

An Adaptive Risk Management Strategy Model for the Successful Implementation of the Bhayangkara 1-Graha Raya-Pondok Serut-Kayu Gede 1-Kayu Gede 2 Road Improvement Project

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Abstract : This study aims to develop an adaptive risk management strategy model to improve the success of the Bhayangkara 1 – Graha Raya – Pondok Serut – Kayu Gede 1 – Kayu Gede 2 Road Improvement Project. The study employs a quantitative approach using a survey method. Data were collected through questionnaires distributed to project personnel and analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS) and Importance Performance Map Analysis (IPMA). The variables examined include project environmental conditions, human resources, construction equipment, adaptive risk management strategy, and project success. The findings indicate that project environmental conditions and construction equipment have a positive and significant effect on adaptive risk management strategy, while human resources do not show a significant effect. Furthermore, adaptive risk management strategy has a positive and significant influence on project success, particularly in achieving project objectives related to cost, time, and quality. The study concludes that implementing an adaptive risk management strategy supported by a conducive project environment and adequate construction equipment is essential for enhancing the success of road improvement projects.

Keywords : Adaptive Risk Management Strategy, Project Success, Road Improvement Project, Project Environment, Construction Equipment, SEM-PLS.

Abstrak : Penelitian ini bertujuan mengembangkan model strategi manajemen risiko adaptif untuk meningkatkan keberhasilan Proyek Peningkatan Jalan Bhayangkara 1 – Graha Raya – Pondok Serut – Kayu Gede 1 – Kayu Gede 2. Penelitian ini menggunakan pendekatan kuantitatif dengan metode survei. Data dikumpulkan melalui kuesioner yang disebarkan kepada personel proyek dan dianalisis menggunakan Structural Equation Modeling–Partial Least Squares (SEM-PLS) serta Importance Performance Map Analysis (IPMA). Variabel yang dikaji meliputi kondisi lingkungan proyek, sumber daya manusia, peralatan konstruksi, strategi manajemen risiko adaptif, dan keberhasilan proyek. Hasil penelitian menunjukkan bahwa kondisi lingkungan proyek dan peralatan konstruksi berpengaruh positif dan signifikan terhadap strategi manajemen risiko adaptif, sedangkan sumber daya manusia tidak menunjukkan pengaruh yang signifikan. Selain itu, strategi manajemen risiko adaptif berpengaruh positif dan signifikan terhadap keberhasilan proyek, terutama dalam pencapaian tujuan proyek yang berkaitan dengan biaya, waktu, dan kualitas. Penelitian

ini menyimpulkan bahwa penerapan strategi manajemen risiko adaptif yang didukung oleh lingkungan proyek yang kondusif dan ketersediaan peralatan konstruksi yang memadai menjadi faktor penting dalam meningkatkan keberhasilan proyek peningkatan jalan.

Kata kunci: Strategi Manajemen Risiko Adaptif, Keberhasilan Proyek, Proyek Peningkatan Jalan, Lingkungan Proyek, Peralatan Konstruksi, SEM-PLS.

INTRODUCTION

A toll road is a highway where users are required to pay a toll, in accordance with Government Regulation of the Republic of Indonesia Number 15 of 2005. The Minimum Service Standards (SPM) established under the Regulation of the Minister of Public Works and Public Housing (PUPR) Number 16/PRT/M/2014 mandate that toll road users receive quality service and encounter good road conditions (Dina & Amin, 2025). Road infrastructure plays a vital role in supporting economic growth, community mobility, and the equitable distribution of development across regions. When road infrastructure is insufficient or poorly maintained, its ability to support these functions is significantly reduced. Inadequate road network facilities will cause traffic congestion problems (Isradi et al., 2021). Well-developed roads enhance transportation accessibility, facilitate the efficient movement of goods and services, and support the social and economic activities of communities. Therefore, the development and improvement of road infrastructure have become one of the government's key priorities in promoting national development. According to the Ministry of Public Works of the Republic of Indonesia (2023), road infrastructure development continues to be carried out to improve regional connectivity and support sustainable economic growth.

In practice, road construction projects are highly complex, as they involve multiple resources, construction methods, technologies, and dynamic site conditions. These complexities expose construction projects to various risks that may affect project success, including project environmental factors, human resources, construction equipment, material delivery delays, and changes in site conditions during project execution. The Project Management Institute (PMI, 2021) defines project risk as an uncertain event or condition that, if it occurs, may have an impact on project objectives, particularly in terms of cost, quality, and schedule.

This study was conducted on the Bhayangkara 1 – Graha Raya – Pondok Serut – Kayu Gede 1 – Kayu Gede 2 Road Improvement Project located in South Tangerang City, Banten Province, with a contract value of IDR 11,737,246,300 and a planned implementation period of 26 weeks, as specified in the Project Budget Plan (RAP) and the project S-curve. The project is one of the road improvement projects with a high level of traffic activity, exposing it to various potential risks during implementation, including weather conditions, limited working space, traffic congestion, workforce coordination, and the use of construction equipment. These conditions require an adaptive risk management strategy capable of responding to dynamic site conditions to ensure that the project's cost, quality, and schedule objectives are achieved optimally. During implementation, however, the project encountered potential delays due to heavy daily traffic volumes and unpredictable weather conditions in South Tangerang. Traffic congestion during peak hours required the project team to reschedule asphalt paving activities to nighttime in order to minimize delays and prevent increased operational costs of heavy equipment. These challenges were further intensified by limited equipment maneuvering space in several densely populated road segments. These empirical findings indicate that project success is strongly influenced by the ability to adapt project execution strategies to changing field conditions, such as shifting paving activities to nighttime to mitigate the impact of traffic congestion. Therefore, an adaptive risk management strategy is essential to effectively manage potential risks while ensuring the achievement of the project's cost, quality, and schedule targets.

This study is important to identify how supporting variables can be integrated into an adaptive risk management strategy to ensure the simultaneous achievement of the project's triple constraint objectives—cost, quality, and time. One of the key factors influencing the implementation of road

construction projects is the project environment. An unfavorable project environment may hinder on-site activities and increase project uncertainty. Rafki and Jumas (2024) found that weather conditions, project site accessibility, and work area conditions significantly affect the effectiveness of road construction project implementation. In addition, traffic congestion and limited workspace may lead to project delays if they are not properly managed.

In addition to the project environment, human resources also play a crucial role in ensuring the success of construction projects. A competent workforce with effective coordination can help projects overcome various challenges encountered during project implementation. As stated by Olanrewaju (2025), high-quality human resources enhance work productivity and enable projects to achieve their cost, quality, and schedule objectives more effectively. Conversely, inadequate workforce competence, poor communication, and a lack of work discipline can increase the likelihood of construction errors and project delays.

Another factor influencing project success is construction equipment. The appropriate use of construction equipment can improve work efficiency and accelerate project completion, whereas equipment failure or an insufficient number of machines may disrupt project activities and delay project execution. Ayu et al. (2024) found that adequate construction equipment enhances work productivity and helps reduce implementation obstacles encountered during road construction projects.

To address these various risks, an adaptive risk management strategy is required to respond effectively to the dynamic conditions of construction projects. Adaptive risk management is an approach that involves the flexible identification, assessment, monitoring, and control of risks in accordance with changing project conditions throughout the project lifecycle. Hillson (2024) emphasized that adaptive risk management is essential in construction projects due to their high level of uncertainty and the need for rapid responses to evolving project conditions. By implementing an adaptive risk management strategy, construction projects are expected to minimize the impact of potential risks and enhance the achievement of project success in terms of cost, quality, and schedule. Project success in this study is measured by the achievement of the project's cost, quality, and schedule objectives. Kerzner (2023) stated that a project can be considered successful if it is completed within the approved budget, on schedule, and in accordance with the specified quality standards. Therefore, the ability to effectively manage project risks is one of the key factors in ensuring the successful implementation of road construction projects.

This study employs Structural Equation Modeling–Partial Least Squares (SEM-PLS) to analyze the relationships among the research variables, as this method enables the simultaneous analysis of latent variables and is well suited for studies with relatively small sample sizes. In addition, Importance–Performance Map Analysis (IPMA) is applied to identify factors that have high importance but relatively low performance, thereby establishing priorities for improving project success. Iskandar (2025) demonstrated that the combination of SEM-PLS and IPMA provides a comprehensive approach for analyzing interrelationships among variables while identifying key factors that require improvement. Therefore, this study is expected to provide a more comprehensive analysis for formulating an adaptive risk management strategy in road improvement projects.

RESEARCH METHODS

This study employs a quantitative data analysis approach using Structural Equation Modeling–Partial Least Squares (SEM-PLS), implemented with SmartPLS 4 software. In addition, Importance–Performance Map Analysis (IPMA) is applied to identify the priority factors for improving the success of road improvement projects. The analysis consists of two main stages: measurement model (outer model) evaluation and structural model (inner model) evaluation. The measurement model is assessed to ensure the validity and reliability of the research instrument. Convergent validity is evaluated using outer loadings and the Average Variance Extracted (AVE), with acceptable thresholds of ≥ 0.70 for outer loadings and ≥ 0.50 for AVE. Reliability is assessed using Cronbach's Alpha and Composite Reliability, with values of ≥ 0.70 indicating satisfactory

reliability. Discriminant validity is examined using the Heterotrait–Monotrait Ratio (HTMT), where HTMT values below 0.90 indicate adequate discriminant validity (Hair et al., 2022).

Furthermore, Importance–Performance Map Analysis (IPMA) is conducted by integrating the importance and performance values of each research variable and indicator. Variables or indicators with high importance but low performance are identified as priority areas for improvement, providing strategic guidance to enhance the success of road improvement projects.

In this study, the population and sample were determined based on the respondents' involvement in the road improvement project. Respondents were selected because they possessed the knowledge, experience, and understanding of the project environment, human resources, construction equipment, adaptive risk management strategies, and project success. The sample was selected using a purposive sampling technique to ensure that the respondents were relevant to the objectives of the study. The minimum sample size was determined based on the 10-times rule, which is a widely accepted guideline in Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis. The research instrument consisted of a structured questionnaire developed using a five-point Likert scale, which was employed to measure respondents' perceptions and opinions regarding the research variables.

Primary data in this study were obtained directly from respondents through questionnaires distributed to project personnel involved in the implementation of the Bhayangkara 1 – Graha Raya – Pondok Serut – Kayu Gede 1 – Kayu Gede 2 Road Improvement Project. The questionnaire measured respondents' perceptions regarding project environmental conditions, human resources, construction equipment, adaptive risk management strategies, and project success. Secondary data were obtained from project administrative documents to support the interpretation of questionnaire results, including contract documents, Bill of Quantities (BoQ), technical specifications, weekly and monthly progress reports (S-Curve), material approval documents, and work permit records. These secondary data were used to validate project progress, identify schedule deviations, and support the analysis of construction equipment utilisation and adaptive risk management implementation.

RESULTS AND DISCUSSION

Table 1. Direct Effect Test

Hubungan	P Value
X1 → Z	0,000
X2 → Z	0,061
X3 → Z	0,000
Z → Y	0,021
X1 → Y	0,247
X2 → Y	0,282
X3 → Y	0,857

Based on the direct effect test presented in Table 1, Project Environmental Conditions (X1) have a positive and significant effect on Adaptive Risk Management Strategy (Z), with a p-value of 0.000. Construction Equipment (X3) also has a positive and significant effect on Adaptive Risk Management Strategy, with a p-value of 0.000. In contrast, Human Resources (X2) do not have a significant effect on Adaptive Risk Management Strategy, as indicated by a p-value of 0.061. Although this value is slightly above the significance threshold of 0.05, the corresponding hypothesis is rejected. Regarding Project Success (Y), only Adaptive Risk Management Strategy (Z) demonstrates a positive and significant direct effect, with a p-value of 0.021. The other exogenous variables Project Environmental Conditions (X1; $p = 0.247$), Human Resources (X2; $p = 0.282$), and Construction Equipment (X3; $p = 0.857$) do not exhibit significant direct effects on Project Success (Y).

Table 2. Indirect Effect Test

Relationship	P Value
$X1 \rightarrow Z \rightarrow Y$	0,052
$X2 \rightarrow Z \rightarrow Y$	0,156
$X3 \rightarrow Z \rightarrow Y$	0,052

Based on the indirect effect test presented in Table 2, the indirect paths from Project Environmental Conditions (X1) to Project Success (Y) through Adaptive Risk Management Strategy (Z) and from Construction Equipment (X3) to Project Success (Y) through Adaptive Risk Management Strategy (Z) each produced a p-value of 0.052. These values are very close to the 0.05 significance threshold and are therefore considered marginally significant, indicating a tendency toward mediation, although they do not meet the 5% significance criterion. Meanwhile, the indirect path from Human Resources (X2) to Project Success (Y) through Adaptive Risk Management Strategy (Z) yielded a p-value of 0.156, indicating that Adaptive Risk Management Strategy does not significantly mediate the relationship between Human Resources and Project Success.

Table 3. Hypothesis Testing

Hypothesis	Relationship	P-Value	Decision
H1	$X1 \rightarrow Z$	0.000	Accepted
H2	$X2 \rightarrow Z$	0.061	Rejected
H3	$X3 \rightarrow Z$	0.000	Accepted
H4	$Z \rightarrow Y$	0.021	Accepted
H5	$X1 \rightarrow Y$	0.247	Rejected
H6	$X2 \rightarrow Y$	0.282	Rejected
H7	$X3 \rightarrow Y$	0.857	Rejected

The results of H2 indicate that Human Resources (X2) do not have a significant effect on Adaptive Risk Management Strategy (Z), with a path coefficient of -0.316 and a p-value of 0.061. Since this value is slightly above the significance threshold of 0.05, H2 is rejected, although the relationship is close to being statistically significant. The results of H3 indicate that Construction Equipment (X3) has a positive and significant effect on Adaptive Risk Management Strategy (Z), with a path coefficient of 0.604 and a p-value of 0.000. Therefore, H3 is accepted. The results of H4 indicate that Adaptive Risk Management Strategy (Z) has a positive and significant effect on Road Improvement Project Success (Y), with a path coefficient of 0.510 and a p-value of 0.021. Therefore, H4 is accepted. The results of H5, H6, and H7 indicate that Project Environmental Conditions (X1), Human Resources (X2), and Construction Equipment (X3) do not have significant direct effects on Road Improvement Project Success (Y), with p-values of 0.247, 0.282, and 0.857, respectively. Accordingly, all three hypotheses are rejected.

Overall, the hypothesis testing results indicate that H1, H3, and H4 are supported, whereas H2, H5, H6, and H7 are not supported. These findings suggest that the success of road improvement projects is not directly determined by project environmental conditions, human resources, or construction equipment, but rather by the project's ability to implement an Adaptive Risk Management Strategy. This finding reflects actual project conditions, where challenges such as adverse weather, unforeseen soil conditions, delays in heavy equipment mobilization, changes in work volume, and coordination issues among stakeholders do not necessarily lead to project failure when they are effectively anticipated through appropriate risk management strategies. Conversely, even when a project benefits from favorable environmental conditions and adequate construction equipment, the absence of early risk identification, continuous risk monitoring, well-developed mitigation plans, and timely responses to changing site conditions may still prevent the achievement of project objectives in terms of cost, quality, and schedule.

The insignificant effect of human resources may be explained by the fact that the project under study operated under standardized work procedures, task allocation, and workforce competencies, resulting in limited variation in human resource quality. Consequently, human resources were not the primary factor influencing the implementation of adaptive risk management strategies. These findings highlight that the success of road improvement projects depends more on an organization's ability to integrate project environmental conditions and construction equipment into an adaptive risk management strategy than on the independent strengths of these factors.

Table 4. Mediation Effect Testing

Relationship	P-Value	Decision
$X1 \rightarrow Z \rightarrow Y$	0.052	Not Significant
$X2 \rightarrow Z \rightarrow Y$	0.156	Not Significant
$X3 \rightarrow Z \rightarrow Y$	0.052	Not Significant

Although the indirect relationships $X1 \rightarrow Z \rightarrow Y$ and $X3 \rightarrow Z \rightarrow Y$ did not reach the 5% level of statistical significance, their p-values of 0.052 indicate that both relationships are very close to the significance threshold. Therefore, these indirect effects can be classified as marginally significant, suggesting a tendency toward mediation, although they do not meet the conventional criterion for statistical significance.

The Influence of Project Environmental Conditions, Human Resources, and Construction Equipment on Adaptive Risk Management Strategy

Project Environmental Conditions (X1) have a positive and significant effect on Adaptive Risk Management Strategy (Z), with a path coefficient of 0.558, a t-statistic of 4.045, and a p-value of 0.000 (H1 supported). These findings indicate that a better understanding of the project environment including project scope, coordination and communication, field risk identification, and change control enhances the project team's ability to formulate and implement an adaptive risk management strategy. This finding is consistent with Bello (2025), who reported that a comprehensive understanding of the project environment strengthens an organization's capability to manage risks adaptively.

The Influence of Adaptive Risk Management Strategy on Road Improvement Project Success

The results indicate that Adaptive Risk Management Strategy (Z) has a positive and significant effect on Road Improvement Project Success (Y), with a path coefficient of 0.510, a t-statistic of 2.304, and a p-value of 0.021 (H4 supported). These findings suggest that the more effectively an adaptive risk management strategy is implemented, the higher the level of project success achieved. Effective risk management minimizes the impact of potential risks on project cost, quality, schedule, and occupational safety, thereby enabling the project objectives to be achieved more efficiently and effectively. This finding is consistent with the Project Management Institute (PMI, 2021), which states that the systematic implementation of risk management increases the likelihood of project success.

The Influence of Project Environmental Conditions, Human Resources, and Construction Equipment on Road Improvement Project Success

In contrast to their effects on the *Adaptive Risk Management Strategy* (Z), the results indicate that the three exogenous variables do not have significant direct effects on Road Improvement Project Success (Y). Project Environmental Conditions (X1) showed a path coefficient of 0.265 with a p-value of 0.247, Human Resources (X2) obtained a path coefficient of 0.208 with a p-value of 0.282, while Construction Equipment (X3) produced a path coefficient of -0.040 with a p-value of 0.857. Therefore, all hypotheses regarding the direct effects of these variables on project success were not supported. Further analysis of the mediating role of *Adaptive Risk Management Strategy* (Z) revealed that the indirect paths of $X1 \rightarrow Z \rightarrow Y$ and $X3 \rightarrow Z \rightarrow Y$ generated p-values of 0.052, which were close to the significance threshold of 0.05 and could be considered marginal effects. Meanwhile, the $X2 \rightarrow Z \rightarrow Y$ pathway produced a p-value of 0.156, indicating that the indirect

effect of human resources through adaptive risk management strategy was not statistically significant. These findings suggest that project environmental conditions and construction equipment may contribute to project success through the implementation of adaptive risk management strategies, whereas human resources did not demonstrate a substantial mediating role within the proposed model.

These findings suggest that Project Environmental Conditions and Construction Equipment do not directly influence Road Improvement Project Success, but instead exert their influence through Adaptive Risk Management Strategy, indicating a tendency toward full mediation, although the indirect effects do not strictly meet the 5% significance level. In other words, favorable project environmental conditions and adequate construction equipment contribute to project success only when they are effectively translated into an adaptive risk management strategy, rather than generating positive outcomes on their own.

Priority Factors Based on Importance Performance Map Analysis (IPMA)

The IPMA results for Adaptive Risk Management Strategy (Z) indicate that Construction Equipment (X3) has the highest importance (0.604) and the highest performance (67.476), followed by Project Environmental Conditions (X1) with an importance value of 0.558 and a performance value of 66.028. Both variables are positioned in the "Keep Up the Good Work" quadrant, indicating that they are highly important and have been performing well. In contrast, Human Resources (X2) falls within the "Low Priority" quadrant, with a negative importance value (−0.316) and the lowest performance score (57.316).

The IPMA results for Road Improvement Project Success (Y) reveal a similar pattern. Project Environmental Conditions (X1) has the highest importance value (0.549) and is positioned in the "Keep Up the Good Work" quadrant. Construction Equipment (X3) records the highest performance score (67.476) but only moderate importance (0.268), placing it in the "Possible Overkill" quadrant, indicating that its performance exceeds its relative importance. Meanwhile, Human Resources (X2) again falls within the "Low Priority" quadrant, with the lowest importance (0.047) and performance (57.316) values.

By integrating the findings from both IPMA analyses, it can be concluded that Project Environmental Conditions and Construction Equipment are the two primary priority factors whose current performance should be maintained, as both demonstrate high levels of importance and satisfactory performance. In contrast, Human Resources represent the lowest priority for improvement compared with the other two factors, although maintaining their current level of performance remains important to prevent future declines.

CONCLUSION AND RECOMMENDATIONS

This study concludes that Adaptive Risk Management Strategy plays a central role in determining the success of the Bhayangkara 1 – Graha Raya – Pondok Serut – Kayu Gede 1 – Kayu Gede 2 Road Improvement Project. The results of the PLS-SEM analysis demonstrate that Project Environmental Conditions and Construction Equipment significantly influence the development of Adaptive Risk Management Strategy, whereas Human Resources do not show a significant effect. Furthermore, Adaptive Risk Management Strategy has a significant positive influence on project success, indicating that the ability of project teams to identify, evaluate, and respond to dynamic risks is a key factor in achieving project objectives related to cost, time, and quality. Although Project Environmental Conditions, Human Resources, and Construction Equipment do not directly affect project success, the findings indicate that Project Environmental Conditions and Construction Equipment contribute indirectly through the implementation of adaptive risk management strategies. The IPMA results further confirm that maintaining construction equipment performance and effective management of project environmental conditions should remain key priorities in improving project performance.

Future research is recommended to examine the proposed model across various infrastructure projects and different geographical contexts to improve the generalisability of the findings. Further studies may also incorporate additional factors, such as contractual management, supply chain reliability, financial conditions, and digital construction technologies, to provide a

more comprehensive explanation of project success determinants. For construction practitioners, companies should strengthen adaptive risk management practices through systematic risk identification, continuous monitoring, mitigation planning, and clear assignment of risk responsibilities. Project managers should integrate equipment readiness assessments and environmental condition analysis into project planning and implementation processes. From a policy perspective, construction project management guidelines should encourage the implementation of structured risk management systems as part of quality assurance mechanisms to support more resilient and sustainable infrastructure development.

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