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Analysis of Communication Management Factors on Rework in Toll Road Construction Projects

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ABSTRACT

Rework is one of the main sources of inefficiency in construction projects because it has an impact on increasing costs, time, and material usage. In toll road projects that have linear work characteristics and involve many stakeholders, rework is often triggered by ineffective communication management. This study aims to identify the communication management factors that cause rework in toll road projects, and determine the dominant factors that cause it, assess the risk level of rework based on the frequency of occurrence and cost impact. The research method uses a quantitative approach through expert validation and surveys of respondents to the Jakarta-Merak Section project, multiple linear regression analysis, descriptive analysis, and risk analysis based on PMBOK® 6th Edition. The results showed that the failure factors of the three components of communication management, namely, planning, management, and monitoring of communication had a significant effect on rework (p-value < 0.05) with a simultaneous contribution of 55.5%. Ten dominant factors were successfully identified, with the main factors being specifications and less detailed working drawings that triggered design adjustments. Then the rework Wrisk analysis showed an average risk score of 0.060 which was in the low risk category. The findings of this study confirm that the effectiveness of communication management has a central role in minimizing rework in toll road projects. Improving the quality of document planning, clarity of communication flows, and information monitoring are needed to reduce the occurrence of rework and improve the efficiency of project resource use.

KEYWORDS communication management, rework, project risk, toll road construction

INTRODUCTION

The construction of toll roads is one of the government's strategic instruments for improving national connectivity, facilitating logistics flows, and reducing transportation costs (Banister & Berechman, 2017; Calderón & Servén, 2018). The Government of Indonesia, through the Ministry of Public Works and Public Housing (PUPR), has made the acceleration of toll road construction a main agenda item since the inclusion of various toll road sections in the National Strategic Project (PSN) (Prasetyo & Firdaus, 2019; Kurniawan et al., 2020). From 1978 to early 2024, the Ministry of PUPR, through the Toll Road Regulatory Agency (BPJT), recorded that the total length of expressways in Indonesia had reached 2,893 km. Broadly, these toll roads are distributed across almost all regions of Indonesia: the island of Sumatra (971.75 km), Java (1,782.47 km), Bali (10.07 km), Kalimantan (97.27 km), and Sulawesi (61.46 km). This length increased compared to the previous year, showing that construction activities are still being carried out on a large scale (World Bank, 2019; Asian Development Bank, 2020; BPJT, 2024).

Entering 2024 marks an important momentum, as the government has begun preparing the pipeline of toll road projects for 2024–2029, including new developments, PPP auctions, and the completion of ongoing projects (Dhapel, 2024; Tekin, 2018; Wibowo & Permana, 2015). The government has also set development priorities for the Trans-Sumatra corridor, expansion of the Trans-Java network, and acceleration of toll road construction in the Kalimantan, Sulawesi, Bali, and Nusa Tenggara regions, particularly to support the relocation of the National Capital City (IKN). Official documents such as the General Plan of the Toll Road Network, the PPP Project Plan for the Toll Road Sector, and the 2024 BPJT Evaluation Report form the basis of this acceleration policy (Ministry of PUPR, 2024). Based on the Ministry of PUPR's Vision until 2030, the target for achieving road stability is set at 99%. One of the key efforts to realize this target is through an infrastructure development plan for the 2025–2030 period, which includes a 2,461 km toll road construction target. This consists of: 1,112 km of construction on the island of Sumatra, 1,306 km on the island of Java, and 43 km on the island of Bali (Andriyono, 2018).

In terms of implementation, the challenges of toll road construction for the 2024–2029 period are increasingly complex due to the growing number of planned sections and diverse geographical conditions (Cvetković et al., 2024; Ndubuisi & FNisafetyE, 2025; Thaw, n.d.). These challenges include land acquisition readiness, stakeholder coordination, the accuracy of technical information delivery, and the risk of rework arising from suboptimal communication management during construction. Empirical studies show that rework in infrastructure projects can increase project costs by 5–15% and cause construction delays (Love et al., 2020). In toll road projects that are large-scale and cross-institutional, the potential for communication errors and rework becomes even more significant, requiring in-depth scientific study. For example, the Jakarta–Merak toll road project—aimed at increasing road capacity and connecting the provinces of Java and Sumatra—is dominated by heavy vehicles, most of which are freight carriers.

In practice, obstacles often occur during the construction process, causing delays in project completion. These delays stem from land acquisition processes, slow design reviews, and rework, which prevent projects from meeting their targets on time. Rework is a persistent problem that hinders construction performance by causing cost overruns and schedule delays. Operationally, rework is a non-value-adding activity because it involves repeating processes or correcting failed work. Data from the Grand Parkway project show a high frequency of quality mismatches—in one reporting period, 447 NCRs were recorded, accompanied by 263 construction deficiencies and 210 maintenance defects, all requiring repair. The large number of these findings underscores that rework is a crucial issue that can significantly reduce cost and time performance in toll road projects. A recent study on the Cinere–Serpong project revealed that rework costs reached 12.37% of the total construction cost, or approximately IDR 284 million (Sumadiyono et al., 2021).

Studies show that the root causes of rework mostly stem from managerial issues. Specifically, a lack of communication is among the three most significant causes of rework identified in construction projects (Yap et al., 2021). In complex projects such as toll roads, this communication failure creates coordination obstacles among various stakeholders. Project management in any organization relies heavily on effective communication, particularly in a global context. Project implementation is greatly influenced by an organization's ability to communicate (PMBOK, 2013). Good communication throughout all project stages is a key success factor that integrates other dimensions of project success. The factors leading to poor communication in construction projects that contribute to rework include inadequate communication planning, poor understanding of stakeholder needs and preferences, an ineffective flow of information, and insufficient coordination.

A study conducted by Alifen (2018) found that the factors causing rework in residential and building construction were leadership and communication (71.25%), while for industrial buildings, the dominant factors were engineering and review (67.50%). Other studies on road construction projects revealed that the resource factor had the highest percentage (74.86%) compared to design and communication (64.57%) and managerial factors (64.50%) (Puspa, 2022). In addition to planning and design aspects, recent research also identifies Project Dynamics and Communication Challenges (PDCC) as significant factors triggering rework in construction projects. With a high coefficient of influence (0.65), this factor shows that ineffective communication, miscoordination, and suboptimal information flow increase the likelihood of errors or rework (Gumusburun et al., 2025). Several studies consistently demonstrate that communication-related factors are among the most significant contributors to rework. For instance, in the road project in Rokan Hulu Regency, communication issues—such as poor information flow, lack of field information, and weak coordination and teamwork—were major contributors to rework, alongside inadequate work control as the dominant factor (Hidayat, 2013).

Therefore, research on the influence of communication management on rework in toll road construction projects is important to conduct. This understanding is expected to help identify critical points in the project communication flow and provide a foundation for improving communication management systems to minimize rework. This study aims to identify communication management factors that can cause rework and determine the level of rework risk in toll road construction projects, as evidence shows that rework has a significant negative impact on the construction process.

This section discusses the identification, formulation, and limitations of the problem, as well as the purpose, objectives, and benefits of the research, to systematically affirm the focus and scope of the study. This research is motivated by the prevalent issue of rework in toll road construction projects, which has a significant impact on project cost, time, and performance. This is reflected in numerous reports of non-conformities, construction deficiencies, and maintenance defects, indicating that rework is both routine and serious. In addition to technical factors and inadequate work control, communication management—such as poor information flow, lack of field information, and insufficient coordination and teamwork—is believed to contribute significantly to the occurrence of rework. However, there have been no comprehensive studies that identify and measure these communication factors to date.

Therefore, this study formulates research problems related to the factors causing rework in construction communication management, the level of rework risk in toll road projects, and the development of a recommendation model to minimize rework resulting from communication failures. The research is limited to a case study of the Jakarta–Merak toll road construction project, focusing on communication systems in the implementation and supervision of work, as well as identifying the dominant factors causing rework. The purpose of this study is to analyze the communication management factors that trigger rework, assess the risk level based on frequency and cost impact, and formulate relevant and applicable strategic recommendations. The results of this study are expected to provide academic contributions to the field of construction management, as well as practical benefits for projects and stakeholders through information and reference strategies in communication management to mitigate rework and its impact on material usage in toll road projects.

METHOD

Types of Research

This study employs a primary research approach using quantitative survey methods and case studies. The research design was formulated to address three main research questions related to the factors causing rework in construction communication management, the level of risks posed, and the development of a preventive recommendation model. The survey method was chosen because it allows the examination of group characteristics or individual behaviors through a quantitative approach, where a larger sample ensures more accurate representation of the population's conditions. Data were collected using a questionnaire with a Likert scale to measure the frequency of occurrences and the impact of rework on project time, cost, and quality.

Population and Sample

The research population includes all construction project personnel on the Jakarta–Merak Toll Road, particularly in two projects: the Addition of the 3rd Lane of the Cilegon Segment and the Construction of the Bitung Toll Interchange, with a total population of 62 personnel. The location was selected due to the toll road's characteristics as one of the oldest and busiest in Indonesia, marked by high complexity and frequent construction activities. The sample size was determined using the Slovin formula with a 95% confidence level (5% margin of error), resulting in 55 respondents. The sampling technique applied purposive sampling, with criteria that respondents must have at least a D3/S1 Engineering qualification, a minimum of three years of construction sector experience, and hold at least the position of engineering staff, quantity surveyor, or field supervisor.

Data Collection Techniques

Primary data were collected through two stages of questionnaires. The first stage involved expert validation by practitioners with at least 10 years of experience and academics holding a minimum of an S2 degree to verify the factors causing rework. The second stage distributed questionnaires to project respondents to measure the frequency and impact of rework using a Likert scale of 1–5. Secondary data were obtained from literature reviews of scientific journals, previous studies, and project documents such as design drawings, technical specifications, RKS, Bill of Quantity, and project reports. Measurements employed the Likert ordinal scale, with frequency categories ranging from very rare to very frequent, and impact categories on time, cost, and quality, defined by predetermined percentage ranges.

Data Analysis

Data analysis was conducted in five sequential stages to answer all research questions. The first stage identified factors through literature analysis and expert validation using the Delphi method. The second stage conducted a pilot survey to test the validity and reliability of the research instruments. The third stage applied multiple linear regression analysis to determine the influence of communication management factors on rework, complemented by homogeneity tests, validity–reliability testing using the Pearson Product Moment and Cronbach's Alpha (≥ 0.70), as well as t-tests and F-tests to assess the significance of variable effects. The fourth stage analyzed risk levels based on the PMBOK® Guide 6th Edition by multiplying frequency and impact values to categorize risks as low (0.01–0.07), medium (0.08–0.20), or high (0.24–0.72). The fifth stage conducted a comparative analysis of material usage between planned and actual quantities to measure the impact of rework on project material consumption.

RESULT AND DISCUSSION

1. Hypothesis Testing

Hypothesis test analysis was carried out to assess the extent to which the independent variables in the regression model had a significant effect on the dependent variables. This test aims to test the correctness of the theoretical conjecture that has been formulated previously using the results parameters of the analysis of the t-test and the F-test to assess the significance of the influence of independent variables on the dependent variables, either partially through the t-test and simultaneously through the F test.

1) Partial Testing (T Test)

Partial testing (t-test) was carried out to assess the significance of the influence of each independent variable on the dependent variable individually. Through this test, it can be known whether each variable makes a meaningful contribution in the regression model. The test criteria are: if the p-value is < α (0.05) or the t-value of the t-calculation > t-table, then H_0 is rejected and the variable is declared to have a significant effect; On the other hand, if p-value ≥ α or t-calculate ≤ t-table, then H_0 is accepted and the variable is declared to have no significant effect. For statistical testing purposes, the value of the t-table is obtained through the formula . With a sample count of 55 and three independent variables (), the degree of freedom obtained is . Based on the degree of freedom and significance level of 0.05, the t-table value for the two-tailed test = 2.008.$df = n - k - 1 k = 3 df = 55 - 3 - 1 = 51$

Table 1. T Test Results

Y1	Coefficient	Std. err.	t	P>|t|	[95% conf. interval]
X1	0.814011	0.303995	2.68	0.010	(0.203716, 1.424306)
X2	0.1460379	0.0623061	2.34	0.023	(0.209532, 0.2711227)
X3	1.325421	0.514091	2.58	0.013	(1.029334, 2.357501)
_cons	-0.4254419	1.198427	-0.36	0.724	(-2.831384, 1.9805)

(Source: Processed Author, 2025)

Table 2. Recapitulation of T Test Results

Variabel	T Count	T Table	Remarks
(X.1.)	2,68	2,008	Influential
(X.2.)	2,34	2,008	Influential
(X.3.)	2,58	2,008	Influential

(Source: Processed Author, 2025)

a. Influence of X.1. (Communication Management Plan) to Y (Rework)
The *t-value* = 2.68 with *the p-value* = 0.010 (< 0.05). These results show that partially, the Communication Management Plan variable has a significant effect on rework.
b. Influence X.2. (Managing Communication) to Y (Rework)
The *t-value* = 2.34 with *the p-value* = 0.023 (< 0.05). These results show that Managing Communication also has a significant effect on rework rework.
c. Influence X.3. (Communication Monitoring) against Y (Rework)
The *t-value* = 2.58 with *the p-value* = 0.013 (< 0.05). These results show that Communication Monitoring has a significant influence on rework rework.

2) Simultaneous Testing (F Test)

Simultaneous testing (F Test) was performed to assess whether all independent variables in the regression model together had a significant effect on the dependent variables. Decision-making is based on the F-statistical value and the resulting p-value, where H_0 is deducted if the p-value is smaller than the established significance level ($\alpha = 0.05$), or if the F-value is calculated to be greater than the F-table. Thus, the F-Test provides a basis for concluding whether the regression model as a whole is statistically significant. With the number of independent variables as many as 3, then $df_1 = k = 3$. Meanwhile, the degree of freedom of the denominator is calculated as $df_2 = n – k – 1$, i.e. 55 – 3 – 1 = 51. With a significance level of $\alpha = 0.05$, the F-table values for $df_1 = 3$ and $df_2 = 51$, then the F-value of the table is 2.786.

Table 3. F Test Results

Source	SS	df	MS
Model	260.706	3	86.902
Residual	209.003	51	4.098
Total	469.709	54	8.698

Additional values:

- Number of obs: 55
- F(3, 51): 21.21
- Prob > F: -0.008
- R-squared: -0.5558
- Adj R-squared: -0.5289
- Root MSE: 0.24

(Source: Processed Author, 2025)

The results of the F test (simultaneous) on the regression output showed *an F-calculated* value of 21.21 with *p-value* = 0.0000 (< 0.05). This means that simultaneously, the three independent variables, namely Communication Management Plan (X1), Communication Management (X2), and Communication Monitoring (X3), have a significant effect on the dependent variables of *Rework*.

2. Mean and Ranking Analysis

The mean and ranking analysis was carried out as an additional step to identify the communication management indicators that had the highest level of assessment from respondents and that most often appeared in project practice. Through the calculation of the mean value, each indicator in the variables of Communication Management Plan (X.1.), Managing Communication (X.2.), and Communication Monitoring (X.3.) was evaluated to determine the tendency of respondents' perception of each aspect. Furthermore, the ranking process is used to determine which indicators are the most dominant and have the potential to contribute more to the occurrence of rework.

Table Error! No text of specified style in document. **Variable Indicator Ranking Data X.1. Communication Management Plan**

(X.1.) Communication Management Plan			
Indicator	**Ranking**	**Mean**	**Std. Dev**
X.1.1	7	2,364	1,207
X.1.2	10	2,236	0,999
X.1.3	6 (10)	2,382	1,239
X.1.4	4 (7)	2,400	1,180
X.1.5	3 (5)	2,436	1,198
X.1.6	12	2,000	1,000
X.1.7	9	2,273	0,970
X.1.8	5 (9)	2,382	0,971
X.1.9	8	2,327	0,943
X.1.10	11	2,182	0,795
X.1.11	13	1,982	0,781
X.1.12	1 (1)	2,618	1,045
X.1.13	2 (4)	2,491	0,900

(Source: Processed Author, 2025)

Table 5 Variable Indicator Ranking Data X.2. Managing Communications

(X.2.) Managing Communications			
Indicator	Ranking	Mean	Std. Dev
X.2.1	1 (2)	2,527	0,766
X.2.2	6	2,164	0,855
X.2.3	9	1,873	0.840
X.2.4	7	2,055	0,931
X.2.5	3 (6)	2,418	0,956
X.2.6	4	2,255	0,775
X.2.7	2 (3)	2,509	0,766
X.2.8	5	2,218	0,762
X.2.9	8	1,909	0,822

(Source: Processed Author, 2025)

Table 6 Variable Indicator Ranking Data X.3. Communication Monitoring

(X.3.) Communication Monitoring			
Indicator	Ranking	Mean	Std. Dev
X.3.1	7	2,236	0,881
X.3.2	5	2,255	0,947
X.3.3	2	2,364	0,754
X.3.4	1 (8)	2,382	0,680
X.3.5	3	2,327	0,794
X.3.6	11	2,018	0,680
X.3.7	8	2,218	0,762
X.3.8	12	2,018	0,652
X.3.9	6	2,236	0,744
X.3.10	10	2,127	0,746
X.3.11	4	2,309	0,813
X.3.12	9	2,218	0,896

(Source: Processed Author, 2025)

From the data analysis carried out on the indicators in each variable, there are the top 10 combined indicator ranking values in each variable in the following order:

Table 7 Ranking Sequence of Factors Causing Rework

No	Factor Codes	Factors Causing Rework
1.	X.1.12	Specifications, working drawings are less detailed and less accurate so that design adjustments often occur.
2.	X.2.1	Information must pass through many parties so that it can change or be delayed.
3.	X.2.7	There are requests for information that are sudden and not part of the routine process.
4.	X.1.13	Inaccurate data submission in the creation of detailed drawings by the contractor, allowing for revision of documents.
5.	X.1.5	Lack of ability to communicate internally between project workers.
6.	X.2.5	There was a delay in information on design changes during construction causing rework.
7.	X.1.4	Delays in providing on-site information from project team members and stakeholders
8.	X.3.4	Delay in decision-making on all work in project implementation.
9.	X.1.8	The obligations of the parties to the contract are poorly understood due to weak communication mechanisms.
10.	X.1.3.	Lack of manpower or capacity causes project communication not to go as planned.

(Source: Processed Author, 2025)

3. Risk Level Analysis

In this study, risk analysis is focused on identifying and measuring the risk of rework in toll road projects. Measurements are carried out based on two main components, namely the frequency of events and the *cost impact*, to obtain a risk score. This approach is used because the impact of costs is considered the most representative indicator in describing the financial consequences of rework risk. Every rework incident has the potential to cause additional expenses, either due to the reuse of resources, work delays, or adjustments to construction schedules.

This analysis is aligned with the 6th edition of the PMBOK risk matrix approach, which assesses risk based on a combination of probability and impact (*probability × impact*). In this study, the frequency of rework events was treated as a representation of probability, while cost impact was used as the main indicator of the level of consequence. The two parameters were then mapped into low, medium, and high categories according to the 6-year PMBOK risk matrix structure.

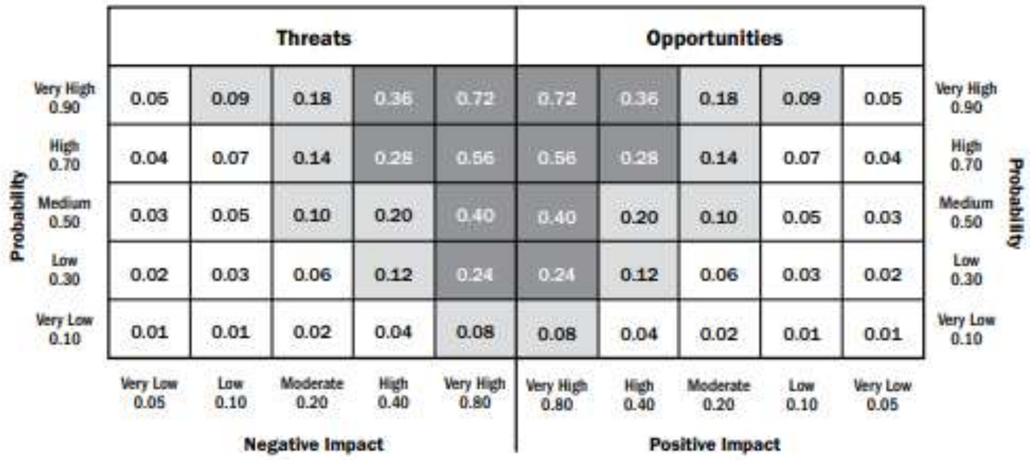

Figure 1. Probability and Impact Matrix
Source: PMBOK Guide 6th Edition

Table 8 Results of Rework Risk Analysis Calculation

They respond	Respondent's Answer		Value Based on *Probability and Impact Matrix PMBOK 6th*		Frequency x Impact	Level Risk
	Rework Frequency	Impact of Rework	Rework Frequency	Impact of Rework		
R1	Low	Low	0.30	0.10	0.03	Low
R2	Low	Low	0.30	0.10	0.03	Low
R3	Medium	Medium	0.50	0.20	0.1	Medium
R4	Medium	Medium	0.50	0.20	0.1	Medium
R5	Height	Medium	0.70	0.20	0.14	Medium
R6	Low	Low	0.30	0.10	0.03	Low
R7	Medium	Low	0.50	0.10	0.05	Low
R8	Very Low	Very Low	0.10	0.05	0.005	Low
R9	Low	Medium	0.30	0.20	0.06	Low
R10	Very Low	Very Low	0.10	0.05	0.005	Low
R11	Low	Low	0.30	0.10	0.03	Low
R12	Low	Medium	0.30	0.20	0.06	Low
R13	Low	Height	0.30	0.40	0.12	Medium
R14	Medium	Medium	0.50	0.20	0.1	Medium
R15	Very Low	Height	0.10	0.40	0.04	Low

They respond	Respondent's Answer		Value Based on *Probability and Impact Matrix PMBOK 6th*		Frequency x Impact	Level Risk
	Rework Frequency	Impact of Rework	Rework Frequency	Impact of Rework		
R16	Low	Height	0.30	0.40	0.12	Medium
R17	Very Low	Low	0.10	0.10	0.01	Low
R18	Medium	Medium	0.50	0.20	0.1	Medium
R19	Medium	Low	0.50	0.10	0.05	Low
R20	Medium	Medium	0.50	0.20	0.1	Medium
R21	Medium	Low	0.50	0.10	0.05	Low
R22	Low	Low	0.30	0.10	0.03	Low
R23	Medium	Medium	0.50	0.20	0.1	Medium
R24	Very Low	Very Low	0.10	0.05	0.005	Low
R25	Medium	Medium	0.50	0.20	0.1	Medium
R26	Very Low	Low	0.10	0.10	0.01	Low
R27	Low	Height	0.30	0.40	0.12	Medium
R28	Very Low	Medium	0.10	0.20	0.02	Low
R29	Very Low	Height	0.10	0.40	0.04	Low
R30	Low	Very High	0.30	0.80	0.24	Height
R31	Height	Height	0.70	0.40	0.28	Height
R32	Low	Very Low	0.30	0.05	0.015	Low
R33	Low	Low	0.30	0.10	0.03	Low
R34	Very Low	Very Low	0.10	0.05	0.005	Low
R35	Low	Low	0.30	0.10	0.03	Low
R36	Medium	Medium	0.50	0.20	0.1	Medium
R37	Low	Low	0.30	0.10	0.03	Low
R38	Very Low	Very Low	0.10	0.05	0.005	Low
R39	Low	Low	0.30	0.10	0.03	Low
R40	Low	Low	0.30	0.10	0.03	Low
R41	Medium	Medium	0.50	0.20	0.1	Medium
R42	Low	Low	0.30	0.10	0.03	Low
R43	Very Low	Very High	0.10	0.80	0.08	Medium
R44	Medium	Low	0.50	0.10	0.05	Low
R45	Low	Low	0.30	0.10	0.03	Low
R46	Low	Low	0.30	0.10	0.03	Low
R47	Very Low	Very Low	0.10	0.05	0.005	Low
R48	Low	Low	0.30	0.10	0.03	Low
R49	Low	Height	0.30	0.40	0.12	Medium
R50	Very Low	Very Low	0.10	0.05	0.005	Low
R51	Medium	Medium	0.50	0.20	0.1	Medium
R52	Low	Medium	0.30	0.20	0.06	Low
R53	Low	Medium	0.30	0.20	0.06	Low
R54	Medium	Low	0.50	0.10	0.05	Low
R55	Very Low	Very Low	0.10	0.05	0.005	Low

(Source: Processed Author, 2025)

Table 9 Risk Level Analysis Results

Variable	Obs	Mean	Std. dev.	Min	Max
risk_score	55	0.0600909	0.0552309	0.005	0.28

risk_cat	Freq.	Percent	Cum.
Rendah (0.01-0.07)	37	67.27	67.27
Sedang (0.08-0.20)	16	29.09	96.36
Tinggi (0.24-0.72)	2	3.64	100.00
Total	55	100.00	

(Source: Processed Author, 2025)

Based on the results of the calculation of *the risk score* (frequency × cost impact), an average risk value of 0.0600 was obtained with a minimum value of 0.005 and a maximum of 0.28. The average value is in the low risk category (0.01–0.07), which indicates that in general, the level of *risk of rework* in toll road projects is still within acceptable limits, with the potential for a relatively small cost impact on the total project budget. The distribution of risk level categories based on respondents' perceptions shows that:

a. 37 respondents (67.27%) were in the low risk category (0.01–0.07). which is the most dominant category.
b. 16 respondents (29.09%) were in the medium risk category (0.08–0.20).
c. 2 respondents (3.64%) were in the high-risk category (0.24–0.72).

Most of the respondents' perceptions show that the risk of rework in toll road projects is in the low category, but more than 20% of respondents consider the risk to be moderate, so this aspect needs special attention in project management to maintain efficiency and cost control.

1. Discussion of Communication Management Factors That Cause Rework

Based on the results of expert validation and respondent surveys, this study shows that the three main aspects in communication management, namely communication planning (X.1.), communication management (X.2.), and communication monitoring (X.3.) have contributed to influencing the occurrence of rework in toll road construction projects. These three aspects are interrelated as a unit of the communication process as stated in PMBOK (2017), so that weaknesses in one of them can worsen the effectiveness of communication as a whole.

Based on the study literature that has been conducted, there are many factors that cause rework in construction projects. The causative factors have been grouped by Fayek et al. (2004) One of the factors causing rework is poor communication between stakeholders. The findings show that communication problems that occur in the field do not stand alone, but arise due to a series of communication processes that do not run optimally from the planning, implementation, to supervision stages. This condition is in line with the opinion (El-Saboni et al., 2009) which states that ineffective communication can hinder mutual understanding between parties, which ultimately increases the risk of errors and rework.

In this study, it was found that 36 factors caused rework in communication management were identified based on the results of literature studies which were then validated by experts so that 34 factors caused rework in communication management in construction projects. Then based on these 34 factors, a survey of respondents was conducted on the Toll Road Project located on the Jakarta-Merak Section.

2. Influence of X.1. Communication Planning for Y Rework (Rework)

Based on the results of the study, it was found that the influence of causative factors (rework) on X.1. Communication Planning for Y (Rework) shows that t-value = 2.68 with p-value = 0.010 (< 0.05). These results show that partially, the Communication Planning variable has a significant effect on rework. This shows that the better the communication planning process so that the factors causing the rework are low, which include identifying information needs, determining communication flows, determining document formats, and scheduling information distribution, the lower the rework of the project. On the contrary, weaknesses in the planning stage cause factors that cause rework such as unclear information, delays in technical revisions, and misunderstandings between stakeholders, thereby increasing the potential for rework.

3. Influence X.2. Communication Management to Y Rework (Rework)

Based on the results of the study, it was found that the influence of causative factors (rework) on X.2. Communication Management to Y (Rework) shows that t-value = 2.34 with p-value = 0.023 (< 0.05). These results show that partially, the Communication Management variable has a significant effect on rework. This shows that the worse the communication management process, the higher the potential for rework. Failure to manage communication in the field causes technical information not to be conveyed completely, work instructions are not documented, design revisions are not distributed to all stakeholders, and the results of coordination meetings are not followed up systematically. This condition encourages misinterpretation, execution errors, and work that must be dismantled and redone.

4. Influence X.3. Communication monitoring of Y Rework (Rework)

Based on the results of the study, it was found that the influence of causative factors (rework) on X.3. Communication monitoring of Y (Rework) showed that t-value = 2.58 with p-value = 0.013 (< 0.05). These results show that partially, the Communication monitoring variable has a significant effect on rework. These findings show that the worse the communication monitoring process in a project, the higher the potential for implementation errors, deviations in technical instructions, and non-conformities in specifications that ultimately trigger rework. This suggests that weaknesses in the communication monitoring process contribute directly to the increased risk of rework, as uncontrolled and poorly verified information often leads to misinterpretations in the field.

5. Multiple Linear Regression Equations

The results of multiple linear regression analysis yielded the equation: Y=-0.4254419+0.0814011X_1+0.1460379X_2+0.1325421X_3

This equation shows how communication management variables consisting of communication planning (X.1.), communication management (X.2.), and communication monitoring (X.3.) affect the occurrence of rework in toll road construction projects.

A constant value of –0.4254419 indicates that when all three independent variables are at zero or do not occur at all, then the rework value is –0.43. This negative value is not interpreted as "negative rework", but indicates that without the contribution of these three variables, the rework rate is at a minimal condition (close to very low), and rework only occurs when the three communication factors begin to increase in value (e.g. ineffectiveness in planning, managing, and monitoring communication).

Regression coefficient for variable X.1. With a positive value of 0.0814, it shows that every one unit increase in communication planning has the potential to increase rework by 0.0814. If the factors cause rework on X.1. (communication planning) increases, so the rework value predicted by the model will also increase. This is in line with the positive regression coefficient on the X.1 variable, which shows that weaknesses in communication planning contribute directly to the increased potential for rework in construction projects.

Variable regression coefficient X.2. 0.1460 is the highest positive value among all variables in the model, which suggests that a one-unit increase in communication management activities can increase rework by 0.1460, assuming the other variables are constant. If the factors cause rework on X.2. The increase in the rework value predicted by the model will also increase. These findings indicate that the communication management aspect has the most dominant role in influencing the occurrence of rework. Thus, the quality of communication management is a critical factor that must be improved to minimize the risk of rework and ensure the alignment of information in the implementation of construction projects.

Variable regression coefficient X.3. value 0.1325, which indicates that a one-unit increase in communication monitoring activities has the potential to increase rework by 0.1325. Conceptually, communication monitoring aims to ensure that the flow of information runs effectively. However, the results of this study show that poorly coordinated monitoring activities can increase the administrative burden, slow down field responses, or even lead to an accumulation of unfiltered information, leading to increased rework.

Thus, the results of this multiple linear regression show that the three communication management variables together have a positive influence on the increase in rework in toll road construction projects. This condition proves that ineffectiveness in planning, management, and monitoring communication has significantly contributed to the emergence of rework. These findings are in line with previous research (Muhammad & Abdelhamed, 2022) which found that the seven main categories that contribute to rework are human factors, coordination and communication, technical and engineering issues, owner-related factors, project management, contract issues, and design issues. Similar results were also obtained (Yap. Chong et.al, 2020) who stated the importance of effective communication, proper supervision, and good project management to reduce rework in construction projects. Therefore, the research hypothesis that states that "problem factors of construction project communication management can cause rework in toll road construction projects" is acceptable and empirically proven.

6. Discussion of the Highest Factors Causing Rework in Communication Management

Based on the results of the mean and ranking analysis of all indicators of communication management variables (X.1., X.2., and X.3.), ten indicators with the highest ranking values were obtained that had the greatest potential to contribute to the occurrence of rework. These indicators consist of aspects of communication planning, communication management, and communication monitoring, each of which has an important role in the success of information delivery during the implementation of road construction projects. The results of the combined rankings of the three variables show the order of the top ten indicators, namely:

a) (X.1.12.) Specifications, working drawings are less detailed and less accurate so that design adjustments are often made.
b) (X.2.1.) Information must pass through multiple parties so that it can change or be delayed.
c) (X.2.7.) There are requests for information that are sudden and not part of the routine process.
d) (X.1.13.) Inaccurate data submission in the creation of detailed drawings by the contractor, allowing for revision of documents.
e) (X.1.5.) Lack of ability to communicate internally between project workers.
f) (X.2.5.) There is a delay in information on design changes during construction causing rework.
g) (X.1.4.) Delays in providing on-site information from project team members and stakeholders
h) (X.3.4.) Delays in decision-making on all work in the implementation of the project.
i) (X.1.8.) The obligations of the parties to the contract are poorly understood due to weak communication mechanisms.
j) (X.1.3.) Lack of manpower or capability causes project communication not to go as planned.

The ranking results show that most of the highest-ranked indicators come from the Communication Management Plan (X1) variables, specifically the X.12, X.1.13, X.1.5, X.1.4, X.1.8, and X.1.3 indicators. This shows that weaknesses in the communication planning stage are a crucial factor that contributes to the occurrence of implementation and rework errors. These findings are in line with (Hwang and Goh, 2014) who found that many rework is often caused by poor communication, unclear client needs, sudden changes from clients, as well as errors in documentation and initial planning.

7. Discussion of Rework Risk Analysis in Toll Road Projects

The results of the risk level analysis show that rework in toll road projects has a relatively low risk level, as reflected in the average risk score of 0.0600, which falls within the low-risk category (0.01–0.07). This value indicates that the frequency of rework occurrences and the associated cost impacts remain within acceptable project tolerance limits. The minimum risk level of 0.005 represents rework events with very minor cost impacts, while the maximum value of 0.28 suggests that certain cases of rework, although infrequent, can have significant cost implications.

Overall, these results demonstrate that the analyzed toll road projects possess a relatively effective quality control system and implementation management practices in preventing large-scale rework. However, the presence of respondents who categorized risks as medium to high indicates that quality control, change control, and communication management effectiveness still require particular attention—especially to prevent rework with major impacts on project costs and schedules.

These findings are consistent with previous research by Ardiyawan et al. (2020), which confirmed that risks associated with design changes, technical errors, and coordination among parties can trigger rework that affects project costs and schedules, even if such events do not occur frequently.

CONCLUSION

Based on the results of analysis and discussion, this study concludes that communication management has a significant role in the occurrence of rework in toll road construction projects. A total of 34 factors causing rework were successfully identified and validated, which simultaneously affected the occurrence of rework by 55.5%, with 10 dominant factors being statistical test results, where the highest factors were unclear specifications and poorly detailed and inaccurate work drawings, which reflected technical communication failures. The results of the risk assessment showed that rework was in the low-risk category with an average risk score of 0.0600, so the frequency and cost impact were still relatively tolerable, although some cases showed significant impacts and indicated the need to improve quality control, change control, and communication effectiveness. So that better management of communication management is an important need to minimize rework on toll road projects.

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