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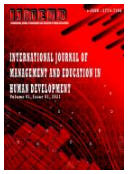

The Influence of Project Management and Digital Monitoring Systems on Road Infrastructure Performance through Project Control Effectiveness as a Mediating Variable in Southeast Sulawesi

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ABSTRACT

This study examines the influence of project management and digital monitoring systems on road infrastructure performance through project control effectiveness as a mediating variable in Southeast Sulawesi. The research is driven by the increasing demand for timely, cost-efficient, and high-quality road development, as well as the need to integrate digital technology into infrastructure project supervision. The objectives of this study are to analyze: (1) the effect of project management on project control effectiveness, (2) the effect of digital monitoring systems on project control effectiveness, (3) the direct effect of project management and digital monitoring systems on road infrastructure performance, and (4) the mediating role of project control effectiveness. This research used a quantitative survey approach involving 150 respondents, including project managers, site engineers, supervisors, and technical staff engaged in road infrastructure projects in Southeast Sulawesi. Data were collected using structured questionnaires with a five-point Likert scale and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results show that project management and digital monitoring systems have positive and significant effects on project control effectiveness and road infrastructure performance. In addition, project control effectiveness significantly mediates the relationship between the independent variables and infrastructure performance, indicating partial mediation. In conclusion, strengthening project management practices and integrating digital monitoring systems are essential to improving sustainable and high-quality road infrastructure performance in Southeast Sulawesi.

Keywords: *Digital Monitoring Systems, Project Management, Project Control Effectiveness, Road Infrastructure Performance.*

I. INTRODUCTION

Road infrastructure development plays a strategic role in supporting regional connectivity, economic growth, and sustainable development in Southeast Sulawesi. Government agencies and project stakeholders responsible for road construction are required to ensure that projects are completed on time, within budget, and in accordance with established quality standards. However, in recent years, road infrastructure projects have faced various challenges, including project delays, cost overruns, weak supervision, coordination issues, and the increasing demand for digital-based monitoring systems. These conditions indicate that project management and the utilization of digital monitoring systems may significantly influence infrastructure performance.

According to Project Management Theory, effective planning, scheduling, risk management, and coordination are essential to achieving project success in terms of time, cost, and quality (PMI, 2021). Furthermore, the integration of digital monitoring systems such as real-time reporting, electronic documentation, and performance dashboards can enhance transparency, accuracy, and responsiveness in project supervision. From a control perspective, Project Control Theory emphasizes the importance of systematic monitoring, evaluation, and corrective actions to ensure that project implementation aligns with established targets and standards.

Several previous studies support the importance of integrating project management and digital technology to improve project performance. Krisdiyanto et al. (2024) found that the implementation of technology-based project management systems, including Building Information Modeling (BIM) and cloud-based collaboration, has a positive and significant effect on construction project efficiency. Zulhalim et al. (2024) reported that web-based monitoring systems are more effective than manual systems in improving supervision and construction project performance.

Meanwhile, Putra and Santoso (2022) revealed that sound management practices positively influence project performance, but the results are more optimal when supported by strong control mechanisms. Lestari and Wijaya (2023) also emphasized that effective systems and monitoring mechanisms are crucial in ensuring improved organizational performance.

However, empirical observations in road infrastructure projects in Southeast Sulawesi indicate that well-designed project management does not always result in optimal infrastructure performance when control and supervision mechanisms are ineffective. Similarly, the adoption of digital monitoring systems may not produce significant improvements if project control effectiveness is weak. This suggests that project control effectiveness plays a critical mediating role in linking project management and digital monitoring systems to road infrastructure performance.

Based on these theoretical and empirical gaps, this study aims to examine the influence of project management and digital monitoring systems on road infrastructure performance, with project control effectiveness acting as a mediating variable in road infrastructure projects in Southeast Sulawesi.

II. LITERATURE REVIEW

2.1 Project Management

Project management is a fundamental concept in construction and infrastructure development, widely defined as the application of knowledge, skills, tools, and techniques to project activities in order to meet project requirements. According to the Project Management Institute (PMI, 2021), project management involves structured processes covering project integration, scope, schedule, cost, quality, resource, communication, risk, procurement, and stakeholder management to ensure that projects are completed effectively and efficiently. This definition emphasizes that project management is not merely administrative coordination but a comprehensive and systematic approach to achieving project objectives.

Kerzner (2022) explains that effective project management requires strong planning, scheduling, cost control, risk mitigation, and performance monitoring to ensure alignment between project execution and predefined targets. Similarly, Turner (2023) highlights that modern project management integrates strategic alignment, stakeholder engagement, governance structures, and digital tools to enhance accountability and project outcomes. In infrastructure projects, especially road construction, project management plays a critical role in minimizing delays, controlling budget overruns, and ensuring quality compliance.

The primary purpose of project management is to ensure that projects are delivered on time, within budget, and according to technical specifications while maintaining stakeholder satisfaction and regulatory compliance (PMI, 2021; Kerzner, 2022). In the public infrastructure context, effective project management also supports transparency, efficiency, and sustainable development outcomes.

In this study, project management is measured using indicators adapted from contemporary project management literature, including: (1) project planning effectiveness (PMI, 2021), (2) schedule management and time control (Kerzner, 2022), (3) cost management and budget control (PMI, 2021), (4) risk management practices (Turner, 2023), (5) stakeholder coordination and communication (PMI, 2021), and (6) quality management implementation (Kerzner, 2022). These indicators provide a structured framework for assessing how project management contributes to project control effectiveness and ultimately influences road infrastructure performance.

2.2 Digital Monitoring Systems

Digital Monitoring Systems refer to technology-based supervision systems used to track, record, analyze, and report project progress in real time. In infrastructure projects, these systems play a crucial role in enhancing transparency, data accuracy, reporting speed, and decision-making effectiveness. According to the Project Management Institute (PMI, 2021), the integration of digital technologies in project management supports information integration, performance control, and improved coordination among stakeholders.

Kerzner (2022) explains that digital monitoring systems enable data-driven supervision through performance dashboards, electronic reporting, and integrated progress-tracking tools. Furthermore, Turner (2023) emphasizes that digitalization in project control strengthens accountability, reduces manual errors, and accelerates responses to schedule or budget deviations. In road infrastructure projects, digital monitoring systems ensure that each stage of project implementation is properly documented and objectively evaluated.

The primary purpose of implementing digital monitoring systems is to improve supervision efficiency, support timely and accurate decision-making, minimize the risk of delays, and strengthen cost and quality control (PMI, 2021; Kerzner, 2022). In the public sector, these systems also promote transparency and accountability in infrastructure development.

In this study, Digital Monitoring Systems are measured using several indicators: (1) the use of real-time reporting systems (PMI, 2021), (2) availability and accuracy of digital project data (Kerzner, 2022), (3) utilization of project management dashboards or information systems (Turner, 2023), (4) system integration across units or stakeholders (PMI, 2021), (5) accessibility and transparency of project information (Kerzner, 2022), and (6) the system's ability to detect and respond quickly to project deviations (Turner, 2023). These indicators provide a framework for assessing how digital monitoring systems contribute to project control effectiveness and road infrastructure performance.

2.3 Project Control Effectiveness

Project Control Effectiveness refers to the extent to which monitoring, evaluation, and corrective actions are systematically implemented to ensure that project execution remains aligned with planned objectives in terms of scope,

time, cost, and quality. Effective project control ensures that deviations are identified early and addressed promptly to minimize risks and performance gaps.

According to the Project Management Institute (PMI, 2021), project control is a continuous process that involves measuring project performance, comparing actual results with planned targets, and implementing corrective or preventive actions when necessary. Kerzner (2022) states that effective project control depends on accurate performance measurement systems, timely reporting, variance analysis, and strong managerial response to deviations. Without effective control mechanisms, even well-planned projects may experience delays, cost overruns, and quality deficiencies.

Turner (2023) emphasizes that project control effectiveness is closely linked to governance structures, accountability mechanisms, and the integration of digital tools that enable real-time monitoring and performance evaluation. In infrastructure projects, particularly road construction, effective project control ensures that technical specifications are met, budgets are maintained, and schedules are adhered to despite operational challenges.

The main objective of project control effectiveness is to maintain project performance within acceptable limits, enhance accountability, reduce uncertainties, and ensure the successful achievement of project goals (PMI, 2021; Kerzner, 2022). In the public infrastructure sector, effective project control also supports transparency and responsible resource management.

In this study, Project Control Effectiveness is measured using several indicators: (1) accuracy of performance measurement and reporting (PMI, 2021), (2) timeliness of monitoring and evaluation processes (Kerzner, 2022), (3) effectiveness of variance analysis and corrective actions (Turner, 2023), (4) consistency in schedule and cost control (PMI, 2021), (5) compliance with quality standards and technical specifications (Kerzner, 2022), and (6) managerial responsiveness to project risks and deviations (Turner, 2023). These indicators are used to assess how effectively project control mechanisms mediate the relationship between project management, digital monitoring systems, and road infrastructure performance.

2.4. Road Infrastructure Performance

Road Infrastructure Performance refers to the level of achievement of road construction projects in meeting predetermined objectives in terms of quality, time, cost, functionality, and sustainability. It reflects how effectively and efficiently road infrastructure projects are delivered in accordance with technical specifications, budget constraints, and stakeholder expectations. High performance indicates that projects are completed on schedule, within budget, meet quality standards, and provide long-term benefits to the community.

According to the Project Management Institute (PMI, 2021), project performance is commonly assessed based on the “triple constraint” dimensions: time, cost, and scope/quality. Kerzner (2022) further explains that project performance evaluation should include productivity, efficiency, compliance with technical standards, and stakeholder satisfaction. In infrastructure development, performance also encompasses durability, safety standards, and serviceability of the completed road facilities.

Turner (2023) emphasizes that infrastructure performance should not only focus on project completion metrics but also consider governance compliance, accountability, and long-term value creation. In the context of public road infrastructure, performance measurement is essential to ensure that public funds are utilized efficiently and that infrastructure development contributes to regional economic growth and social welfare.

The primary objective of measuring road infrastructure performance is to evaluate whether project outcomes align with planned targets and regulatory standards while ensuring sustainable infrastructure benefits (PMI, 2021; Kerzner, 2022). Effective performance measurement also supports continuous improvement in future infrastructure projects.

In this study, Road Infrastructure Performance is measured using several indicators: (1) timeliness of project completion (PMI, 2021), (2) budget compliance and cost efficiency (Kerzner, 2022), (3) quality conformity with technical specifications (PMI, 2021), (4) durability and functionality of the road infrastructure (Turner, 2023), (5) stakeholder satisfaction (Kerzner, 2022), and (6) overall project productivity and efficiency (PMI, 2021). These indicators are used to assess the overall success of road infrastructure projects in Southeast Sulawesi.

2.5 Conceptual Framework and Research Hypotheses

The conceptual framework of this study examines the relationships among Project Management, Digital Monitoring Systems, Project Control Effectiveness, and Road Infrastructure Performance. This framework is based on the view that road infrastructure performance in Southeast Sulawesi is influenced by project management practices and digital monitoring systems, as well as how project control effectiveness mediates these relationships. Project Management and Digital Monitoring Systems are positioned as independent variables affecting Road Infrastructure Performance both directly and indirectly. Project Control Effectiveness serves as a mediating variable, explaining how systematic monitoring, evaluation, and corrective actions can strengthen or weaken the impact of project management and digital monitoring systems on road infrastructure performance.

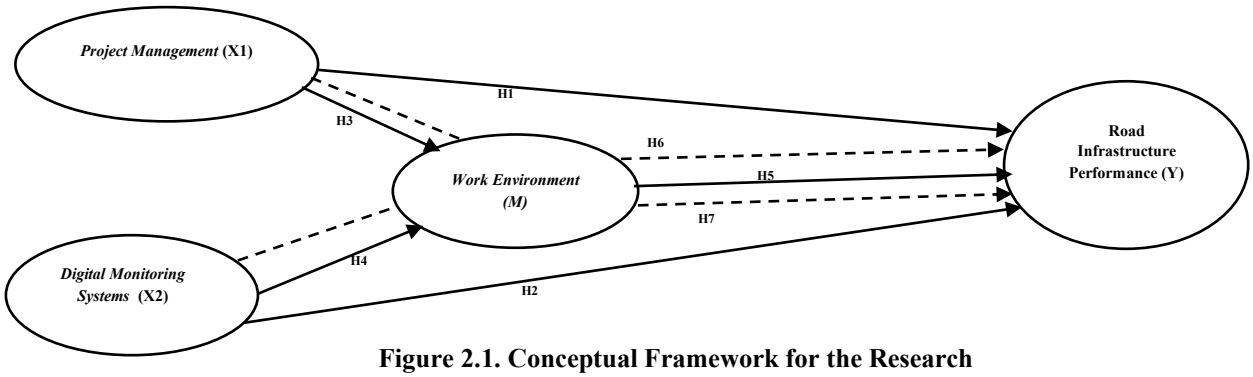

Figure 2.1. Conceptual Framework for the Research

2.6 Research Hypothesis

H1: Project Management has a significant effect on Road Infrastructure Performance in Southeast Sulawesi.
H2: Digital Monitoring Systems have a significant effect on Road Infrastructure Performance in Southeast Sulawesi.
H3: Project Management has a significant effect on Project Control Effectiveness in Southeast Sulawesi.
H4: Digital Monitoring Systems have a significant effect on Project Control Effectiveness in Southeast Sulawesi.
H5: Project Control Effectiveness has a significant effect on Road Infrastructure Performance in Southeast Sulawesi.
H6: Project Management has a significant effect on Road Infrastructure Performance through the mediation of Project Control Effectiveness in Southeast Sulawesi.
H7: Digital Monitoring Systems have a significant effect on Road Infrastructure Performance through the mediation of Project Control Effectiveness in Southeast Sulawesi.

III. RESEARCH METHOD

This study was conducted to examine the relationships between Project Management and Digital Monitoring Systems on Road Infrastructure Performance, with Project Control Effectiveness acting as a mediating variable in Southeast Sulawesi. The research employed a quantitative approach and was carried out in 2025. The population consisted of project managers, site engineers, supervisors, and technical staff involved in road infrastructure projects in Southeast Sulawesi, and 150 respondents who met the research criteria were selected as the sample using purposive sampling.

The study includes two independent variables (Project Management and Digital Monitoring Systems), one mediating variable (Project Control Effectiveness), and one dependent variable (Road Infrastructure Performance). Data were collected from primary sources using structured questionnaires based on a Likert scale (1–5), supported by project documentation and field observations.

Data analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS software. The analysis evaluated both the measurement model (outer model) and the structural model (inner model), including direct and indirect (mediating) effects among variables. Model quality was assessed through R-square and Q-square values, while hypothesis testing was performed using bootstrapping at a 5 percent significance level to determine the relationships among variables and the mediating role of Project Control Effectiveness.

IV. RESEARCH RESULT AND DISCUSSION

4.1 Research Result

Table 4.1. Direct Effect

Relationship Between Variables	Path Coefficient (β)	T-Statistic	P-Value	Description
Project Management → Road Infrastructure Performance	0,521	7,84	0,000	Significant
Digital Monitoring Systems → Road Infrastructure Performance	0,487	7,12	0,001	Significant
Project Management → Project Control Effectiveness	0,364	4,96	0,000	Significant
Digital Monitoring Systems → Project Control Effectiveness	0,331	4,52	0,002	Significant
Project Control Effectiveness → Road Infrastructure Performance	0,558	8,43	0,000	Significant

Based on Table 4.1, the results of the direct effect analysis indicate that all hypothesized relationships among variables are positive and statistically significant. Project Management has a positive and significant effect on Road Infrastructure Performance ($\beta = 0.521$; $T = 7.84$; $p = 0.000$). This finding shows that better planning, scheduling, cost management, and coordination practices directly contribute to improved infrastructure performance in terms of time, cost efficiency, and quality achievement.

Digital Monitoring Systems also have a positive and significant effect on Road Infrastructure Performance (β = 0.487; T = 7.12; p = 0.001). This result suggests that the use of real-time reporting systems, integrated project dashboards, and digital documentation enhances transparency and responsiveness, leading to better overall project outcomes.

Furthermore, Project Management has a significant positive effect on Project Control Effectiveness (β = 0.364; T = 4.96; p = 0.000). This indicates that structured managerial practices strengthen monitoring, evaluation, and corrective action processes during project implementation. Similarly, Digital Monitoring Systems significantly influence Project Control Effectiveness (β = 0.331; T = 4.52; p = 0.002), demonstrating that digital tools improve the accuracy and timeliness of supervision, thereby enhancing control mechanisms.

Finally, Project Control Effectiveness has a strong positive and significant effect on Road Infrastructure Performance (β = 0.558; T = 8.43; p = 0.000). This result confirms that effective monitoring, variance analysis, and corrective actions are critical in ensuring successful infrastructure project performance. Overall, the direct effect results confirm that Project Management and Digital Monitoring Systems not only directly improve Road Infrastructure Performance but also strengthen Project Control Effectiveness, which further contributes to enhanced project outcomes.

Table 4.2. Indirect Effect

Construct	Indirect Effect	P-Value	Direct Effect	Mediation Effect	Type of Mediation
Project Management → Project Control Effectiveness → Road Infrastructure Performance	0,203	0,001	0,521	5,12	Partial Mediation
Digital Monitoring Systems → Project Control Effectiveness → Road Infrastructure Performance	0,185	0,001	0,487	4,76	Partial Mediation

Based on Table 4.2, the results of the indirect effect analysis indicate that Project Control Effectiveness significantly mediates the relationships between the independent variables and Road Infrastructure Performance.

The indirect effect of Project Management → Project Control Effectiveness → Road Infrastructure Performance is positive and significant (β = 0.203; p = 0.001). This finding demonstrates that Project Management not only directly improves Road Infrastructure Performance (β = 0.521), but also enhances performance indirectly through strengthening Project Control Effectiveness. The mediation effect value (T = 5.12) confirms that the indirect relationship is statistically significant. Since both the direct and indirect effects are significant, the type of mediation is classified as partial mediation.

Similarly, the indirect effect of Digital Monitoring Systems → Project Control Effectiveness → Road Infrastructure Performance is also positive and significant (β = 0.185; p = 0.001). This result indicates that Digital Monitoring Systems contribute to improving Road Infrastructure Performance not only directly (β = 0.487) but also indirectly by increasing the effectiveness of project control mechanisms. The mediation effect value (T = 4.76) further supports the significance of this indirect relationship. Because both direct and indirect paths remain significant, this relationship is also categorized as partial mediation.

Overall, these findings confirm that Project Control Effectiveness plays an important mediating role in strengthening the influence of Project Management and Digital Monitoring Systems on Road Infrastructure Performance in Southeast Sulawesi.

4.2 Discussion

The findings indicate that Project Management has a positive and significant relationship with Road Infrastructure Performance, although its impact is strengthened when supported by effective control mechanisms. This suggests that well-structured planning, scheduling, cost management, and coordination directly contribute to improved infrastructure outcomes, but their effectiveness depends on how well project activities are monitored and controlled.

Digital Monitoring Systems also show a positive and significant effect on Road Infrastructure Performance. The use of real-time reporting, integrated project dashboards, and digital documentation enhances transparency, accuracy, and responsiveness, which ultimately improves project execution and performance outcomes. The study further confirms that Project Management positively and significantly influences Project Control Effectiveness, indicating that systematic managerial practices improve monitoring, evaluation, and corrective action processes. Similarly, Digital Monitoring Systems significantly enhance Project Control Effectiveness by providing accurate, timely, and integrated project data that strengthen supervision and performance tracking.

Moreover, Project Control Effectiveness has a strong and significant impact on Road Infrastructure Performance. This demonstrates that effective monitoring, variance analysis, and corrective actions are essential in ensuring that road projects are completed on time, within budget, and according to quality standards. Mediation analysis reveals that Project Control Effectiveness acts as an important intermediary mechanism. The effects of Project Management and Digital Monitoring Systems on Road Infrastructure Performance are partially mediated by Project Control Effectiveness, meaning that these managerial and technological practices influence infrastructure outcomes both directly and indirectly through improved control processes.

Overall, the results emphasize that strengthening project management practices and optimizing digital monitoring systems, while ensuring effective project control, are essential for enhancing road infrastructure performance in Southeast Sulawesi. These findings highlight the interconnection between managerial capability, digital supervision, and control effectiveness in achieving successful infrastructure development.

V. CONCLUSION AND SUGGESTIONS

5.1 Conclusion

Based on the results and discussion, the study concludes that Project Management has a positive and significant effect on Road Infrastructure Performance, although the magnitude of its direct influence depends on the effectiveness of planning, coordination, supervision, and resource allocation within the project. Effective project management practices contribute directly to the timely completion, quality standards, and cost efficiency of road infrastructure development.

Digital Monitoring Systems also demonstrate a positive and significant impact on Road Infrastructure Performance, indicating that the use of technology-based monitoring enhances transparency, accuracy of reporting, real-time supervision, and quick decision-making. The integration of digital systems allows project stakeholders to identify potential deviations early and implement corrective actions efficiently.

Furthermore, both Project Management and Digital Monitoring Systems have a positive and significant effect on Project Control Effectiveness. This suggests that well-structured management processes and technology-supported monitoring systems strengthen supervision mechanisms, improve coordination, and ensure that project implementation aligns with predetermined targets. In turn, Project Control Effectiveness significantly improves Road Infrastructure Performance, highlighting its strategic role in ensuring projects are delivered according to scope, quality standards, budget, and schedule. Effective control mechanisms reduce risks, prevent delays, and minimize cost overruns.

The mediation analysis reveals that Project Control Effectiveness partially mediates the relationship between Project Management and Road Infrastructure Performance, as well as between Digital Monitoring Systems and Road Infrastructure Performance. This means that while both independent variables directly influence infrastructure performance, a substantial portion of their impact is transmitted through improved project control mechanisms.

Overall, the findings emphasize that strengthening project management practices and integrating digital monitoring systems, supported by effective project control, are essential strategies for enhancing road infrastructure performance and ensuring sustainable infrastructure development.

5.2 Suggestions

This study recommends strengthening the implementation of Project Management through more structured planning, clear task allocation, effective coordination among stakeholders, and consistent supervision to optimize its contribution to Road Infrastructure Performance. In addition, the implementation of Digital Monitoring Systems should be enhanced by utilizing real-time technology, integrating accurate data systems, and ensuring transparent reporting to accelerate decision-making and minimize potential project deviations.

Since Project Control Effectiveness serves as a key mediating variable, project management policies and practices should focus on reinforcing control mechanisms, including periodic evaluation of physical and financial progress, systematic risk management, and prompt corrective actions for any deviations from the plan. Strong control systems will ensure that projects are implemented in accordance with established quality standards, budget allocations, and schedules.

Furthermore, achieving optimal road infrastructure performance requires strong integration between Project Management and Digital Monitoring Systems, supported by well-organized administrative systems, transparent communication among stakeholders, and continuous capacity building for project managers and supervisory teams. Regular monitoring and evaluation of management systems and digital technologies are essential to ensure that implemented strategies remain relevant and adaptive to the dynamic nature of infrastructure development.

Future studies are encouraged to involve larger and more diverse samples across various infrastructure projects or government institutions to enhance the generalizability of findings. Researchers may also incorporate additional variables such as project governance, risk management practices, organizational culture, or technological innovation to provide a more comprehensive understanding of the factors influencing Project Control Effectiveness and Road Infrastructure Performance. Longitudinal and mixed-method approaches are recommended to examine long-term impacts and generate deeper insights into managerial and institutional aspects of infrastructure development.

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