and reflective indicators. Generally, if possible, researchers are encouraged to obtain more observational data, especially on consumer projects. However, under certain conditions such as business studies with a small population (less than 100), PLS-SEM remains a structural approach that is able to produce meaningful solutions even with a limited sample size. The selection of respondents in this study was based on consideration of their understanding and involvement in the *PLTMG* project in Sumbawa. Respondents came from various divisions such as project managers, engineering divisions, procurement, construction, QA/QC, project management, and field supervisors.

Data Collection Techniques

In this study, data collection was carried out using questionnaires as an instrument to obtain data from the contractor. A questionnaire is a data collection method that is carried out by providing a number of questions or written statements to respondents to be answered (Sugiyono, 2017). This method is classified as efficient because it allows researchers to know exactly the variables to be measured and the information they want to obtain from the respondents. In addition, questionnaires are very suitable for use when the number of respondents is large and spread across various regions. The questions in the questionnaire can be in a closed or open-ended form and can be submitted in person, by mail, or online. In its implementation, the distribution of questionnaires was carried out personally through online media. Respondents were asked to fill out a questionnaire that contained questions in written form and was compiled using the Likert scale. The sampling technique used in this study is judgmental sampling or purposive sampling.

RESULTS AND DISCUSSION

Evaluation of the Outer model

Evaluation of the measurement model (outer model) is carried out to test the level of validity and reliability of the model. In this study, the relationship between latent variables and indicators is described through a reflective measurement model. The assessment of the reflective model includes four main aspects of each construct, namely the value and significance of the outer loading indicator, construct reliability (internal consistency reliability), Convergent Validity, and discriminant validity.

The initial step in the testing process begins with evaluating the value of the external loading indicator (Hair et al., 2017). The results of the outer loading test are as shown in Figure 1 below.

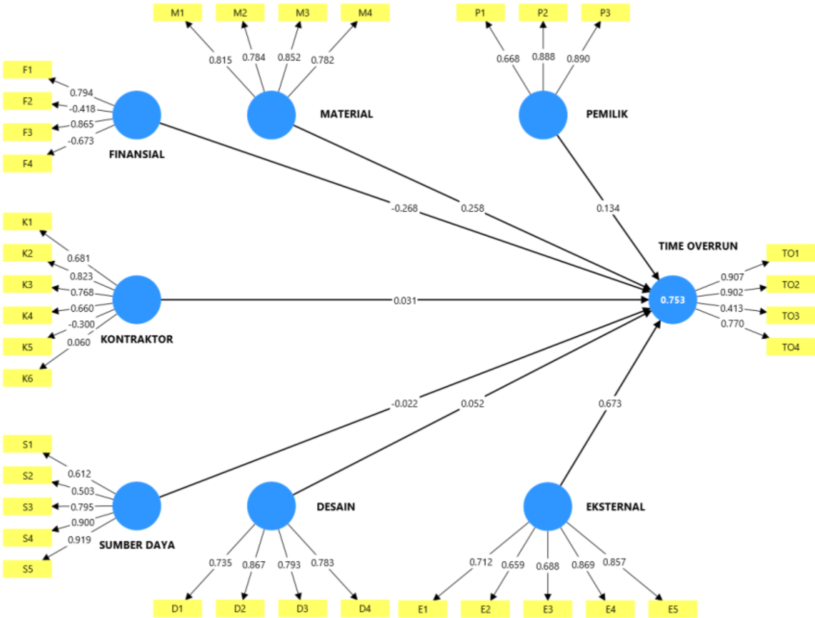

Figure 1. Results of the outer loading test

Source: Author's processed data, 2025

The initial step in the testing process begins with evaluating the value of the external loading indicator (Hair et al., 2017). The results of the outer loading test are as shown in Figure 1 below.

Based on the results of the outer loading test, the scores for each indicator were obtained as follows:

Table 1. Value of the results of the outer loading test

Variable	Code	Indicator	Value	Validity
Financial Factors	F1	The contractor experienced obstacles in the financial aspect.	0,794	Valid
	F2	Uncertainty in macroeconomic conditions.	-0,418	Invalid
	F3	Ineffective budget management.	0,865	Valid
	F4	There was a delay in the payment of the work in progress.	-0,673	Invalid
Resource Factor	S1	The availability of skilled labor is insufficient.	0,612	Invalid
	S2	The number of workers in the field is limited.	0,503	Invalid
	S3	Low labor productivity levels.	0,795	Valid

Variable	Code	Indicator	Value	Validity
	S4	The technical personnel of the contractor are inadequately qualified.	0,900	Valid
	S5	Construction work facilities and equipment are insufficient.	0,919	Valid
Factor contractor	K1	The application of construction methods is not in accordance with operational standards.	0,681	Invalid
	K2	Project planning and scheduling are carried out suboptimally.	0,823	Valid
	K3	Field supervision and project implementation management are not good.	0,768	Valid
	K4	The number of workers is insufficient to meet the needs of the project.	0,660	Invalid
	K5	Subcontractors or vendors are experiencing problems.	-0,300	Invalid
	K6	Lack of communication and coordination between the main contractor and the subcontractor.	0,060	Invalid
Material factor	M1	Delays in the process of ordering materials.	0,815	Valid
	M2	The materials available are not to specification or of low quality.	0,784	Valid
	M3	The materials received are not in accordance with the quantity or shortage.	0,852	Valid
	M4	The work had to be repeated due to errors in the construction process.	0,782	Valid
Employer Factors	P1	The government's procurement procedures are considered to be in favor of certain parties.	0,668	Invalid
	P2	The decision-making process on the part of the project owner takes a long time.	0,888	Valid
	P3	Lack of communication between the contractor and the project owner.	0,890	Valid
Design Factor	D1	Engineering design is immature or delayed.	0,735	Valid
	D2	Too often design changes occur.	0,867	Valid
	D3	There are errors or damage to the design used.	0,793	Valid
	D4	The design document is incomplete at the tender stage.	0,783	Valid
External Factors	E1	There is a change in government regulations or political interference.	0,712	Valid
	E2	Problems with unexpected soil conditions.	0,659	Invalid
	E3	The licensing process is delayed in various government agencies.	0,688	Invalid
	E4	Bad weather in the construction area hinders work.	0,869	Valid
	E5	The influence of culture and social norms in the project environment.	0,857	Valid
Project Delays *(Time Overrun)*	TO1	**Cost increases exceed budget upon project completion**	0,907	Valid
	TO2	**Disputes and claims for compensation due to delays**	0,902	Valid
	TO3	**Project delays that negatively impact image or reputation**	0,413	Invalid
	TO4	**Dispute resolution through the arbitration mechanism/Dispute Board**	0,770	Valid

Source: Author's data processing, 2025

According to Hair et al. (2017), the value of the outer loading indicator is recommended to be above 0.70. If the value is between 0.40 and 0.70, the indicator can still be considered for retention, unless its removal may increase the Composite Reliability or Average Variance

Extracted (AVE) value above the specified minimum. Referring to Figure 4.1 Results of the Outer Loading Test and Table 4.2, it is known that not all indicators meet the criteria for loading factor values, because there are still a number of indicators with values below 0.7 that must be eliminated. Indicators with loading factor values below 0.7 include: F2, F4, S1, S2, K1, K4, K5, K6, P1, E2, E3, and TO3. The next process is to remove the indicator with a loading factor value that is below 0.7 from the smallest and then retest it. This procedure is repeated until all remaining indicators have a loading factor value above 0.7. Based on the results of the re-testing with all the indicators used, it has a loading factor value above 0.7 as shown in Figure IV.2.

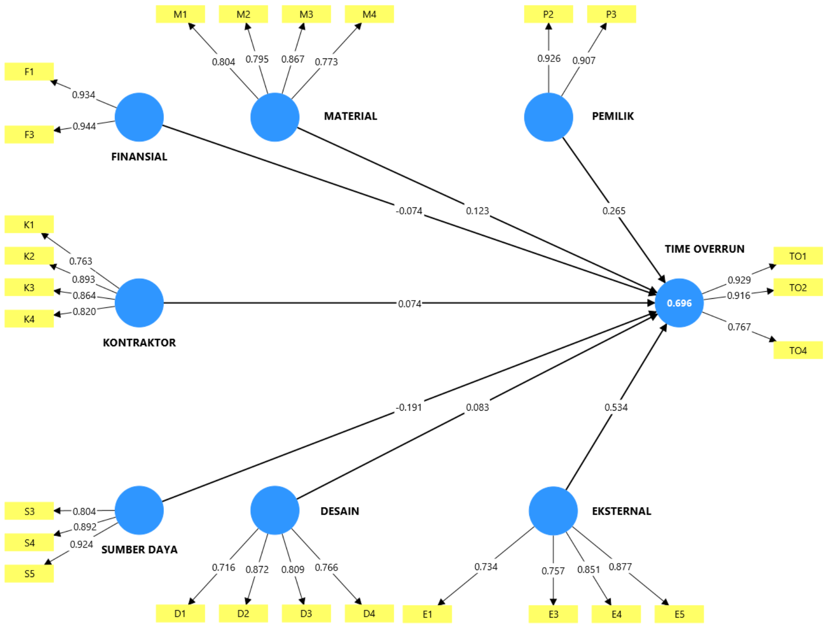

Figure 2. Final test results of outer loading

Source: Author's data processing, 2025

Based on the results of the final outer loading test, the outer loading values for each indicator were obtained as follows:

Table 2. Value of the final test results of outer loading

Variable	Code	Indicator	Value	Validity
Financial Factors	F1	The contractor experienced obstacles in the financial aspect.	0,934	Valid
	F3	Ineffective budget management.	0,944	Valid
Resource Factor	S3	Low labor productivity levels.	0,804	Valid
	S4	The technical personnel of the contractor are inadequately qualified.	0,892	Valid
	S5	Construction work facilities and equipment are insufficient.	0,924	Valid
Factor contractor	K1	The application of construction methods is not in accordance with operational standards.	0,763	Valid
	K2	Project planning and scheduling are carried out suboptimally.	0,823	Valid
	K3	Field supervision and project implementation management are not good.	0,768	Valid
	K4	The number of workers is insufficient to meet the needs of the project.	0,820	Valid

Variable	Code	Indicator	Value	Validity
Material factor	M1	Delays in the process of ordering materials.	0,804	Valid
	M2	The materials available are not to specification or of low quality.	0,794	Valid
	M3	The materials received are not in accordance with the quantity or shortage.	0,867	Valid
	M4	The work had to be repeated due to errors in the construction process.	0,773	Valid
Employer Factor	P2	The decision-making process on the part of the project owner takes a long time.	0,926	Valid
	P3	Lack of communication between the contractor and the project owner.	0,907	Valid
Design Factor	D1	Engineering design is immature or delayed.	0,716	Valid
	D2	Too often design changes occur.	0,872	Valid
	D3	There are errors or damage to the design used.	0,809	Valid
	D4	The design document is incomplete at the tender stage.	0,766	Valid
External Factors	E1	There is a change in government regulations or political interference.	0,704	Valid
	E3	The licensing process is delayed in various government agencies.	0,757	Valid
	E4	Bad weather in the construction area hinders work.	0,851	Valid
	E5	The influence of culture and social norms in the project environment.	0,877	Valid
Project Delays *(Time Overrun)*	TO1	**Cost increases exceed budget upon project completion**	0,929	Valid
	TO2	**Disputes and claims for compensation due to delays**	0,916	Valid
	TO4	**Dispute resolution through the arbitration mechanism/Dispute Board**	0,767	Valid

Source: Author's data processing, 2025

Based on table 2, the loading factor value for each indicator has a value greater than 0.7 so that it meets the requirements for further data testing.

Validity and Reliability

After the outer loading value has been in accordance with the test criteria, the next step is to conduct a validity and reliability test. In this research, the validity and reliability test is used through a reflective measurement model approach, so that the test involves several important aspects of each construction model, namely: (1) internal consistency such as Cronbach's alpha and composite reliability, (2) convergent validity which includes indicator reliability and average variance extracted, and (3) discriminant validity.

A. Internal Consistency Testing

According to Hair et al. (2017), the acceptable Composite Reliability value to measure the internal consistency of a construct is more than 0.7. In the context of exploratory research, values between 0.6 and 0.7 are still tolerable. A range of values between 0.7 to 0.95 is considered to indicate an excellent level of reliability. Cronbach's Alpha is used as the lower boundary, while Composite Reliability is used as the upper limit of internal consistency testing. The results of the evaluation of construct reliability and validity in this study are presented in the following Table 3.

Table 3. Results of the Internal Consistency Test

VARIABEL	*Cronbach's alpha*	*Composite Reliability (rho_a)*	*Composite Reliability (rho_c)*	*Average variance extracted (AVE)*
Financial	0,865	0,869	0,937	0,881
Contractor	0,861	0,889	0,903	0,700
Resources	0,847	0,867	0,907	0,765
Time Overrun	0,842	0,859	0,906	0,763
Material	0,830	0,856	0,884	0,657
External	0,823	0,851	0,881	0,651
Design	0,817	0,823	0,871	0,629
Owner	0,810	0,816	0,913	0,840

Source: Author's data processing, 2025

Table 3 presents the results of the construct reliability test which includes two main indicators, namely Cronbach's Alpha and Composite Reliability (rho_c). Based on these results, all variables in this study had a Composite Reliability value above the minimum threshold of 0.7, which indicates a good level of internal consistency. The highest Composite Reliability (rho_c) value is shown by the Financial variable of 0.937 while the lowest value is found in the Design variable of 0.871, both are still in the very reliable category.

In the Cronbach's alpha indicator, the Owner variable has the lowest value of 0.783, but this value is still above the minimum limit of 0.7 required in the study (Hair et al., 2017). In accordance with the value of the indicators that have been obtained, all constructs in this study can be declared to meet the internal consistency criteria and are suitable for further model testing.

B. Convergent Validity Testing

According to Hair (2017), Convergent Validity is an indicator used to assess the extent to which a construct correlates positively with alternative measures of the same construct. The measurement of Convergent Validity is carried out by looking at the value of Average Variance Extracted (AVE), where a construct is said to meet the convergence validity if the AVE value exceeds 0.5.

Referring to the test results in Table 4.4, all variables in this study had an AVE value above 0.5. The highest value is shown by the Financial variable of 0.881, while the lowest value is found in the Design variable which is 0.628. Even so, all AVE values remain within the recommended limits. Thus, it can be concluded that all constructs in this model have qualified for Convergent Validity and are valid for use in further analysis.

C. Discriminant Validity Testing

Discriminant Validity is a measure used to determine the extent to which a construct differs significantly from other constructs. One commonly used method to test the validity of discriminators is cross-loading. This technique aims to assess the extent to which an indicator has a higher correlation to the construct it represents compared to other constructs. In other words, the outer loading value of an indicator should be greater in the relevant construct than in the correlation value of other constructs. A commonly used way to present cross-loading results is through tables that arrange indicators in rows and latent constructs in columns. Based on this, Table 4 presents the results of the discriminant validity – cross loading test.

Table 4. Results of the discriminant validity test – cross loading

	Design	External	Financial	Contractor	Material	Owner	Resources	*Time Overrun*
D1	0,716	0,196	0,088	0,066	0,24	0,116	-0,003	0,11
D2	0,872	0,364	-0,267	-0,273	-0,176	0,517	-0,368	0,412
D3	0,809	0,266	-0,173	-0,165	-0,039	0,458	-0,319	0,51
D4	0,766	0,557	-0,308	-0,304	-0,089	0,417	-0,298	0,439
E1	0,224	0,734	-0,261	-0,034	-0,016	0,412	-0,167	0,508
E3	0,364	0,757	-0,351	-0,267	-0,131	0,308	-0,245	0,48
E4	0,442	0,851	-0,65	-0,551	-0,545	0,542	-0,563	0,736
E5	0,435	0,877	-0,424	-0,38	-0,339	0,38	-0,428	0,684
F1	-0,24	-0,479	0,934	0,684	0,811	-0,457	0,772	-0,482
F3	-0,271	-0,541	0,944	0,748	0,751	-0,588	0,785	-0,521
K1	0,026	-0,194	0,559	0,763	0,683	-0,065	0,574	-0,16
K2	-0,404	-0,37	0,675	0,893	0,707	-0,395	0,766	-0,363
K3	-0,245	-0,311	0,553	0,864	0,62	-0,27	0,68	-0,33
K4	-0,151	-0,441	0,75	0,82	0,802	-0,343	0,759	-0,341
M1	-0,086	-0,424	0,746	0,7	0,804	-0,366	0,725	-0,329
M2	-0,115	-0,158	0,613	0,775	0,795	-0,154	0,687	-0,184
M3	-0,035	-0,231	0,693	0,664	0,867	-0,304	0,684	-0,271
M4	-0,06	-0,28	0,6	0,584	0,773	-0,25	0,532	-0,223
P2	0,415	0,489	-0,634	-0,415	-0,471	0,926	-0,615	0,636
P3	0,587	0,458	-0,377	-0,228	-0,155	0,907	-0,364	0,572
S3	-0,16	-0,428	0,693	0,66	0,682	-0,336	0,804	-0,37
S4	-0,477	-0,369	0,681	0,782	0,664	-0,564	0,892	-0,502
S5	-0,305	-0,432	0,811	0,762	0,808	-0,49	0,924	-0,454
TO1	-0,364	-0,561	-0,47	-0,342	-0,505	-0,541	0,919	-0,492
TO2	0,621	0,683	-0,532	-0,437	-0,349	0,615	-0,544	0,916
TO4	0,209	0,663	-0,392	-0,182	-0,184	0,449	-0,216	0,767

Source: Author's data processing, 2025

The discriminant validity test aims to ensure that each indicator is more representative of its own construct than the other. One of the methods used is cross loadings, where the loading value of each indicator against its construct is compared to the loading value of other constructs.

Based on table 4 presented, the following can be concluded:

1) Construct Design (D1–D4)
   a. D1–D4 has the highest loading value to Design constructs compared to other constructs.
   b. Example: D2 loading to Design = 0.872 > compared to loading to External (0.364), Financial (-0.267), etc.
   c. This indicates that the D1–D4 indicator is valid in measuring Design constructs.
2) External Construct (E1–E5)
   a. All indicators E1–E5 show the highest loading against the External construct, for example: E5 to External = 0.877, higher than all other loads.
   b. This proves the validity of a good discriminator on the External construct.
3) Financial Constructs (F1, F3)
   a. The F1 and F3 indicators show high loading against the Financial construct (0.934 and 0.944) and much lower against the other constructs.
   b. The discriminatory validity of the Financial construct is met.
4) Construct Contractor (K1–K4)
   a. The four indicators have the highest value to the Contractor's construct.

b. K2 loading to the Contractor = 0.893, much higher than loading to other constructs.
c. Therefore, it can be concluded that K1–K4 is discriminatically valid in measuring the Contractor's construct.

5) Construct Materials (M1–M4)
   a. The M1–M4 indicator also shows the highest loading value against the Material construct.
   b. M3 loading to Material = 0.867, very high compared to other constructs.
   c. Thus, the Material construct has good discriminant validity.

According to Hair et al., (2017) an indicator is said to be discriminatically valid when: "The indicator's loading on its associated latent variable should be higher than all of its cross-loadings with other latent variables." Based on this criterion and from the results of the table, all indicators contain the highest loading values for their respective constructs, so that the validity of the discriminator through cross loadings has been met for all constructs.

Evaluation of the Inner model

Based on the model Outer Test that has been carried out, it can be ensured that the proposed model is valid and reliable. Next, the test stage that will be carried out is to evaluate the structural model (inner model). This test is carried out by predicting the relationship between independent variables and dependent variables.

A. Determinant Coefficient Test (R-Square)

The first step in the evaluation of the inner model is to determine the value of the coefficient of determination (R-square). This coefficient serves to measure the extent to which the independent variables used in the model are able to explain the dependent variables. In other words, R-square indicates the magnitude of the predictive contribution of the free variable to the bound variable. The results of the analysis of the determination coefficient (R-square) are shown in the following Table 5.

Table 5. Results of the determinant coefficient (R-Square) test

Variable Dependency	R-square	R-square Adjusted
Time Overrun	0,696	0,660

Source: Author's data processing, 2025

Based on Table 5, the value of the determination coefficient (R-square) for the Time Overrun variable is 0.696, which shows that 69.6% of the variation that occurs in the Time Overrun can be explained by the exogenous variables in this study, namely Design, External, Financial, Contractor, Material, Employer, and Resource. The remaining 30.4% is explained by other variables outside the model. According to Hair et al, (2017), the R-square value can be categorized into three, namely strong (≥0.75), medium (≥0.50), and weak (≥0.25). Thus, the R-square value of 0.696 is in the medium category, which indicates that the model has a good predictive rate of the Time Overrun variable.

B. Effect Size Test (f-square)

The next stage in the inner model test is to measure the effect size or f-square. This effect measure is used to find out the extent to which the change in the value of the determination coefficient (R-square) occurs when one exogenous variable is removed from the model. The f-square calculation aims to assess whether the exclusion of predictor variables in structural models has a significant impact on endogenous variables. Based on the guidelines, an f-square value of 0.02 indicates a small effect, 0.15 indicates a moderate effect, and 0.35 indicates a large effect. Meanwhile, a value below 0.02 indicates that the exogenous variable does not have a significant influence on the endogenous variable. The results of the f-square test are shown in the following Table 6.

Table 6. Effect size (f-square) test results

No.	Variable Relationships	The value of f-square	Category Effect Size
1	Design → *Time Overrun*	0,012	Has no effect
2	External → *Time Overrun*	0,536	Huge effect
3	Financial → *Time Overrun*	0,003	Has no effect
4	Contractor → *Time Overrun*	0,004	Has no effect
5	Material → *Time Overrun*	0,008	Has no effect
6	Employer → *Time Overrun*	0,108	Small effects
7	Resources → *Time Overrun*	0,020	Has no effect

Source: Author's data processing, 2025

Based on Table 6, the effect size (f-square) test results show how much influence each exogenous construct would have on the endogenous construct of Time Overrun if it had been removed from the model.

Based on this data, only the External variable has a major influence on the Time Overrun with an f-square value of 0.536. The Employer variable (0.108) showed a small influence. Meanwhile, the Design, Financial, Contractor, Materials and Resources variables have an f-square value below 0.02, so it is considered not to have a significant influence on the Time Overrun.

C. Blindfolding Test

According to Hair et al. (2017), predictive capabilities in structural models were evaluated using the cross validated redundancy method through blindfolding (Q-square) testing. A Q-square value greater than zero indicates that the model has an acceptable prediction accuracy for a given endogenous construct. A Q-square value between 0 and 0.02 reflects a low predictive relevance, a value of around 0.15 indicates moderate relevance, and a value close to 0.35 indicates a strong prediction. The results of the evaluation using the blindfolding method are shown in Table 7.

Table 7. Blindfolding Test Results

Construct	Q^2 *predict*	RMSE	IT IS
Time Overrun	0,516	0,686	0,518

Source: Author's data processing, 2025

Based on the results of the Q-square predict test on the Time Overrun construct, a value of 0.516 was obtained. Referring to the criteria of Hair et al. (2017), a Q^2 value greater than 0 indicates the presence of predictive relevance in the model. With this value, the Time Overrun construct is in the category of high predictive relevance, so this structural model can be said to have good predictive ability for these variables.

D. Bootstrapping Testing

In this study, bootstrapping testing was carried out using a two-tailed test approach and a significance level of 5%, using a t-statistical value of 1.96 as a threshold. Through the visualization of the structural paths displayed in the bootstrapping output, constructs that have a significant influence on the Time Overrun can be identified. The values on the relationship path and the accompanying p-value indicators are the basis for drawing conclusions about the causal relationship between variables in the research model. The results of the bootstrapping test are presented in the following Figure IV.3.

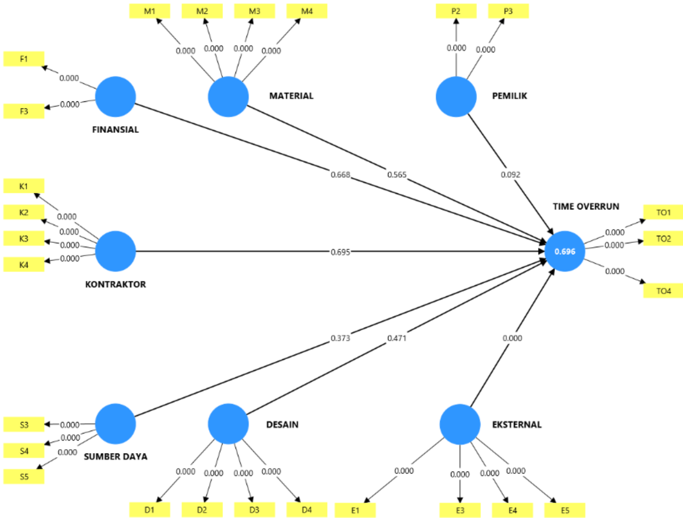

Figure 3. Bootstrapping Test Results

Source: Author's data processing, 2025

The results of bootstrapping testing showed that most of the relationships between constructs in the model had a p-value of 0.000. This value does not mean that it is an absolute zero value, but is the result of rounding the system to a very small p-value (< 0.001). This indicates that the relationship between constructs in the model is statistically significant, as the p-value is well below the significance threshold of 0.05.

Using a two-tailed test and a critical value of 1.96 for a significance level of 5%, it can be concluded that all relationships that have a p-value of 0.000 have a confidence level above 99.9%. Therefore, the relationship between latent variables such as External → Time Overrun, Financial → Time Overrun, Contractor → Time Overrun, and other constructs in this model can be accepted as statistically significant.

E. Path Coefficient Test

Path coefficient testing was carried out to determine how much of a direct influence of exogenous variables on endogenous variables in the structural model, as well as to test the significance of these relationships through t-statistics and p-values using the bootstrapping technique. The significance value was determined based on the t-statistical value > 1.96 or the p-value < 0.05 (Hair et al., 2017). In the context of testing p-values with a significance level of 5%, then if the p-value is less than 0.05 or the t-statistical value exceeds 1.96, it can be concluded that there is a significant influence. Conversely, if the p-value is greater than 0.05 or the t-statistic value is below 1.96, then the relationship tested is declared to have no significant effect.

Table 7. Path Coefficient Test Results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Design -> *Time Overrun*	0,083	0,123	0,115	0,720	0,471
External -> *Time Overrun*	0,534	0,549	0,110	4,861	0,000
Financial - > *Time Overrun*	-0,074	-0,041	0,173	0,429	0,668
Contractor -> *Time Overrun*	0,074	0,091	0,188	0,392	0,695
Material -> *Time Overrun*	0,123	0,090	0,214	0,576	0,565
Owner -> *Time Overrun*	0,265	0,249	0,157	1,688	0,092
-> Time Overrun resources	-0,191	-0,204	0,214	0,890	0,373

Source: Author's data processing, 2025

Based on the table above, only the External variable has a significant influence on the Time Overrun, with an original sample value of 0.534, a t-statistics value of 4.861, and a p-value of 0.000. This shows that external factors have a significant contribution to the project time overrun.

Proving Research Hypotheses

This study aims to identify and measure the influence of seven factors causing delays on Time Overrun in the EPC project of PLTMG in Sumbawa. Hypothesis testing was carried out using the Partial Least Squares – Structural Equation Modeling (PLS-SEM) method with a bootstrapping technique at a significance level of 5% (two-tailed test). A summary of the path coefficient test results is presented in Table 8 below:

Table 8 Path Coefficient Test Results

Hypothesis	Variable Relationships	Koef. Line (O)	t-statistic	p-value	Results
H1	Design → *Time Overrun*	0,083	0,720	0,471	Rejected
H2	External → *Time Overrun*	0,534	4,861	0,000	Accepted
H3	Financial → *Time Overrun*	-0,074	0,429	0,668	Rejected
H4	Contractor → *Time Overrun*	0,074	0,392	0,695	Rejected
H5	Material → *Time Overrun*	0,123	0,576	0,565	Rejected
H6	Employer → *Time Overrun*	0,265	1,688	0,092	Rejected
H7	Resources → *Time Overrun*	-0,191	0,890	0,373	Rejected

Source: Author's data processing, 2025

Test criteria: The hypothesis is accepted when the p-value is < 0.05 or the t-statistic > 1.96.

H1: The Effect of Design Factors on Time Overrun

The results showed that the design factor had no significant effect (p=0.471) on the project delay. This shows that despite constraints such as design changes, technical errors, or incompleteness of documents at the tender stage, these factors are not the main determinants of delays in the project.

1) Interpretation: In the context of the Sumbawa PLTMG, the potential risks of the design have been managed well through technical coordination in the early stages and the use of effective design review procedures.
2) Literature comparison: These findings differ from Alsuliman (2019) and Ajayi & Chinda (2022) which place design as a significant factor in delays, but are in line with the research

of Fertilia et al. (2018) which states that design mitigation in mature EPC projects can reduce its impact.
3) Implications: The design planning process in this project is relatively effective, so the focus on mitigation should be directed to other factors that have proven to be significant.

H2: Influence of External Factors on Time Overrun

External factors had a significant effect ($p=0.000$; $\beta=0.534$) and had a large effect ($f^2=0.536$) on project delays. These factors include changes in government regulations, extreme weather, licensing delays, and socio-cultural influences at the project site.

1) Interpretation: External factors are beyond the direct control of project management, but have a substantial impact on the time of completion. Delays in permits and weather disturbances at the Sumbawa location are likely to be the main contributors.
2) Literature comparison: These findings are consistent with Assaf & Al-Hejji (2006) and Aziz & Abdel-Hakam (2016) who stated that external conditions are a significant cause of delays, particularly in public projects.
3) Implications: More proactive risk management strategies are needed, such as early permitting processes, contingency planning for severe weather, and intensive communication with local authorities.

H3: The Influence of Financial Factors on Time Overrun

Financial factors did not have a significant effect ($p=0.668$) on project delays. Although indicators such as late payments or contractor financial constraints are often associated with delays, in this project this is not statistically proven.

1) Interpretation: There is a good enough payment arrangement between the project owner and the contractor, or there is financial support from the parent company so that cash constraints do not directly affect the progress of the project.
2) Literature comparison: In contrast to Haseeb et al. (2012) who stated that financial factors are often dominant in developing countries, but in line with the findings of Alrasheed et al. (2023) which show that these factors can be minimized with healthy contract schemes.
3) Implications: Existing financial controls are adequate, but monitoring is still needed to avoid escalation of costs due to delays.

H4: The Influence of Contractor Factors on Time Overrun

No significant effect was found ($p=0.695$). Factors such as planning, work methods, and field supervision are not the main determinants of delays in this project.

1) Interpretation: This can be interpreted that the contractor's performance on this project is relatively stable and does not cause significant delays.
2) Comparison of the literature: In contrast to Chan & Kumaraswamy (1997) who place contractor performance as the main cause of delays, it is shown that the context and management of contractors are decisive.
3) Implications: Strengthening contractors remains important, but not a top priority for time risk mitigation.

H5: Influence of Material Factors on Time Overrun

There was no significant effect (p=0.565). This means that the availability of materials, quality, and smooth distribution of materials are not the main causes of delays in this project.

1) Interpretation: It is likely that material procurement has been effectively managed with a planned supply chain.
2) Literature comparison: In contrast to Sholeh & Fauziyah (2022) who emphasized that procurement problems often trigger delays. In this case, the logistics management system plays an important role in avoiding delays.
3) Implications: The material procurement procedures applied can be used as best practices for similar projects.

H6: The Influence of Employer Factors on Time Overrun

The effect was close to significant (p=0.092) with a small effect (f^2=0.108). Slow decision-making processes and lack of communication with contractors have a tendency to affect delays.

1) Interpretation: Although it is not yet statistically significant at the level of 5%, this factor is worth noting because it can be crucial if not anticipated, especially in public projects that involve lengthy bureaucracy.
2) Literature comparison: Consistent with Samarah & Bekr (2016) which emphasizes the important role of project owners in avoiding delays.
3) Implications: There is a need to improve coordination mechanisms and faster decision-making processes on the part of the owners.

H7: Influence of Resource Factors on Time Overrun

No significant effect was found (p=0.373) although initial indicators showed limited labor and equipment.

1) Interpretation: This indicates that resource constraints have been overcome, for example through subcontracting or mobilizing additional resources.
2) Literature comparison: In contrast to Yap et al.'s (2021) research that showed labor limitations as a dominant factor in many construction projects.
3) Implications: Resource management in this project is effective, but it still requires monitoring, especially in the critical construction phase.

From the proof of the hypothesis that has been carried out on the seven factors of delay in the EPC PLTMG project in Sumbawa, based on hypothesis testing using the SEM-PLS tool, the researcher found that only External Factors (H2) were proven to have a significant effect on the delay of the project (Time Overrun), with a large contribution. Other factors according to the initial hypothesis include: design, finance, contractors, materials, employers and resources do not show significant influence, so in this study these factors are not the main cause of the delay in EPC project work, especially in the PLTMG project in Sumbawa.

Recommendations for Fixes Using Tree Diagrams

Based on the results of the analysis in CHAPTER 4, where it has been proven that external factors are the main cause of project delays (Time Overrun) in the EPC work of PLTMG, then a Focus Group Discussion (FGD) was carried out involving representatives of Project Owners, Contractors, and Construction Supervision Consultants. This FGD aims to identify the root of the problem and formulate recommendations for improvement that can be implemented directly in the field. The discussion process was carried out by considering the results of the analysis at the previous research stage, the practical experience of related parties, and the specific conditions of the project.

The results of the FGD are outlined in the form of a Tree Diagram that maps the relationship between the main problems, causal factors, and mutually agreed solutions. The diagram shows that external factors can be grouped into four main causes, each with the following improvement recommendations:

1. Regulatory Changes
   The FGD participants assessed that changes in government regulations often have an impact on the project implementation process, especially related to licensing and technical standards. The agreed solutions are:
   Conducting regular consultations with relevant government agencies to obtain the latest information and prevent potential delays due to new regulations.
2. Weather
   Extreme weather conditions, especially high rainfall at the project site, are considered to affect the progress of the work. The agreed solutions are:
   Build flexible work schedules by leveraging weather forecast data from official weather apps, so adjustments can be made before disruptions occur.
3. Licensing Management
   The long and complex licensing administration process is one of the obstacles to project implementation. The agreed solutions are:
   Appoint a special liaison officer who is responsible for coordinating and accelerating the licensing process in the relevant agencies.
4. Socio-Cultural
   The social and cultural dynamics of the community around the project site also affect the smooth running of the work. The agreed solutions are:
   Collaborating with community leaders as mediators to bridge communication between the project team and residents, so that the potential for resistance can be minimized.

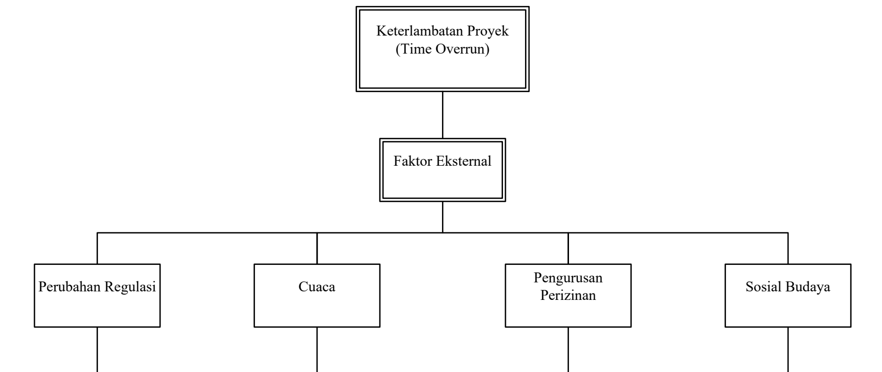

Figure 4. Results of Recommendations using Tree Diagram
Source: Author's data processing, 2025

CONCLUSIONS

Based on the results of the analysis using the Partial Least Squares – Structural Equation Modeling (PLS-SEM) method on the factors causing the delay of the *PLTMG* EPC project in Sumbawa, as well as the discussion presented in the previous chapter, it can be concluded that: External factors are the dominant cause of project delays. This factor has a positive and significant influence on project time overrun, with a path coefficient of 0.534 and a p-value of 0.000. External factors include regulatory changes, adverse weather conditions, permitting delays, and socio-cultural influences at the project site. Design, financial, contractor, material, employer, and resource factors do not have a significant effect on project delays. This shows that these internal aspects have been managed well, so they are not the main cause of delays. The research model has good predictive ability. An R^2 value of 0.696 indicates that 69.6% of project delay variations can be explained by factors in the model, while a Q^2 value of 0.516 indicates high predictive ability. Improvement recommendations are focused on mitigating external factors through the formation of a legal team to monitor regulations, the preparation of weather-adaptive work schedules, the acceleration of the licensing process by appointing liaison officers, and increasing socialization and collaboration with community leaders. Based on the findings of this study, EPC project stakeholders, especially in locations such as the Sumbawa *PLTMG*, are advised to proactively mitigate external factors by forming regulatory monitoring teams, implementing flexible work schedules that are adaptive to the weather, appointing liaison officers to expedite licensing, and improving communication with the community through local figures. On the internal management side, continuous improvements in coordination, logistics, and resource allocation remain necessary, supported by periodic audits to ensure effective practices. For future development, advanced research can investigate the dynamic interactions between external factors and project governance, as well as use a qualitative approach to understand stakeholder perspectives more deeply. These recommendations are expected to improve the timeliness and success of EPC projects in challenging environments.

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