

Analysis of Structural Equation Modeling (SEM) on the Factors of Delays in Utility Duct Work at the Mandalika Special Economic Zone (KEK) and A Comparison of Construction Method Efficiency

M. Refandhy Ginting*, Jauhar Fajrin, Ngudiyono

Universitas Mataram, Indonesia

Email: refandhyg@gmail.com*, jauhar.fajrin@unram.ac.id, ngudiyono@unram.ac.id

Abstract

This study aims to analyze the factors contributing to delays in utility duct work in the Mandalika SEZ using a structural equation modeling (SEM) approach, while also comparing the efficiency of precast and cast-in-situ construction methods. A mixed-methods approach was employed. Delay factors were analyzed using partial least squares–structural equation modeling (PLS-SEM) based on questionnaire data collected from project stakeholders. Model evaluation included construct validity and reliability testing, structural relationship analysis, and mediation effect testing. Furthermore, construction method efficiency was assessed through mathematical analysis of actual project data, incorporating field observations for quality evaluation and project documents for cost and time analysis. The SEM results indicate that the construction method has a significant direct effect on utility duct work delays. Environmental conditions significantly influence the construction method and act as an indirect factor contributing to delays. In contrast, construction management, regulation and licensing, and social and economic variables did not show significant direct effects. Efficiency analysis revealed that the cast-in-situ method provided more consistent field quality and lower costs compared to the precast method, while time performance varied depending on site conditions. Overall, the findings highlight the importance of technical and environmental factors, as well as construction method selection, in minimizing delays and improving project efficiency.

Keywords: *utility duct, project delay, PLS-SEM, construction method, efficiency.*

INTRODUCTION

Urban spatial planning and infrastructure development in Indonesia still face various challenges, especially related to the efficiency of space utilization, increased mobility, and the need for an integrated infrastructure system (Arif & Gupta, 2020; Bao et al., 2023; Pandey et al., 2025). One of the problems often encountered in urban areas is the irregularity of the utility system, such as overhead cable networks and repeated excavation activities along roadways for installing pipes and other utility networks. This condition not only interferes with the comfort and safety of road users but also negatively impacts the aesthetics of the area and the sustainability of urban infrastructure. In a study on the development of urban underground infrastructure, Curiel-Esparza and Canto-Perelló (2004) emphasized that unintegrated utility arrangements can cause environmental disturbances, space utilization conflicts, and a decline in the quality of infrastructure services in the long term.

As a solution to these problems, the concept of utility ducts—or underground integrated utility channels—has been widely applied. Utility ducts are designed to accommodate various utility networks—such as electricity, telecommunications, clean water, and drainage systems—in one integrated system, reducing the need for repetitive excavations and improving the orderliness of infrastructure arrangements. According to Hunt et al. (2014), in the context of large-scale

regional development, the application of utility ducts is an important element in supporting space efficiency, ease of maintenance, and sustainability of infrastructure systems.

The Mandalika Special Economic Zone (SEZ), designated as a National Strategic Project through Government Regulation Number 52 of 2014, is one of the areas that has adopted the utility duct system as part of its basic infrastructure development. With an area of more than 1,000 hectares and an orientation toward international tourism development, the Mandalika SEZ demands the provision of organized, reliable, and long-term quality infrastructure (Agastya et al., 2024; Cantika Yuli et al., 2025; Salahuddin et al., 2021). In this context, utility duct work plays a strategic role because it is a prerequisite for the functioning of various other utilities and follow-up work on them, such as roads, drainage, pedestrian facilities, and regional infrastructure.

However, in its implementation, the utility duct work in the Mandalika SEZ faces challenges in the form of delays in completion. Delays in this work have the potential to create chain effects on other dependent work, thus affecting the overall time performance of the project. In addition, delays also have implications for the cost and quality aspects of work, especially considering the character of utility ducts as underground structures that are sensitive to connection quality, waterproofness, and structural stability (Assaf & Al-Hejji, 2006).

The problem of delays in construction projects is generally caused by various complex and interrelated factors, such as the construction method applied, implementation management, environmental conditions, regulatory aspects, and social and economic factors (Putra Agritama et al., 2018). Therefore, delays cannot be understood partially but rather require an analytical approach that captures the causal relationships between factors simultaneously and in a structured manner. Conventional statistical approaches that have been widely used in previous research, such as linear regression or correlation analysis, tend to explain only one-way relationships and have not fully represented the complexity of interactions between delay factors in infrastructure projects (Doloi et al., 2012).

Based on these conditions, this study uses the Structural Equation Modeling (SEM) approach based on Partial Least Squares (PLS) to analyze the factors causing delays in utility duct work in the Mandalika SEZ. Rahmat and Wibowo explained that the SEM approach allows modeling causal relationships between latent variables that cannot be measured directly but are represented through measurable indicators obtained from the perceptions of project stakeholders. Thus, SEM is not only used to identify the dominant factors causing delays but also to measure the magnitude of the influence and linkages between these factors comprehensively (Hair et al., 2019).

In addition to the delay analysis, this study also conducts a comparative analysis of the efficiency of construction methods used in utility duct work, namely precast and cast-in-situ methods. The selection of construction methods is one of the technical aspects that has the potential to affect the performance of time, cost, and quality of work. In a study on the application of off-site and on-site construction, Bliskas and Wakefield (2009) explained that the precast-based construction method has different characteristics compared to the in-situ method, especially related to the cost structure, logistics needs, and implications for productivity and quality of work results. Therefore, the comparison of the two methods in this study is carried out based on actual project data, by reviewing cost efficiency through the calculation of technical quantities and unit prices, quality through field observations of the condition of the work results, and time through analysis of the implementation duration of each method.

By combining SEM-based delay analysis and comparative analysis of construction method efficiency, this study is expected to provide a more comprehensive understanding of the problem

of utility duct work delays in the Mandalika SEZ. The results of this study are expected to be not only useful as a technical evaluation of the project under review but also serve as a reference and basis for decision-making in the selection of construction methods and control of the implementation of utility duct work in similar projects in the future.

This study examines delays in utility duct work as a crucial component of underground infrastructure development in the Mandalika Special Economic Zone (SEZ) by addressing two main issues: identifying the dominant factors causing delays and comparing the efficiency of precast and cast-in-situ construction methods in terms of cost, quality, and time. Using a mixed-methods approach, the research applies Partial Least Squares–Structural Equation Modeling (PLS-SEM) to analyze the influence of five exogenous variables—construction method, construction management, environmental conditions, regulations and licensing, and social and economic factors—on utility duct work delays, based on questionnaire data from contractors, construction management consultants, and area managers directly involved in the project.

In parallel, a comparative efficiency analysis of precast and cast-in-situ methods is conducted using actual project data, focusing on direct construction costs, observable field quality indicators, and implementation duration based on equivalent units of analysis. The study is limited to utility duct work in the Mandalika SEZ, excludes destructive laboratory testing, indirect costs, and overall project scheduling, and relies on visual quality assessment and productivity-based time evaluation.

This study provides practical recommendations for selecting construction methods that are efficient and suitable for field conditions in the Mandalika SEZ, based on integrated cost, quality, and time considerations. It also offers a scientific basis for stakeholders in making informed decisions regarding construction method selection to improve execution efficiency and reduce delay risks. Furthermore, the findings contribute to the development of academic and applied research in construction management, particularly in the application of Structural Equation Modeling (SEM) for analyzing delay factors in underground infrastructure projects.

RESEARCH METHOD

This study is designed using a mixed methods approach that integrates quantitative and qualitative analysis to answer the two main focuses of the research, namely the identification of the factors causing the delay in utility duct work in the Mandalika SEZ and the evaluation of the efficiency of the construction methods applied. This approach was chosen to allow for measurable testing of causal relationships between delay factors, while providing a contextual understanding of the actual conditions of work implementation in the field. The use of mixed methods is considered relevant because the problem of delays in construction work is not only quantitative, but also influenced by technical characteristics and empirical implementation conditions (Doloi et al., 2012).

A quantitative approach is carried out through the application of Partial Least Squares–Structural Equation Modeling (PLS-SEM) to analyze questionnaire data obtained from utility duct work stakeholders. The PLS-SEM method was chosen because it is able to analyze causal relationships between latent variables simultaneously, is flexible to relatively limited sample sizes, and is suitable for exploratory and predictive research models. The use of PLS-SEM in the study of construction work delays has been widely applied in previous studies, including by Putra et al. (2020). In this study, PLS-SEM was used to model the influence of construction methods, construction management, environmental conditions, regulations and licensing, as well as social and economic factors on utility duct work delays, by data processing using SmartPLS software.

A qualitative approach was carried out through visual field observation of utility duct work results to support the efficiency analysis of construction methods, especially in comparing precast and cast in situ methods. Observations are focused on the quality aspects of utility duct work that can be visually identified, including the quality of connections and gaps between elements, the surface condition of the structure, the level of watertightness, the stability of the shape and position of the elements, and the existence of traces of post-implementation improvements.

The visual observation approach is used because the structure of the utility duct being analyzed is already installed and embedded, so destructive laboratory testing is not possible to be carried out without interfering with the functioning of the structure. Therefore, field quality assessment is carried out through visual inspection of technical indicators that can be observed directly, as an approach commonly used in evaluating the quality of existing construction (Wiyanto, 2020)

Overall, the design of this study integrates quantitative and qualitative approaches in a complementary manner. PLS-SEM analysis serves as the main method in identifying and measuring the influence of delay factors, while field observation is used to support the evaluation of the efficiency of construction methods from the quality aspect. The integration of these two approaches is expected to produce findings that have a strong analytical basis and are relevant to the actual conditions of the implementation of utility duct work in Mandalika SEZ.

The population in this study includes key stakeholders who are directly involved in the implementation of utility duct work in the Mandalika Special Economic Zone (SEZ). The population includes area managers, construction management consultants), and implementing contractors. The selection of this population is based on the consideration that each party has a direct involvement in the process of planning, implementing, and controlling utility duct work, so that they have a relevant understanding of the factors that affect the delay in the implementation of the work.

The sample determination was carried out using the purposive sampling technique, which is the selection of respondents based on certain criteria that are adjusted to the purpose of the research. This technique is used to ensure that the respondents involved have adequate experience, roles, and levels of involvement in the utility duct work being studied, so that the data obtained is informative and relevant to be analyzed using the Structural Equation Modeling (SEM) approach. The use of purposive sampling in this study is not intended to generalize statistics to a wider population, but rather to gain an in-depth understanding of the phenomenon of delay in a specific project context.

The criteria of respondents in this study are grouped into three main categories, namely: 1) The area management, which plays a role in strategic planning, decision-making, and technical and regulatory arrangements; 2) Construction management consultants, who are involved in the preparation of technical planning, quality control of work, as well as control of implementation time and costs; 3) The implementing contractor, who is responsible for the implementation of construction methods in the field and directly faces technical conditions and challenges in the implementation of the work.

The number of samples in this study was determined by referring to the Partial Least Squares–Structural Equation Modeling (PLS-SEM) analysis guidelines. According to Joseph F. Hair Jr., PLS-SEM is flexible to sample size and is suitable for use in research with exploratory and predictive models.

The number of respondents who were successfully collected and analyzed in this study was 48 respondents, who came from parties directly involved in utility duct work in the Mandalika

SEZ. Taking into account the complexity of the model and the number of structural paths analyzed, the sample size was considered adequate for PLS-based SEM analysis.

Data collection in this study was carried out through two types of sources, namely primary data and secondary data. The two types of data are used in a complementary manner to support the analysis of utility duct work delay factors and the evaluation of the efficiency of construction methods applied in the Mandalika SEZ.

Primary data in this study were collected through questionnaire distribution and field observation, while secondary data were obtained from relevant project documents and supporting literature. The questionnaires were distributed to area management personnel, planning and construction management consultants, and implementing contractors directly involved in utility duct work, with the purpose of capturing respondents' perceptions regarding factors influencing work delays; the resulting data were subsequently used as input for Structural Equation Modeling (SEM) analysis based on Partial Least Squares (PLS) to identify causal relationships among delay factors.

In addition, primary data were also gathered through direct visual field observations of completed utility duct structures to assess work quality as a basis for comparing the efficiency of precast and cast in situ construction methods; these observations were conducted at representative locations, focused on visually identifiable quality indicators, and carried out by competent technical personnel, considering that destructive laboratory testing was not feasible due to the embedded condition of the structures.

Secondary data consisted of technical and administrative project documents, including the Bill of Quantity (BoQ), implementation schedules, progress reports, delay reports, and field inspection records, which were used primarily for comparative cost and time analysis between construction methods. Furthermore, technical standards and relevant literature on concrete structures, construction quality, and project cost and time management were incorporated to ensure analytical consistency and scientific validity. The integration of primary and secondary data provided a comprehensive and reliable database to support both the PLS-SEM delay analysis and the comparative efficiency evaluation of construction methods.

The research instruments in this study are used as a measuring tool to collect the data needed to answer the two main focuses of research, namely the analysis of the factors of delay in utility duct work and the comparison of the efficiency of construction methods based on quality aspects. The instruments used consisted of questionnaire instruments and field observation instruments, each of which was designed according to the characteristics of the data and the analysis method used.

The questionnaire instrument was used to measure respondents' perception of factors that affect the delay in utility duct work. The questionnaire was compiled based on latent variables used in the Structural Equation Modeling (SEM) model, namely Construction Methods, Construction Management, Environmental Conditions, Regulation and Licensing, and Social and Economic, with the Impact of Delay as an endogenous variable.

Each latent variable is represented by a number of indicators that are formulated into a closed-ended question. All question items were measured using a five-level Likert scale, namely: 1) Strongly disagree. 2) Disagree. 3) Neutral. 4) Agree. 5) Strongly agree

The use of the five-level Likert scale was chosen because it provides adequate response variation, is easy for respondents to understand, and is in accordance with the needs of analysis using the PLS-SEM approach. Evaluation of the quality of the questionnaire instruments, including validity and reliability tests, is carried out statistically at the analysis stage through an external

model evaluation, so that it does not require a separate preliminary test before the main data collection.

In addition to the questionnaire instrument, this study uses field observation instruments to assess the quality of utility duct work results as the basis for comparative analysis of the efficiency of precast and cast in situ construction methods. The observation instrument is compiled in the form of a list of technical quality indicators that can be visually identified in the field, without conducting destructive laboratory testing on the installed structure.

The quality observation instrument is prepared in the form of indicators that directly reflect the technical performance and potential quality problems in the utility duct structure, especially in underground works that are sensitive to leaks and deformation.

The use of a three-level scale is intended to maintain the consistency of assessment between observation points and minimize observer subjectivity. This observation instrument is used to produce a field quality score which is then analyzed descriptively and comparatively at the stage of analyzing research results. The quality indicator assessment table is presented in the following table.

Table 1. Quality observation assessment indicators

Quality Indicators	Meaning/Aspects Assessed	Grade Criterion 3 (Good)	Grade Criterion 2 (Medium)	Grade Criterion 1 (Less)
Connections & Gaps	Assess the condition of the connections between structural elements, including the suitability of dimensions, joint density, and the quality of filling the gaps between the elements (precast and cast in situ).	The joints are tight and uniform, the gaps are well closed, no visible cracks or irregularities of the joints.	There are minor imperfections in the joints, such as small gaps, imneat gap filling, or fine cracks.	Joints are not tight, gaps are clearly open, cracks are wide, or joints are misaligned.
Surface Structure	Assess the visual quality of the concrete surface as the final result of the work, including smoothness, uniformity, and the presence of surface defects.	The concrete surface is smooth, flat, uniform, without visual defects such as honeycombs or hair cracks.	The concrete surface shows minor defects, such as variations in texture or color, hair cracks, or minor irregularities.	Rough, corrugated concrete surfaces, lots of honeycomb, or obvious visual defects.
Water Resistance	Assess the ability of the structure to resist the ingress of water based on visual indications of seepage or moisture.	There is no indication of seepage, moisture, or stagnation; The surface is dry.	There is light moisture or water stains, but it does not form stagnation and does not interfere with function.	There is a clear active seepage or stagnation of water on the joints or walls of the structure.
Stability of Shape & Position of Elements	Visually assess the suitability of the position and robustness of structural elements, including indications of shift or misalignment.	The structural elements appear stable, aligned, and show no indication of shift or visual deformation.	There are indications of misalignment or minor deformation, but they have not interfered with the functioning of the structure.	Obvious shifts, tilts, or deformations are visible and potentially affect function.
Improvement Trail	Assessing the existence and quality of repair work as an indication of quality problems at the previous stage of implementation.	There are no traces of repairs, or repairs are very minimal and are	There are visible traces of improvement, but it is still neat and does not interfere with	There are many traces of repairs that are rough, untidy, or show significant quality problems.

Quality Indicators	Meaning/Aspects Assessed	Grade Criterion 3 (Good)	Grade Criterion 2 (Medium)	Grade Criterion 1 (Less)
		carried out neatly and uniformly.	function or appearance.	

The implementation of observation and the provision of quality scores is carried out by the Chief Inspector from the supervisory consultant, with the researcher acting as the compiler of the instrument, the observation assistant, and the manager and analyst of the assessment data. This approach was chosen to ensure that the quality assessment is based on the technical competence and experience of the field supervisor, as well as reflects the actual conditions of utility duct work at the research site.

The data obtained from questionnaires, field observations, and project documentation first goes through the processing stage before analysis. This data processing stage aims to ensure that all data is in a feasible, consistent, and structured condition according to the needs of each analysis method used in the research.

The processing of questionnaire data begins with checking the completeness and consistency of respondents' answers. Data that are incomplete or do not meet the eligibility criteria are evaluated and are not used in the analysis process. Furthermore, the questionnaire data is encoded and compiled in a numerical format according to the measurement scale used, so that it is ready for use in structural modeling based on Partial Least Squares.

Field observation data was processed separately from questionnaire data. The results of the observations are recapitulated and tabulated based on the quality indicators that have been set for each observation point. The processing of observation data is focused on the preparation of scores and summaries of field quality conditions, which are then used as the basis for comparative analysis of the quality of construction methods, without being incorporated into the SEM analysis.

Secondary data obtained from project documents, such as Bill of Quantity (BoQ), execution schedule, and work progress reports, are compiled and tabulated to support cost and time comparative analysis. All secondary data are adjusted to equivalent units of analysis so that they can be directly compared between construction methods.

All data that has gone through the processing stage is then prepared in an appropriate format for further analysis using the analysis techniques described in the next subchapter.

The data analysis in this study was carried out through two main approaches. The first approach uses Structural Equation Modeling (SEM) based on Partial Least Squares (PLS) to analyze the causal relationship between factors causing utility duct work delays based on questionnaire data. The second approach is in the form of a comparative analysis of the efficiency of precast and cast in situ construction methods which are carried out separately, by reviewing aspects of cost, quality, and time based on actual project data and the results of field observations. The separation of these two approaches is carried out to maintain the consistency of the analysis method in accordance with the characteristics of the data used.

The analysis of the causal relationship between variables in this study was carried out using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) approach with the help of SmartPLS software. This approach was used to test the influence of factors causing delays on the impact of utility duct work delays based on respondents' perceptions obtained through questionnaires.

Cost comparison analysis in this study was conducted to compare the economic efficiency between precast and cast in situ construction methods on utility duct work. The comparison was carried out using the same unit of analysis, namely one segment of utility duct with a length of

1.20 meters, so that the two methods could be compared proportionally and objectively without being influenced by the difference in the total volume of work.

The comparative analysis of quality in this study was carried out to compare the quality of utility duct work between precast and cast in situ construction methods based on field observation data. The quality comparison is focused on the results of the work that has been built (as-built quality), so that it reflects the actual conditions of the construction implementation in the field.

Quality data was obtained from the results of visual observations carried out at predetermined observation points. The assessment is carried out by scoring each quality indicator according to the actual conditions in the field.

For each observation point, the total quality score was obtained by calculating the average score of all quality indicators assessed. All indicators are given equal weight, considering the unavailability of comparative parameters in the form of laboratory test results and to maintain equality of assessment between indicators. The average score is used as a representation of the level of quality of the work results at the observation point concerned.

A comparative analysis of time in this study was carried out to evaluate the efficiency of the implementation duration between the precast and cast in situ construction methods on utility duct work. The comparison is focused on the time it takes to produce equivalent work outputs, so that the two methods can be compared objectively and proportionally. The main indicator used in time analysis is the duration of completion of work per equivalent unit length, which is expressed in the duration of execution per segment or per specific length. The selection of this indicator is intended to describe the actual speed of implementation of each construction method in the field without being influenced by

RESULTS AND DISCUSSION

Number and Distribution of Respondents

A total of 48 respondents participated in filling out the questionnaire and all respondent data was declared to be able to be used in the analysis. Respondents came from three main stakeholder groups, namely project owners, construction management consultants, and implementing contractors. The distribution of respondents by category is shown in the table below.

Table 2. Number and distribution of respondents

No	Category Respondent	Number (people)	Percentage (%)
1	Project Owner	6	13%
2	Construction Management Consultant	21	44%
3	Implementing Contractor	21	44%
Total		48	100.0%

Based on Table 4.1, the composition of respondents is dominated by construction management consultants and implementing contractors, each by 44%. Meanwhile, respondents from the project owner amounted to 13%. This composition reflects the representation of parties directly involved in the implementation and supervision of utility duct work in the Mandalika SEZ.

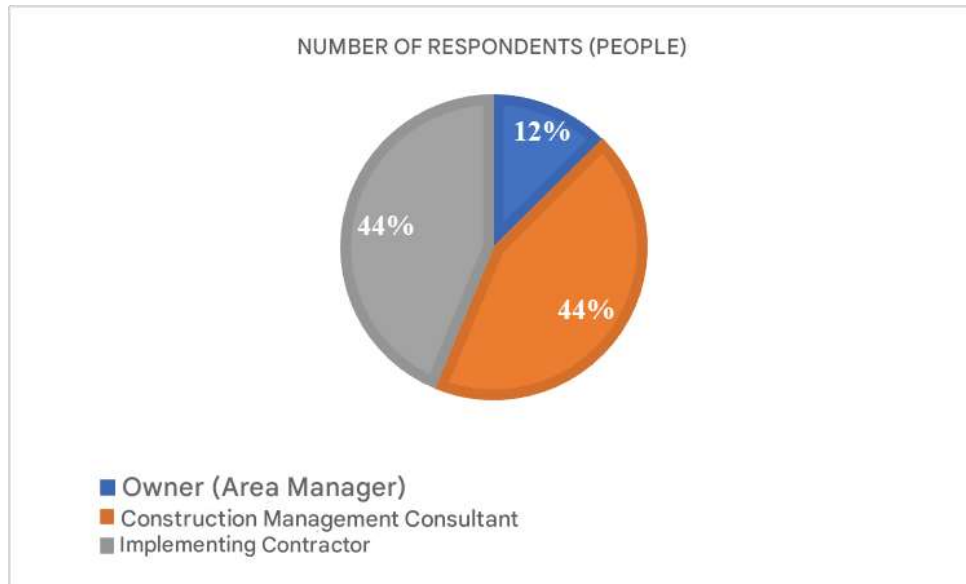


Figure 1. Distribution of respondents by stakeholder category

Characteristics of Respondent Experience

The characteristics of the respondents were also reviewed based on the length of experience involved in utility duct work. The distribution of respondents based on the length of the respondent's experience is shown in this report.

Table 3. Characteristics of respondents based on length of experience

Long Experience	Number (people)	Percentage (%)
< 1 year	1	2%
1–2 years	9	19%
> 2 years	38	79%
Total	48	100,0

Based on the table above, the majority of respondents have more than two years of experience in utility duct work, which is 79%. Respondents with one to two years of experience accounted for 19%, while respondents with less than one year of experience accounted for 2%. This distribution illustrates the variation in the level of experience of respondents involved in utility duct work in the Mandalika SEZ.

Job Description/Role

Based on the job description included in the questionnaire, respondents have roles spread across various job functions in the project, including managerial, administrative, technical supervision, and construction implementation roles. The diversity of roles shows that respondents come from various functions involved in the implementation of utility duct work in the Mandalika SEZ.

ANALISIS STRUCTURAL EQUATION MODELING (SEM)

SEM Research Model

This subchapter presents a Structural Equation Modeling (SEM) model that is tested to analyze the relationship between factors causing delays in utility duct work in the Mandalika SEZ. The tested model consisted of five exogenous variables and one endogenous variable, with the Construction Method (X1) positioned as the mediator variable

Exogenous variables in the model include:

1. X1 – Construction Method
2. X2 – Construction Management
3. X3 – Environmental Conditions
4. X4 – Regulation and Licensing
5. X5 – Social and Economic

The endogenous variables in the model are:

- Y – Impact of Utility Duct Work Delays

In this structural model, the Construction Method (X1) acts as a mediator that connects the influence of external factors to the impact of delay. Thus, the model contains the direct relationship between exogenous variables and endogenous variables, as well as indirect relationships through mediator variables.

The direct effects tested in the model include:

- X1 → Y
- X2 → Y
- X3 → Y
- X4 → Y
- X5 → Y

Indirect relationships through mediator variables (indirect effects) include:

- X2 → X1 → Y
- X3 → X1 → Y
- X4 → X1 → Y
- X5 → X1 → Y

In addition, the model also tests the relationship between exogenous variables and mediator variables as follows:

- X2 → X1
- X3 → X1
- X4 → X1
- X5 → X1

The tested SEM model is shown in the figure below, which illustrates the relationship structure between variables according to the research model.

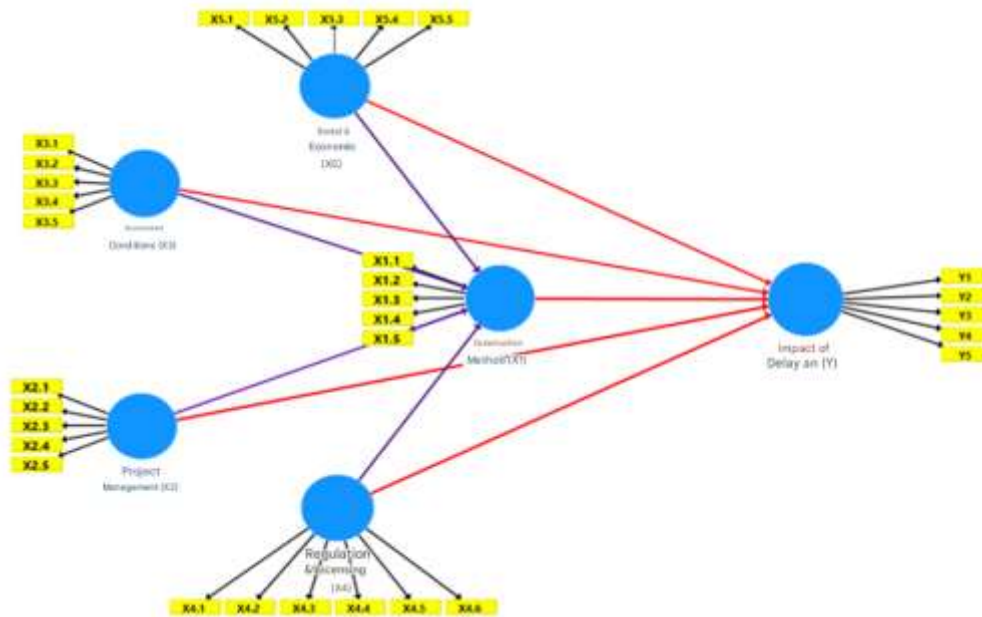


Figure 2. SEM analysis model

Evaluation of Measurement Models

The evaluation of the measurement model was carried out to ensure that each construct in this study met the criteria of validity and reliability as required in the Structural Equation Modeling analysis based on Partial Least Squares (PLS-SEM). Evaluation of the measurement model is a crucial stage because it serves to assess the extent to which the indicators used are able to represent latent constructs consistently and accurately.

Testing at this stage includes convergent validity, discriminant validity, and construct reliability. The fulfillment of all the criteria in the measurement model is an important prerequisite before the evaluation of the structural model, so that the causal relationships between the latent constructs analyzed can be reliably interpreted and have a strong measurement basis.

Convergence Validity

Convergent validity is evaluated to assess the extent to which indicators in a single construct have a high degree of interconnectedness and consistently represent the latent construct being measured. In this study, the convergent validity was evaluated using outer loading values and Average Variance Extracted (AVE). The outer loading value is used to assess the strength of the relationship between each indicator and the latent construct, while the AVE value indicates the proportion of indicator variance that can be explained by the latent construct as a whole.

Based on the results of the evaluation carried out, all indicators used in the measurement model have met the criteria for convergent validity after making the necessary adjustments. This shows that these indicators have adequate ability to represent the latent constructs that are measured and are suitable for use at the next stage of structural model analysis. The results of the outer loading value test for all indicators in each construct are presented below.

All indicators in each construct show an adequate outer loading value. In the construct of the Construction Method (X1), the value of the outer loading indicator is in the range of 0.834–0.933. The construct has an outer loading value between 0.681–0.873, with one indicator being slightly below 0.70 but still showing a considerable contribution to the construct.

The Environmental Conditions (X3) and Regulation and Licensing (X4) constructs show high and consistent outer loading values, in the range of 0.830–0.946 and 0.832–0.938, respectively. Meanwhile, the Social and Economic construct (X5) has an outer loading value between 0.737–0.903. For the endogenous variable Delay Impact (Y), all indicators (Y1–Y5) had an outer loading value in the range of 0.786–0.935, which shows the consistency of the indicators in representing the delay impact construct.

Discriminatory Validity

The evaluation of discriminant validity using the Fornell–Larcker Criterion approach was carried out by comparing the square root value of the Average Variance Extracted (AVE) in each construct with the correlation value between other constructs. Discriminant validity is stated to be fulfilled if the square root value of AVE in a construct is greater than its correlation with another construct, indicating that the construct has adequate differences and does not overlap empirically. The entire square root value of AVE located on the diagonal is higher than the correlation value between other constructs. These results show that each construct has adequate differences and does not overlap each other empirically.

Multicollinearity Test (VIF)

Multicollinearity tests are performed to ensure that the indicators in the model do not have excessive correlation levels, so that the estimation of the model parameters can be interpreted stably and reliably. High levels of multicollinearity have the potential to affect the accuracy of coefficient estimation and increase standard errors in structural models.

Multicollinearity evaluation was carried out using the Variance Inflation Factor (VIF) value. The criteria used stated that a VIF value of < 5 indicated the absence of significant multicollinearity problems, while a more conservative limit set a VIF value < 3.3 to avoid potential lateral collinearity bias in the PLS-SEM model (Joseph F. Hair Jr. et al., 2019; Ned Kock, 2015).

Most indicators show VIF values that are at moderate levels. Some indicators have relatively higher VIF values than others, but generally do not show excessive patterns of collinearity between indicators in the measurement model. Overall, the results of the VIF test showed that the level of multicollinearity between the indicators was at a level that was still controllable in the model being tested.

A. Effect of Construction Method (X1) on the Impact of Delay (Y)

The results of the path coefficient analysis showed that the Construction Method (X1) had a positive and significant effect on the Impact of Delay (Y), with a value of $\beta = 0.699$ and a p-value of < 0.001 . These findings indicate that the selection and application of construction methods has an important role in determining the level of delay in utility duct work in the Mandalika SEZ, especially in underground works that have a high dependence on the order and technique of implementation.

The results of this study are consistent with the findings of Sharifzada et al. (2025) which show that the method factor in the 4M1E framework has a direct and significant effect on the delay of construction projects. This alignment confirms that construction methods are a technical factor that contributes to project time performance, although the degree of influence can vary depending on the characteristics and complexity of the project being researched.

B. Impact of Construction Management (X2)

The results of the path coefficient analysis showed that Construction Management (X2) did not have a significant influence on either the Construction Method (X1) or the Delay Impact (Y),

with a p-value of > 0.05 in both relationships. These findings indicate that the direct influence of managerial aspects on utility duct work delays was not statistically identified in this study model.

The insignificance of the direct influence of construction management can be explained by the character of utility duct work which is dominated by the technical complexity of implementation, so that the problem of delays is more triggered by operational technical factors than managerial factors. A similar condition was also reported by Rashida et al. (2020) who showed that in some construction project contexts, certain non-technical factors do not have a direct significant influence on project delays, depending on the characteristics and environment of the project being studied.

C. Influence of Environmental Conditions (X3)

The results of the path coefficient analysis showed that Environmental Conditions (X3) had a positive and significant effect on the Construction Method (X1), with a coefficient value of $\beta = 0.681$ and p-value = 0.023. In contrast, the direct influence of Environmental Conditions (X3) on the Impact of Delay (Y) showed no statistical significance, with p-value = 0.911. These findings indicate that environmental conditions do not directly trigger delays in utility duct work, but rather affect delays through their role in determining and adjusting construction methods applied in the field.

Conceptually, these results are in line with the framework of thought put forward by Sharifzada et al. (2025), which places environmental factors as aspects that affect the conditions and effectiveness of construction implementation, including in the selection and application of construction methods. In this framework, the influence of environmental factors on project time performance is understood to occur through the technical mechanism of implementation, not as a direct trigger factor for delays. Thus, the results of this study confirm that the control of utility duct work delays needs to be focused on adapting construction methods in accordance with the actual environmental conditions in the field.

D. The Influence of Regulation and Licensing (X4)

The results of the path coefficient analysis showed that Regulation and Licensing (X4) did not have a significant influence on both the Construction Method (X1) and the Delay Impact (Y). The relationship of $X4 \rightarrow X1$ results in a value of $\beta = -0.199$ with a p-value = 0.414, while the direct relationship of $X4 \rightarrow Y$ has a value of $\beta = -0.047$ with a p-value = 0.771. These results show that the direct influence of regulatory and licensing factors on utility duct work delays is not statistically identified in this study model.

The insignificance of the influence of regulation and licensing can be explained by the characteristics of the stages of project implementation, where the licensing process has generally been completed before construction work begins. This condition is in line with the findings of Assaf and Al-Hejji (2006) who stated that regulatory and administrative factors are more influential in the early stages of the project, but are not always the main cause of delays in the construction implementation phase. Thus, the results of this study indicate that the delay in utility duct work in the Mandalika SEZ is more influenced by technical and operational factors than by direct regulatory and licensing factors.

E. Social and Economic Influences (X5)

The results of the path coefficient analysis showed that the Social and Economic variables (X5) did not have a significant influence on both the Construction Method (X1) and the Impact of Delay (Y). The relationship of $X5 \rightarrow X1$ results in a value of $\beta = -0.394$ with a p-value = 0.143, while the direct relationship of $X5 \rightarrow Y$ has a value of $\beta = -0.225$ with a p-value = 0.164. These

findings indicate that the direct influence of social and economic factors on utility duct work delays is not statistically identified in the structural model of this study.

Conceptually, the findings are in line with the results of a literature study of infrastructure projects in Indonesia which shows that social and economic factors are not always the dominant causes of project delays, and their influence is highly dependent on the context and characteristics of the project being studied. In many cases, technical and operational factors determine time performance more than social and economic factors. This framework of thought is supported by Surri (2025), who places socio-economic factors as contextual and non-dominant factors in the delay in infrastructure projects in Indonesia. Thus, the results of this study confirm that in utility duct work in the Mandalika SEZ, delays are more influenced by technical factors of implementation than direct social and economic factors.

Overall, the results of the path coefficient analysis show that the Construction Method (X1) is a variable that has a significant influence on the delay in utility duct work, while the Environmental Condition (X3) plays a significant role in influencing the construction method applied. In contrast, the variables of Construction Management (X2), Regulation and Licensing (X4), and Social and Economic (X5) did not show a significant direct influence on delays in the developed structural model.

CONCLUSION

The PLS-SEM analysis reveals that delays in utility duct work at the Mandalika SEZ are predominantly driven by the Construction Method (X1), with no significant direct effects from Construction Management, Environmental Conditions, Regulation and Licensing, or Social and Economic factors—though Environmental Conditions exert indirect influence via the Construction Method. Comparative evaluation shows no universally superior method: precast excels in execution speed but incurs higher costs and variable connection quality, whereas cast-in-situ offers cost and quality advantages through its monolithic structure that minimizes connections and leakage risks, despite longer timelines. Thus, a hybrid approach is optimal, applying precast for straight, long sections to accelerate progress and cast-in-situ at bends, manholes, or high-leakage-risk areas to enhance durability. For future research, investigators could extend this by integrating longitudinal data on long-term maintenance costs and structural performance under varying soil conditions, or apply advanced simulations like BIM-integrated SEM to optimize hybrid method allocations across diverse SEZ projects.

REFERENCES

- Agastya, D. M., Yasa, I. W., & Negara, I. D. G. J. (2024). Optimization of Pengga Reservoir in the Mandalika Special Economic Zone for irrigation and water supply. *Journal of the Civil Engineering Forum*, 10(2). <https://doi.org/10.22146/jcef.7913>
- Arif, M., & Gupta, K. (2020). Spatial development planning in peri-urban space of Burdwan City, West Bengal, India: Statutory infrastructure as mediating factors. *SN Applied Sciences*, 2(11). <https://doi.org/10.1007/s42452-020-03587-0>
- Bao, Y., Huang, Z., Li, L., Wang, H., Lin, J., & Liu, G. (2023). Evaluating the human use efficiency of urban built environment and their coordinated development in a spatially refined manner. *Resources, Conservation and Recycling*, 189, 106723. <https://doi.org/10.1016/j.resconrec.2022.106723>

- Cantika Yuli, S. B., Azizurrohman, M., Pramuja, R. A., & Ginting, Y. M. (2025). Tourism-driven development: Evaluating the benefits of the Mandalika Special Economic Zone. *Cogent Social Sciences*, 11(1). <https://doi.org/10.1080/23311886.2025.2460317>
- Pandey, B., Brelford, C., & Seto, K. C. (2025). Rising infrastructure inequalities accompany urbanization and economic development. *Nature Communications*, 16(1). <https://doi.org/10.1038/s41467-025-56539-w>
- Salahuddin, M. A. A., Rohayani, I. S., & Candri, D. A. (2021). Species diversity of birds as bioindicators for mangroves damage at Special Economic Zones (SEZ) Mandalika in Central Lombok, Indonesia. In *IOP Conference Series: Earth and Environmental Science* (Vol. 913, No. 1, Article 012058). <https://doi.org/10.1088/1755-1315/913/1/012058>
- Assaf, S. A., & Al-Hejji, S. (2006). Causes of delay in large construction projects. *International Journal of Project Management*, 24(4), 349–357.
- Blismas, N., & Wakefield, R. (2009). Drivers, constraints and the future of offsite manufacture in Australia. *Construction Innovation*, 9(1), 72–83. <https://doi.org/10.1108/14714170910931552>
- Curiel-Esparza, J., & Canto-Perelló, J. (2004). Establishing sustainable strategies in urban underground engineering. *Science and Engineering Ethics*, 10(3), 523–530.
- Doloi, H., Sawhney, A., Iyer, K. C., & Rentala, S. (2012). Analysing factors affecting delays in Indian construction projects. *International Journal of Project Management*, 30(4), 479–489.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2019). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed.). Sage Publications.
- Hunt, D. V. L., Nash, D., & Rogers, C. D. F. (2014). Sustainable utility placement via multi-utility tunnels. *Tunnelling and Underground Space Technology*, 39, 15–26.
- Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration*, 11(4), 1–10. <https://doi.org/10.4018/ijec.2015100101>
- Putra, J. C. P., Safrilah, & Asmi, A. (2017). Application of structural equation modeling in the analysis of factors causing delays in completion of construction projects in Indonesia. *Civil Engineering*, 6(2), 113–122.
- Putra Agritama, R., Huda, M., & Rini, T. S. (2018). Factors affecting construction project delays in Surabaya. *Journal of Civil Engineering*, 8(3), 213–220.
- Rashid, Y. (2020). Analysis of delay factors and their effects on construction projects. *Management Science Letters*, 10(7), 1465–1476. <https://doi.org/10.5267/j.msl.2019.12.002>
- Sharifzada, M., Rahmani, F., & Yadollahi, M. (2025). Factors affecting construction delay: A structural equation modeling approach. *Journal of Engineering, Project, and Production Management*, 15(1), 1–15.
- Surri, D. A. (2025). Factors causing delays in infrastructure projects in Indonesia and management strategies. *Journal of Sustainable Construction*, 5(1), 45–60.

Analysis of Structural Equation Modeling (SEM) on the Factors of Delays in Utility Duct Work at the Mandalika Special Economic Zone (KEK) and A Comparison of Construction Method Efficiency

Wiyanto, H. (2020). Penerapan soft system methodology pada metode penilaian kerusakan beton secara visual. *Media Komunikasi Teknik Sipil*, 26(1), 20–31.
<https://doi.org/10.14710/mkts.v26i1.21371>

Copyright holder:

M. Refandhy Ginting*, Jauhar Fajrin, Ngudiyono (2026)

First publication right:

Asian Journal of Engineering, Social and Health (AJESH)

This article is licensed under:

