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ANALYSIS OF CONSTRUCTION DELAY FACTORS ON PROJECT QUALITY PERFORMANCE THROUGH QUALITY STANDARDS AND SPECIFICATIONS

Lala Diana[1], Mawardi Amin[2]
Mercubuana University, Indonesia
Email: ala18dianata@gmail.com, mawardi@mercubuana.ac.id

ABSTRACT

This study aims to examine the relationship between construction delay factors, quality standards and specifications, and quality performance of building construction projects. In addition, this study also explores the role of quality standards and specifications as a mediator in the relationship between construction delays and project quality. By using the Structural Equation Modeling method based on Partial Least Squares (SEM-PLS), this research is able to analyze complex relationships between variables that cannot be measured directly. The research data was obtained through questionnaires distributed by stakeholders. In addition, to explore the factors that cause delays, the Root Cause Failure Analysis (RCFA) method is used to identify the root of the problem, and Failure Mode and Effect Analysis (FMEA) to analyze the risk of delays using a risk priority number (RPN). RPN is calculated based on severity, likelihood of occurrence, and detectability for each failure mode identified, prioritizing critical risks that need to be addressed immediately. The results show a very high level of significance, indicating that the delay factor plays a role in influencing project quality performance through quality standards and specifications as a mediating variable. The RCFA and FMEA methods proved effective in identifying the causes of delay and providing recommendations for corrective measures. This research contributes to construction project management by emphasizing the importance of implementing quality standards and specifications, as well as the need for systematic management of delay risks. The findings are relevant for practitioners and academics to improve efficiency and quality in the delivery of construction projects in Indonesia.

KEYWORDS *construction delay, project quality, specification standard, SEM-PLS, RCFA, FMEA.*

INTRODUCTION

Infrastructure development is an important indicator of a country's progress and contributes greatly to economic growth and job creation. In Indonesia, the construction sector plays a significant role in the economy, contributing 10.39% to GDP in the third quarter of 2021 (BPS, 2021). The sector is also a facilitator in the movement of goods and services as well as employment. However, despite the increasing number of construction companies, service quality is often not optimal. This can be seen from issues such as project delays, low resource efficiency, and failure to meet specified quality standards (PMBOK, 2017).

Construction delays are considered a major challenge that negatively impacts project economics and quality (Durdyev & Hosseini, 2020; Gurgun et al., 2024; Kamandang & Casita, 2018). For example, the construction of the Tamiang Layang PA Building experienced a progress deviation of 13% due to equipment delays. Dominant factors causing delays include weather, materials, and design for government projects, and finance for private projects. In addition, research shows that low project quality is caused by lack of work experience, design errors, and poor material quality (Aryanda et al., 2023; Hijazi, 2021; Miralda et al., 2023; Rauzana & Usni, 2021).

To address this issue, the study proposed an analysis model using SEM-PLS and Root Cause Failure Analysis (RCFA) and Failure Mode and Effect Analysis (FMEA) methods to identify the main causes of delay. This approach is expected to provide comprehensive solutions through in-depth analysis and focus group discussions (FGDs), to significantly improve the quality performance of construction projects and reduce the negative impact of delays.

This study aims to analyze the influence of construction delay factors on quality standards, specifications, and project quality performance in building projects, and to examine the mediating role of quality standards and specifications in these relationships. Using SEM-PLS, RCFA, FMEA, and FGD methods, this research focuses on identifying root causes and improvement strategies that can be applied to control the impact of construction delays to improve project quality performance. Respondents involved construction project stakeholders such as owners, supervisory consultants, and contractors. The research results are expected to provide academic benefits as a reference in project management, support users and construction service providers to manage project delays effectively, and contribute to the development of the construction industry through comprehensive management strategies to achieve timely project completion with optimal quality.

In the era of globalization, the construction sector is experiencing rapid development in terms of technology, project capacity, and fund allocation (PMBOK, 2017). Construction projects include various activities such as the construction of buildings, roads, and other infrastructure, which are regulated through legal frameworks such as the Minister of PUPR Regulation No. 1 Year 2023. The focus of construction projects is to meet time, cost, and quality constraints, known as the triple constraints. Construction projects are classified into three main types: building construction, civil building, and special construction, as per the Indonesian Standard Industrial Classification (KBLI, 2020).

Project management plays an important role in ensuring project success by implementing effective planning, control, and coordination from the beginning to the end of the project (Amirtash et al., 2021; Demirkesen & Ozorhon, 2017; George, 2020; Lock, 2016; Vrchota et al., 2021). The project life cycle includes five stages: initiation, planning, pre-implementation, execution, and termination (Dimyati & Nurjaman, 2014). Each of these stages is designed to ensure the project runs on schedule and achieves the end goal, with special attention to planning that includes financial, resource, and risk aspects.

Project delays are one of the main challenges that affect the success of construction projects. According to Ervianto (2005), delays can occur due to design changes, adverse weather conditions, or inadequate material availability. The impacts include cost overruns, quality degradation, and violation of the agreed schedule. In this context, regulations such as Law No. 2 Year 2017 and Presidential Regulation No. 54 Year 2010 stipulate fines for service providers who fail to meet time targets.

To improve project quality and overcome delays, analytical methods such as SEM-PLS, RCFA, and FMEA are used. SEM-PLS helps predict latent variable relationships in exploratory research, while RCFA identifies the root causes of failure. On the other hand, FMEA evaluates the risk of failure based on severity, likelihood of occurrence, and detection, thus providing strategic solutions in construction project management.

This study proposes three key hypotheses: (a) testing whether construction delay factors significantly relate to quality standards and specifications (H1) or not (H0); (b) examining whether quality standards and specifications significantly influence project quality performance (H1) or not (H0); and (c) investigating whether quality standards and specifications mediate the relationship between construction delays and project quality (H1) or not (H0). These hypotheses aim to determine the interconnected effects of delays, quality standards, and overall project performance.

RESEARCH METHOD

This research uses descriptive quantitative methods to analyze the relationship between construction delay factors and project quality performance mediated by quality standards and specifications. Primary data were obtained through a Likert-scale questionnaire distributed to respondents via Google Forms, while secondary data were collected from literature, journals, and related documents. Data analysis was conducted using SEM-PLS to model the structural relationships between latent variables, complemented by Root Cause Failure Analysis (RCFA) to identify the root causes of problems, and Failure Mode and Effect Analysis (FMEA) to evaluate risks and formulate mitigation strategies.

Data collection techniques involved several methods, including expert interviews, direct observation of the research object, and focus group discussions (FGDs) to validate the findings. The research population included stakeholders in construction projects, such as consultants, contractors, and project owners. The sample was drawn using the MOE formula, resulting in 100 respondents for representative analysis. The research variables included construction delay factors as independent variables, quality standards and specifications as mediators, and project quality performance as dependent variables.

The analysis was conducted comprehensively using the SEM-PLS model to test the relationships between variables and to evaluate the validity and reliability of the data. RCFA was used to identify the root causes of construction delays, while FMEA helped assess risks and prioritize mitigation based on the Risk Priority Number (RPN). This approach aims to provide systematic solutions to improve the quality of construction projects while minimizing the negative impact of delays.

RESULT AND DISCUSSION

Data Collection

This research utilized both primary and secondary data for analysis. Primary data was collected through a Likert scale-based questionnaire, distributed online using Google Forms, as well as through focus group discussions (FGDs), enabling efficient collection of data directly from respondents. Secondary data was obtained from literature, journals, reports, and other relevant sources to support the analysis. The analytical methods used include SEM-PLS to identify dominant factors, RCFA to determine root cause prioritization, and FMEA to evaluate risks and formulate improvement strategies. FMEA helps identify potential project delays and quality risks and establishes preventive or corrective measures based on risk prioritization. The results of this analysis generate recommendations based on the main conclusions and suggestions that are relevant to improving project quality performance.

Questionnaire Data Processing

The processing of questionnaire data in this study involved the distribution of questionnaires to 100 targeted respondents via the Google Forms platform during July to August 2024. Once the data was collected, descriptive statistical analysis was used to evaluate the respondents' profiles, including education level, work experience, job title, and institution of employment. The majority of respondents had a higher education background (79% bachelor’s degree), work experience between 2-5 years (48%), and relevant job titles such as project manager (16%) and staff (15%). Most respondents worked in the contracting sector, indicating a strong representation of key stakeholders in construction projects. These results ensure the validity of the data as it includes respondents with relevant backgrounds and sufficient work experience to support the research.

***SEM-PLS* Analysis**

The collected questionnaire data will be processed and analyzed using the Structural Equation Modeling (SEM) method, which is a comprehensive analytical approach. This method allows detailed evaluation of responses attributed to relevant latent variables. In the SEM method, observed variables are known as observed variables, which act as representations of latent variables. This research uses SmartPLS software version 3.0 to facilitate the analysis. The purpose of applying SEM-PLS is to explore and verify the complex relationships between variables, providing deeper insights into the interactions between variables in the context of this study. In the context of this study, the logic of hypothesis development and the structure of the relationship model are described, with the SEM-PLS model illustrated in Figure 1.

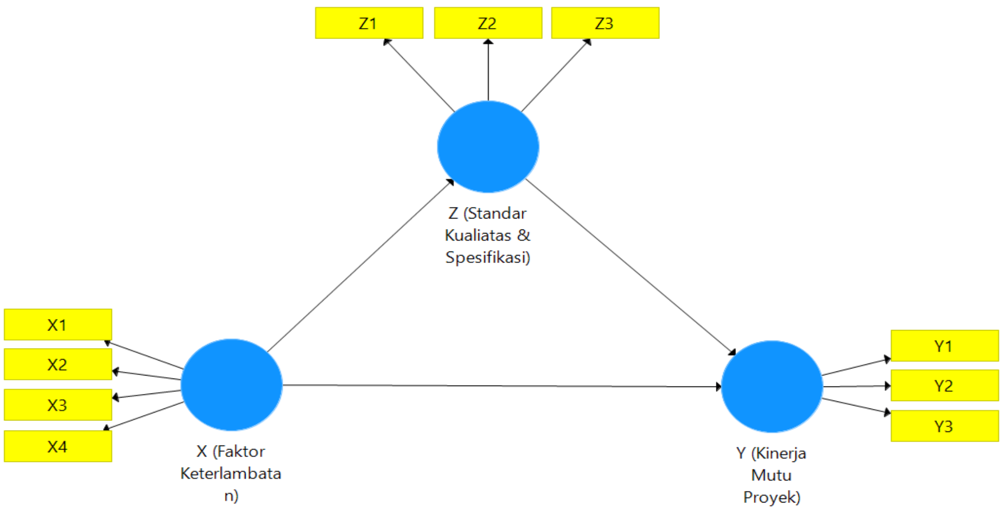

Figure 1. SEM-PLS Relationship Model
Source: Processed Data

The primary data obtained were compiled in tabulated format and saved as CSV files for analysis using SEM-PLS through the SmartPLS 3.0 program. Relevant indicators were mapped as manifest variables to represent latent variables, where exogenous variables (X) were delay factors that included permits, design changes, weather, and funding. The mediating variable (Z) of quality standards and specifications is represented by compliance with quality standards, technical specifications, and specification changes. Meanwhile, the endogenous variable (Y) is project quality performance that includes aspects of human resources, materials, and management. In the model, the latent variables are depicted in blue, while the indicators are in yellow, reflecting the structural relationships that cover all components of the study.

The evaluation of the measurement model (outer model) in SEM-PLS focuses on assessing the validity and reliability of relationships between latent variables and their indicators. Convergent validity is confirmed when outer loading values exceed 0.70, though values between 0.50-0.60 may be acceptable in specific contexts. Construct reliability, measured through composite reliability and Cronbach's alpha, should ideally be above 0.70, while Average Variance Extracted (AVE) must meet a minimum threshold of 0.50 to ensure both convergent and discriminant validity. Discriminant validity is verified by comparing the square root of AVE with inter-construct correlations, ensuring each construct is distinct. Additionally, cross-loading analysis confirms that indicators load more strongly on their intended constructs than on others, reinforcing discriminant validity.

The discriminant validity test ensures that each latent construct is empirically distinct from others. This is assessed through convergent validity (AVE > 0.5) and discriminant validity, where the square root of AVE for each construct should exceed its correlation with other constructs. All constructs meet these criteria, with AVE values above 0.5, indicating robust convergent and discriminant validity. Fornell and Larcker (1981) note that even if AVE is slightly below 0.5, high composite reliability can compensate, as it reflects strong internal consistency. The result confirms discriminant validity, as the square root of AVE for each variable surpasses its correlations with other variables, ensuring distinctness.

Collinearity testing examines whether independent variables in the regression model are overly correlated, using the Variance Inflation Factor (VIF). A VIF value below 5.0 indicates no significant collinearity issues. All indicators have VIF values well under this threshold, confirming the absence of multicollinearity. This ensures that each independent variable contributes uniquely to the model without redundancy, allowing for reliable interpretation of their effects on the dependent variables.

The significance of outer weights is tested to evaluate each indicator's contribution to its latent construct. All outer weights are statistically significant ($p < 0.05$), confirming their validity. Indicators with outer loadings above 0.5 are retained, while those below may be reconsidered based on p-values. The high significance of all indicators in this study underscores their relevance in measuring their respective constructs, supporting the model's robustness.

Reliability is assessed using composite reliability and Cronbach's alpha, with values above 0.7 considered acceptable. While some Cronbach's alpha values fall slightly below 0.7, composite reliability meets the threshold, indicating sufficient consistency. Hair et al. (2014) suggest that exploratory research may tolerate lower Cronbach's alpha (0.6-0.7), especially in developing constructs. Thus, the model remains valid for testing direct and indirect relationships despite minor reliability deviations.

R-square (R^2) measures the model's explanatory power, with values above 0.67 indicating strong predictive ability. Project Quality Performance (Y) has an R^2 of 0.653, suggesting the model explains 65.3% of its variance, while Quality Standards & Specifications (Z) has a weaker R^2 of 0.334. This implies that the model effectively predicts project quality but has limited explanatory power for quality standards, highlighting areas for improvement.

Effect size (f^2) evaluates the relative impact of independent variables. Delay Factors (X) have a large effect on both Project Quality Performance (Y) ($f^2 = 0.482$) and Quality Standards & Specifications (Z) ($f^2 = 0.500$). Meanwhile, Project Quality Performance (Y) moderately influences Quality Standards & Specifications (Z) ($f^2 = 0.319$). These findings emphasize the critical role of delay factors in project outcomes and the need to manage them effectively.

The SEM-PLS analysis results confirm all hypotheses, showing significant direct and indirect effects. Delay Factors (X) negatively impact both Project Quality Performance (Y) and Quality Standards & Specifications (Z), while the latter mediates the relationship between delays and project quality. IPMA analysis identifies Delay Factor (X4) and Quality Standards (Z1–Z3) as the most influential indicators, guiding targeted improvements to enhance project outcomes.

RCFA & FMEA Analysis

Based on the results of data processing using the Smart-PLS method, four indicators were found to have a dominant influence on project quality performance. Furthermore, an in-depth analysis was carried out on each of these indicators using the Root Cause Failure Analysis (RCFA) method with the 5 Whys Analysis approach to identify the main causes and root causes of problems, so as to obtain potential failures and possible failure effects.

In addition, an analysis using Failure Mode and Effect Analysis (FMEA) is carried out to provide recommendations for improvements to the potential and effects of failures that have been identified. This analysis also aims to determine the Risk Priority Number (RPN) value of each potential and effect failure, to obtain priority recommendations that will be implemented in the sample project.

Root Cause Failure Analysis Using 5 Why's

At this stage, the causes of failure were analyzed by identifying the main root causes of each indicator using the 5 why's analysis method. The data used came from the results of suggestions and discussions in the Focus Group Discussion (FGD). The results of the analysis are as follows:

Table 1. RFCA Analysis With 5 *Why's*

Indicator	Key Issues	Why 1	Why 2	Why 3	Why 4	Why 5	The Root of the Problem
X4: Funding	Delays in construction project funding	Why is the project experiencing a delay in funding?	Why was the funding application approved late?	Why is there a discrepancy between the proposed budget and the planning?	Why there is a change in design or scope of work that affects the budget?	Why is there a lack of communication between the design team, project management, and the client?	Lack of a structured communication system to handle changes in design and project specifications.
		Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	
		Because the application for funds was late approved by the relevant parties.	Because there is a discrepancy between the proposed budget and the previously approved plan.	Because of changes in the design or scope of work that cause cost estimates not to be in accordance with the initial budget.	Due to lack of communication between the design team, project management team, and client about changing project needs and specifications.	Because there is no clear communication system or protocol to handle design changes or requirements that occur during the project.	
Z1: Compliance with Quality Standards	The results of the work are not in accordance with quality standards.	Why do the results of the work not meet the quality standards?	Why don't workers understand quality standards?	Why is training not provided regularly?	Why doesn't management give priority to training?	Why management is not aware of the impact?	Lack of training and understanding of workers on quality standards due to the lack of management priority on training and regular quality evaluation
		Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	
		Because workers do not understand the quality standards that must be met.	Because training is not provided regularly.	Because management does not prioritize training.	Because the management does not realize the importance of training in maintaining quality.	Because there is no evaluation system that detects quality non-conformities.	
Z2: Compliance with Technical Specifications	Technical specifications are not well socialized.	Why does the work not conform to the technical	Why is the team not aware of the technical	Why is the socialization of specifications not	Why there is no such standard procedure?	Why is communication not going well?	Lack of communication and socialization of technical

Indicator	Key Issues	Why 1	Why 2	Why 3	Why 4	Why 5	The Root of the Problem
		specifications?	specifications?	carried out?			specifications due to the absence of standard procedures that require socialization and poor communication between departments
		Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	
		Because the team was not aware of the required technical specifications	Because there is no socialization or lack of attention from project management to the implementation of the field.	Because the socialization of specifications is not carried out as it should by the management	Because communication between apartments does not go well	Efficient and real-time to ensure the delivery of information	
Z3: Compliance with specification changes	Disorganized communication processes related to specification changes.	Why is it difficult to adapt to changes in specifications?	Why isn't information delivered quickly?	Why is the communication process not organized?	Why are there no systems or tools in use?	Why there is no awareness of the importance of change management?	The slow delivery of information related to changes in specifications due to poorly organized internal communication and the lack of management priority for change management
		Answer 1	Answer 2	Answer 3	Answer 4	Answer 5	
		Due to problems with price adjustments and slow learning of documents	Because the process needs to coordinate with several parties, so it takes time to convey to the workers	Because no communication system is used for specification changes.	Because management does not give priority to the development of the system	Due to the lack of information and education regarding change management in the organization	

Source: Data Processing

The table above presents a root cause analysis of several indicators that lead to construction delay factors on project quality performance through quality standards and specifications. In the analysis of problems related to funds/funding which explains that these problems often occur in construction projects. Furthermore, compliance with quality standards, it was found that the work results were not in accordance with the established standards. This problem stems from the lack of training provided regularly, as well as the inability of employees to understand and apply existing quality standards. In addition, management did not consistently prioritize training, which resulted in employees' lack of understanding of the importance of maintaining quality work. The quality evaluation system is also considered not running effectively, so that quality monitoring and improvement are not carried out optimally.

Furthermore, problems related to compliance with technical specifications were caused by the vagueness of specifications and the lack of socialization of technical specifications in the field. This was exacerbated by the lack of coordination between departments in communicating changes to the specifications. Ineffective communication is one of the main causes of delays in conveying information related to technical specifications. As a result, the work often did not meet the predetermined technical standards, and the socialization of changes was also not carried out in a timely manner.

Finally, the issue of non-compliance in the specification change process arises from an unstructured communication process. This problem stems from unclear responsibilities and procedures for conveying information about specification changes. In addition, management paid little attention to the importance of accurate and prompt information delivery, which ultimately resulted in delays in the process of implementing changes in the field. These shortcomings resulted in the team's inability to adapt to the changes, resulting in a mismatch between the work and the latest specifications.

Overall, the main problems found were a lack of effective communication and socialization, inadequate training, and a lack of management attention to the importance of implementing a quality monitoring and evaluation system. To overcome these problems, it is necessary to improve the aspects of regular training, improve the communication system between departments, and reaffirm the standards and specifications that must be followed in the field.

Analysis of Failure Mode and Effect Analysis (FMEA)

From the root cause of the problem obtained in the 5 why's analysis on the selected indicators, the next step is to determine the priority level for taking corrective action. The method used to determine the priority level is the Failure Mode and Effects Analysis (FMEA) method.

Table 2. FMEA Analysis Before Improvement

Indicator	Failure Mode	Effects of Failure	The Root of the Problem	S	O	D	RPN	Category Risk McDermott	Action
X4: Funding	Lack of a structured communication system	Delays in applying for funds will lead to project prolongation, which has the potential to increase costs and reduce work efficiency in the field.	Lack of a structured communication system to handle changes in design and project specifications.	9	7	6	378	High	Need for immediate action

Indicator	Failure Mode	Effects of Failure	The Root of the Problem	S	O	D	RPN	Category Risk McDermott	Action
Z1: Compliance with Quality Standards	Workers do not understand quality standards.	Defective products increase, high repair costs, and dissatisfied customers.	Lack of training and understanding of workers on quality standards due to the lack of management priority on training and regular quality evaluation	8	6	5	240	High	Need for immediate action
Z2: Compliance with Technical Specifications	Technical specifications are not well socialized.	Mismatched work results, rework, and delayed projects.	Lack of communication and socialization of technical specifications due to the absence of standard procedures that require socialization and poor communication between departments	7	7	6	294	High	Need for immediate action
Z3: Compliance with specification changes	Changes in specifications are not communicated in time.	Implementation errors, project delays, and increased costs.	The slow delivery of information related to changes in specifications due to poorly organized internal communication and the lack of management priority for change management	9	5	4	180	Medium	Corrective action needed

Source: Processed Data

Table 3. FEMA Analysis After Improvement

Delays in applying for funding will lead to project prolongation, which has the potential to increase costs and reduce work efficiency in the field.	Lack of a structured communication system to handle changes in project design and specifications.	Implement an integrated change management system with budget and funding update automation	6	3	2	36	Medium
Defective products increase, high repair costs, and dissatisfied customers.	Lack of training and understanding of workers on quality standards due to the lack of management priority on training and regular quality evaluation	Training and Education – Conduct regular training to improve workers' understanding of the expected quality standards.	4	2	6	48	Medium
Work results are not suitable, rework, and projects are delayed.	Lack of communication and socialization of technical specifications due to the absence of standard procedures that require socialization and poor communication between departments	Periodic Socialization - Conduct regular meetings to ensure all parties understand the necessary technical specifications.	3	2	6	36	Medium
Implementation errors, project delays, and increased costs.	The slow delivery of information related to changes in specifications due to poorly organized internal communication and the lack of management priority for change management	Formal Procedures for Changes – Develop formal procedures for managing and documenting all changes to specifications.	5	3	4	60	Medium

Source: Processed Data

In the Failure Mode and Effects Analysis (FMEA) analysis conducted on four main indicators, namely funding, compliance with quality standards, compliance with technical specifications, and compliance with specification changes, several potential failures were found along with their impacts and root causes. The Risk Priority Number (RPN) value is calculated based on the severity (S), chance of occurrence (Occurrence, O), and detectability (Detection, D) for each failure. The RPN value provides an indication of the risk and the priority of corrective action to be taken.

The results of FMEA analysis before improvement show that there are several failure modes with high RPN values, especially in indicators X4: funds/funding Z1: compliance with quality standards and Z2: compliance with technical specifications, which have RPNs of 378, 240 and 294 respectively. These three categories are classified as high risk and require immediate action to reduce the negative impact that could affect the smooth running of the project.

Meanwhile, in indicator Z3: Compliance with Specification Changes, although the RPN value of 180 falls into the medium category, corrective action is still needed to avoid future problems. Therefore, the focus of improvement needs to be on improving communication, periodic training, and implementing clearer and more organized standard procedures. This analysis provides a foundation for developing more appropriate improvement strategies, so that existing risks can be minimized, the project can run more efficiently, and the quality of the results can be maintained according to the set standards. To address the problems identified, various improvement strategies were implemented as follows:

1. X4: Implement an integrated change management system with budget automation - Develop a Standard Operating Procedure (SOP) that covers the steps of managing design changes, approving changes, and updating relevant budgets and schedules. All proposed changes must go through a verification process and be approved before implementation. With the aim of reducing the risk level of funding delays in construction projects. A more structured system enables faster change detection, reduces the frequency of problems, and minimizes their impact, making projects more efficient and timelier.
2. Z1: Training and Education - Conduct regular training to improve workers' understanding of the expected quality standards. The aim is to ensure workers understand the expected quality standards, thereby reducing errors and improving the quality of the work. Regular training also helps keep quality standards consistent throughout the project process.
3. Z2: Periodic Socialization - Conduct regular meetings to ensure all parties understand the required technical specifications. This aims to ensure every team member understands and follows the established technical specifications, reduce the risk of implementation errors, and accelerate project completion.
4. Z3: Formal Procedures for Changes - Develop formal procedures for managing and documenting all specification changes. With the aim of minimizing miscommunication and delays in implementing changes that could affect the project.

Based on the FMEA results after improvement, there is a significant decrease in the level of risk in each indicator. Table 3 shows the RPN value for each risk category after the implementation of the improvement strategy that has been carried out. Risk categories are determined based on the RPN value, which reflects the severity, frequency, and detectability of the identified risks.

In indicator X4, related to funds/funding with the strategy of implementing an integrated change management system with budget automation succeeded in reducing the RPN value from 378 to 36, with the risk category changing from "high" to "low". A more structured system enables faster detection of changes, reduces the frequency of problems, and minimizes their impact, making projects more efficient and timelier. Indicator Z1, related to compliance with quality standards, the routine training strategy succeeded in reducing the RPN value from

240 to 48, with the risk category changing from "High" to "Medium". This shows that regular training is effective in improving workers' understanding of quality standards, thereby reducing the frequency and impact of failures.

On indicator Z2, which concerns compliance with technical specifications, the periodic socialization implemented reduced the RPN from 294 to 36. This reduction shows that better communication between teams and departments helps minimize errors and project delays, with the risk also dropping from "High" to "Medium". And on indicator Z3 regarding compliance with changes to specifications, the development of formal procedures to manage changes reduced the RPN from 180 to 60. These procedures helped ensure specification changes were delivered on time, reducing the risk of implementation errors and additional costs.

Overall, all risk categories after remediation fall within the medium category, and the decrease in RPN values compared to the condition before remediation demonstrates the effectiveness of the measures implemented. However, it is important to continue to monitor and manage these risks on an ongoing basis.

Discussion of Research Results

The results of the research data analysis are then discussed further, including the main findings, relevance of the research, implications for the industry, and limitations of the research.

Key Findings

Analysis using SEM-PLS reveals that construction delay factors have a significant influence on quality standards and specifications, which in turn affect project quality performance. Quality standards and specifications also proved to be an important mediator in this relationship. The IPMA results show that factor X4 (funds/funding) has the greatest impact on project quality performance, followed by Z1 (adherence to quality standards), Z2 (adherence to technical specifications), and Z3 (adherence to specification changes). These findings confirm the importance of good financial management and consistent application of quality standards and specifications to improve project outcomes.

Through RCFA, key root causes were identified, such as lack of structured communication in funding management (X4), lack of training on quality standards (Z1), lack of socialization of technical specifications (Z2), and absence of formal procedures for managing specification changes (Z3). To address these issues, FMEA recommends corrective measures, including an integrated change management system, regular training, periodic specification socialization, and development of formal procedures for specification changes. Implementation of these strategies is projected to reduce project risk and improve overall performance quality.

CONCLUSION

Based on the factor analysis of construction delays on project quality performance mediated by quality standards and specifications, this study concludes that construction delays significantly influence quality standards and specifications, which directly impact project quality performance. SEM-PLS analysis confirmed that quality standards and specifications serve as significant mediators between delays and project quality ($p\text{-value} < 0.05$). IPMA highlighted key factors such as funding (X4) and adherence to quality standards, technical specifications, and specification changes (Z1, Z2, Z3) as critical to project quality. Using RCFA and FMEA, root causes like lack of training, poor technical communication, and disorganized specification change processes were identified, and targeted improvements notably reduced risk levels—for example, the RPN for funding dropped from 378 to 36, demonstrating effective mitigation. For future research, it is recommended to explore additional factors influencing project quality, develop more efficient delay control methods leveraging project management technologies, and apply the mediation model to other construction types such as roads or bridges. Furthermore, incorporating geographical factors and local regulations could broaden the applicability of these findings across the construction sector.

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