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Analysis OF THE Influence OF Technological Innovation AND Project Management ON THE Operational Performance OF Airport Contractors IN Indonesia Using Structural Equation Modeling-Partial Least Square (Semp-Pls) AND Importance-Performance Map Analysis (Ipma) Methods

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Abstract
Effective project management supported by technological innovation plays a crucial role in improving the operational performance of airport infrastructure contractors in Indonesia. This study aims to evaluate the contribution of project management in improving efficiency, timeliness, and work quality, as well as to identify the synergistic relationship between these two factors to support the operational success of projects. This study employs a quantitative approach with an explanatory research design, analyzing causal relationships between variables through online and face-to-face questionnaires administered to 131 respondents from small and medium-sized airport contractors in Indonesia. Data processing uses Structural Equation Modeling Partial Least Square (SEM-PLS) and Importance Performance Map Analysis (IPMA) to generate data-driven strategic recommendations. Using these methods, the research model yields an explanatory power (R^2 = 0.246) and predictive ability (Q^2 = 0.134). Thus, the model is considered to provide both theoretical and practical contributions and has acceptable predictive power. The findings indicate that technological innovation is the driving force behind work efficiency, while project management serves as the managing structure and influences the effective utilization of technology.
Keywords: *Technological Innovation; , Project Management; Contractor Performance; Airport*

INTRODUCTION

Contractors in Indonesia play a key role in national infrastructure development, but often face challenges such as project delays, cost overruns, and poor quality of work. A study shows that contractors, especially medium-sized ones, do not yet fully consider technological capability development as a strategic part of their corporate strategy [1]. Therefore, the operational performance of contractors can be improved by crucial factors such as technological innovation and project management. In recent years, there has been increasing interest in infrastructure development, particularly airport projects. Project management plays a crucial role in achieving targets for timeliness, cost efficiency, and work quality. These are supported by factors such as project planning, project control, and team coordination, which have an impact on productivity and ultimately client satisfaction. “To achieve construction project goals relating to the construction duration, cost, quality, safety, and environmental sustainability, risk management has been considered a critical procedure within project management” [2]. “Advanced technology is also a key factor for successful project outcomes because it enhances efficiency and precision in construction processes” [3]. “Contractor capabilities, including financial and technical competence, skilled workforce management and quality assurance are critical for avoiding delays and ensuring compliance with standards” [4]. Airport construction projects are known for their complexity, involving activities across various zones such as the airside, terminal, and landside areas. Effective project management is essential for managing operational, technical, financial, environmental, legal, political, and cultural factors. This is crucial to ensure contractors can operate efficiently, especially given that such projects often face delays and cost overruns [5]. Contractors who adopt advanced technology tend to have better project performance due to increased transparency and communication efficiency [6].

“Using advanced technology in construction, combined with effective resource management, built upon timely and well-considered decisions by the client, and a proactive procurement can significantly boost project performance" [7]. "Leveraging technologies such as building information modelling (BIM), geographic information systems (GIS) and the internet of things (IoT) can facilitate seamless project planning, design optimisation and infrastructure asset management" [8]. "In modern construction techniques, the convergence of Technological Innovation and sustainable design concepts has received substantial attention to improve construction projects' efficacy, quality, and environmental responsibility" [9]."The benefits of using smart technology in the supply chain to improve operational performance in the manufacturing industry" [10].

In addition to analyzing the impact of technological innovation on contractors' operational performance, particularly airport specialist contractors in Indonesia, this study also aims to evaluate whether project management plays a role in improving the efficiency, timeliness, and quality of the contractor's work, as well as identifying how the synergistic relationship between technological innovation and project management supports the successful operational performance of airport contractors. "Smart technology can improve project management processes and performance. The specific application of smart technology selected for construction project management can be the first step in facilitating the digital transformation of the construction industry" [11]. The initial step of any systematic literature review involves formulating the research questions . The research questions will be discussed as follows:

RQ1 : To what extent does technological innovation influence project management among airport contractors in Indonesia?

RQ2 : Does project management mediate the impact of technological innovation on the operational performance of airport contractors in Indonesia?

RQ3 : How do technological innovation and project management influence the operational performance of airport contractors in Indonesia?

METHOD

This study uses quantitative methods with online questionnaires as a data collection technique using platforms such as Google Forms to facilitate access and improve data collection efficiency., as well as directly (face-to-face) to obtain relevant and representative information from respondents. "Primary quantitative data was collated via a survey research strategy to facilitate a systematic data collection, spread across a large geographical distance" [8]. The respondents selected were project managers and operational staff of airport contractors with small and medium-sized company qualifications. This was to ensure they had relevant experience in airport projects in Indonesia. In this study, there were 133 respondents, a number obtained using the Slovin formula, calculated from a population of 188 airport contractors in Indonesia, according to active data for 2023-2025 from the Bureau of Procurement and Management of State Property of the Indonesian Ministry of Transportation.

Data Processing

Quantitative data processing in this study used the Structural Equation Modeling Partial Least Square (SEM-PLS) method. This process involved evaluating the measurement model to ensure its validity and reliability, then testing it to evaluate the significance of complex and accurate relationships between variables. "SEM-PLS was selected due to its suitability for analyzing complex models involving latent variables and its robustness with relatively small sample sizes"[12]. Given the experimental character of the present research and the multidimensional relationships among technological innovation, project management and contractors operational performance, "PLS-SEM offers a predictive-oriented approach appropriate for this research which is aligned with previous research". Furthermore, "PLS-SEM initiates continuous evaluation of both the measurement and structural models, making it ideal for the integrated nature of this study framework" [13]. After data processing using SEM-PLS, the data is further processed using Performance and Importance Mapping Analysis (IPMA), which is applied to deepen the analysis by identifying and mapping variables based on their level of importance and performance, thereby providing strategic insights into which aspects need to be prioritized for improvement [14]. This process ensures that the results of the data processing are relevant and can be recommended for further action to enhance technological innovation and effective project management in airport construction projects.

Variables and Indicators

In this study, there are three variables that are latent variables, or variables that cannot be measured directly. In addition, there are several indicators for each variable that are used as questionnaire items. The determination of research variables and indicators can be seen in Table 1.

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Table 1. Variables and Indicators

Variables	Indicators	Statement	Labels
Technological Innovation	Information Technology	The project utilizes information technology to simplify work.	TI1
	Process Digitization	The project process has made extensive use of digital technology.	TI2
	Modern Toold	Modern equipment is used to improve work efficiency.	TI3
	Digital Monitoring Systems	A digital monitoring system is used to monitor project progress.	T14
	Project Automation	Automation is used to reduce manual errors in project work.	TI5
Project Management	Project Planning	Structured construction implementation planning to ensure operational efficiency and effectiveness.	PM1
	Project Control	The project is constantly monitored and controlled to ensure it is in line with the plan.	PM2
	Risk Management	Risk identification is carried out thoroughly before the project begins, and its impact on the project is analyzed.	PM3
	Human Resources	The need for employees with the right skills, experience, and knowledge of construction implementation for good performance.	PM4
	Team Communication	Smooth communication among team members throughout project implementation.	PM5
	Team Welfare	The well-being of project team members is a top priority for management.	PM6
	Project Procurement	The procurement process for personnel, materials, and tools is conducted according to project needs.	PM7
	Problem Solving	Issues arising during the project are resolved quickly and effectively.	PM8
	Documentation Management	Project documentation is properly stored and easily accessible when needed.	PM9
	Stakeholders	Stakeholder involvement ensures that every project step leads to the desired outcome.	PM10
Contractor Operational Performance	Time Efficiency	The project is completed on time according to the planned schedule.	COP1
	Cost Control	Project cash flow management is effectively managed to avoid budget overruns.	COP2
	Quality of Result	The project delivers final results of quality consistent with standards at every stage of the project.	COP3
	Occupational Health and Safety	Health and safety standards are properly implemented to protect all project workers.	COP4
	Client Satisfaction	The client is satisfied with the results of the project implementation.	COP5

Variables and Indicators

The research model is implemented in Figure 1.1.

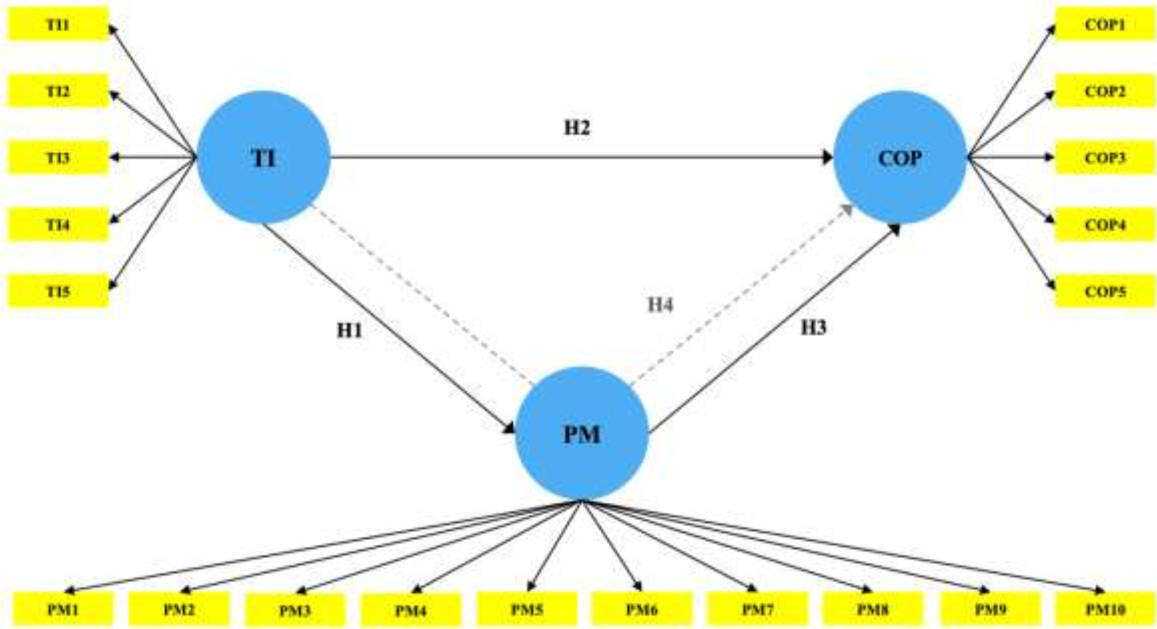

Fig. 1. Research Hypothesis Model

Thus, the following hypothesis can be obtained :

Table 2, Hypothesis

H1	Technological Innovation has a direct impact on Project Management.
H2	Technological Innovation has a direct impact on Contractor Operational Performance.
H3	Project Management has a direct impact on Contractor Operational Performance.
H4	Technological Innovation has a impact on Contractor Operational Performance mediated by Project Management.

In this study, hypothesis were designed to test the relationship between variables such as Technological Innovation, Project Management, and Contractor Operational Performance. The hypothesis were formulated based on relevant theories and previous studies that showed a correlation between these factors [15].

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Research Flow Chart

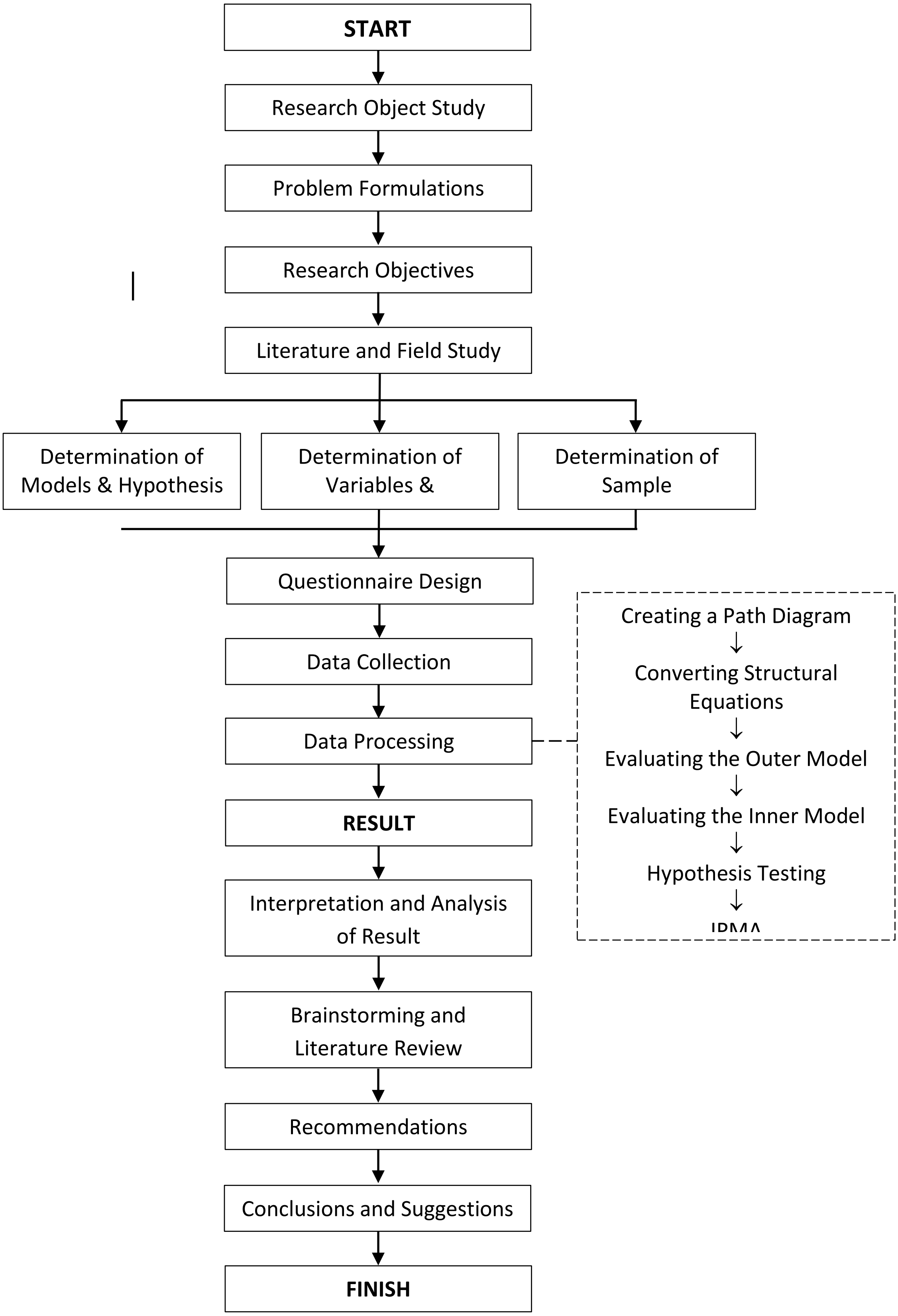

Figure 2. Research Flow Chart

RESULTS AND DISCUSSION

Result

In this study, the characteristics analyzed include highest level of education, work experience, company domicile, and company qualifications. These four aspects were chosen because they are relevant in describing individual competencies and the classification of the institutions where they work, which can influence perceptions and responses to the research.

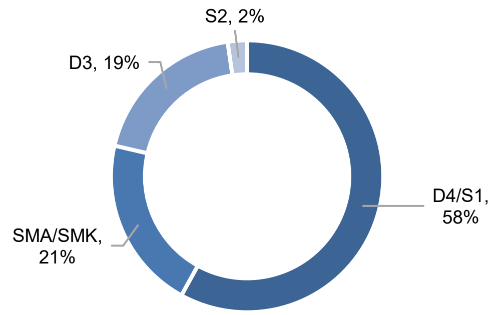

Figure 3. Chart of Respondents' Latest Education

Figure 3. shows the distribution of the respondents' highest level of education involved in this study. Of the total 131 respondents, the majority had a bachelor's degree (D4/S1) background, totaling 76 people or around 58%. This reflects that most respondents already have academic competencies at a higher education level relevant to their field of work in the construction sector, particularly airport projects.

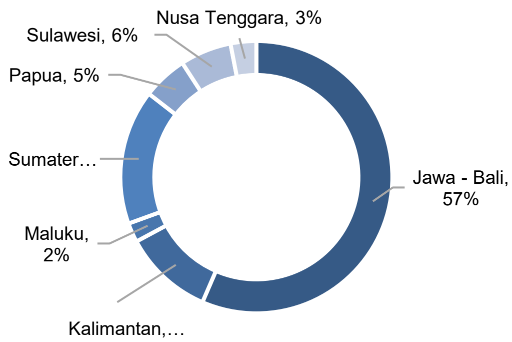

Figure 4. Chart of Respondents' Company Domiciles

Figure 4. shows the distribution of the companies where respondents work. It can be seen that the Jawa-Bali region dominates with the highest number of companies, accounting for 57% of the total respondents. This reflects the high concentration of construction activities and airport projects in the region, in line with the rapid infrastructure development on the island of Jawa and the strategic region of Bali.

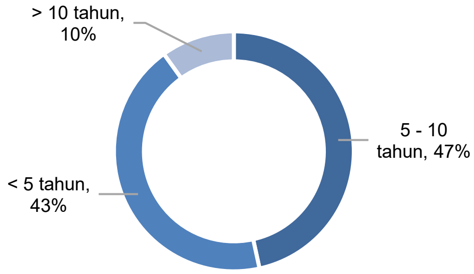

Figure 5. Chart of Respondents' Work Experience

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Figure 5. shows the distribution of work experience among the respondents involved in this study. Of the total 131 respondents, the majority had work experience ranging from 5 to 10 years, namely 61 people or around 47%. This indicates that most respondents have sufficient professional experience in the construction field, enabling them to provide objective assessments of the implementation of technological innovations and project management in the field.

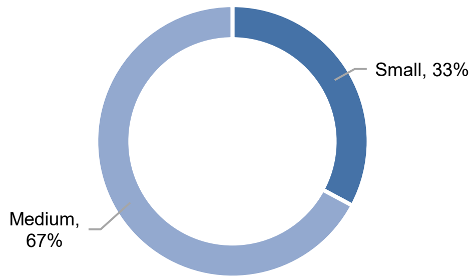

Figure 6. Chart of Respondent Company Qualifications

Figure 6. illustrates the classification of companies where respondents work based on business scale, namely small and medium qualifications. Of the total 131 respondents, 88 people or 67% came from companies with medium qualifications. This dominant percentage indicates that medium-sized companies play a significant role in the implementation of airport construction projects in Indonesia, both in technical, managerial, and administrative aspects. Meanwhile, 43 respondents (33%) came from small-sized companies. Contractors with average technical performance cannot be trusted to work on complex and specialized infrastructure development projects. Therefore, contractors can work on projects in accordance with their performance and qualifications [16].

Reliability Test of Indicators

In this study, indicators are considered reliable if they have an outer loading value ≥ 0.70. However, indicators with values between 0.40 and 0.70 may still be considered for retention if their contribution to content validity or construct validity is considered theoretically significant."This test is the first step in ensuring that each indicator used is suitable for further analysis in the structural model [17].

Table 3. Outer Loadings

	Label	Outer loadings
TI	TI1, TI2, TI3, TI4, TI5	0.883, 0.826, 0.859, 0.756, 0.699
COP	COP1, COP2, COP3, COP4, COP5	0.802, 0.761, 0.765, 0.806, 0.793
PM	PM1, PM2, PM3, PM4, PM5, PM6, PM7, PM8, PM9, PM10	0.850, 0.792, 0.821, 0.840, 0.748, 0.715, 0.839, 0.828, 0.800, 0.705

The reliability test results based on outer loading values indicate that all indicators in this study have values above 0.70, except for one indicator, TI5, which has a value of 0.699. Therefore, the TI5 indicator can still be retained as it is close to the minimum threshold and does not deviate significantly. Overall, other indicators are feasible to use and have sufficient reliability in explaining their latent variables.

Internal Consistency Test

Internal consistency is generally tested using Composite Reliability (CR) and Cronbach's Alpha values. A CR value exceeding 0.70 indicates that the indicators have a good level of reliability in measuring the intended construct [17].

Table 4. Composite Reliability

	(rho_c)
TI	0.903
COP	0.890
PM	0.945

The results of the internal consistency test show that the composite reliability (rho_c) value for all latent variables is above 0.70, so all variables in this study are declared to meet the internal consistency requirements and are reliable for use in further structural model testing.

Convergent Validity Test

Convergent validity is evaluated through the Average Variance Extracted (AVE) value, which describes the proportion of indicator variance that is successfully explained by the latent construct. A construct is considered to meet convergent validity if its AVE value is ≥ 0.50, indicating that more than half of the variance in the indicators can be explained by that construct [18].

Table 5. Average Variance Extracted

	AVE
TI	0.652
COP	0.617
PM	0.633

Based on the test results, all constructs in this model meet an AVE value greater than 0.50, which means that the constructs are able to explain more than 50% of the variance of their indicators. Thus, all constructs have adequate convergent validity and can be used for further structural analysis.

Discriminant Validity Test

Discriminant validity is tested using several methods, including the Fornell-Larcker criterion, cross loading, and the Heterotrait-Monotrait Ratio (HTMT). A model is said to meet discriminant validity if the AVE value of a construct is greater than the square of the correlation between constructs (Fornell-Larcker), the indicator has the highest loading on the construct it measures (cross loading), and the HTMT value is below the recommended threshold (usually 0.90) [17].

Table 6. Heterotrait-Monotrait Ratio

Construct ↔ Contruct	HTMT
COP ↔ TI	0.489
PM ↔ TI	0.494
PM ↔ COP	0.469

The results of the discriminant validity test approach in this study show values of 0.489 between COP and TI, 0.494 between PM and TI, and 0.469 between PM and COP. All values are well below the 0.90 threshold. Therefore, it can be concluded that the three constructs in the TI, PM, and COP model have excellent discriminant validity and do not overlap conceptually.

Significance Test of Influence

A direct influence test is conducted to see the extent to which independent variables contribute directly to dependent variables in the structural model. The path coefficient value indicates the strength and direction of influence, while the p-value is used to test its significance. If the p-value is < 0.05, the influence is considered statistically significant [17].

Table 7. Direct Effect Test

	Path Coefficient	**P-values**
TI → COP	0.291	0.006
TI → PM	0.448	0.000
PM → COP	0.293	0.002

The test results show that all hypotheses produce p-values < 0.05, indicating that TI has a direct positive impact on COP. TI acts as the primary driver in shaping more effective and efficient, and PM directly influences COP, as proven empirically and significantly.

After the direct effect is established, the indirect effect in this model aims to determine whether Project Management (PM) mediates the relationship between Technological Innovation (TI) and Contractor Operational Performance (COP).

Table 8. Indirect Effect Test

	Path Coefficient	**P-values**
TI → PM → COP	0.131	0.014

Based on the test results, a path coefficient value of 0.131 with a p-value of 0.014 was obtained, which means that TI indirectly has a significant effect on COP through PM. Thus, the mediation path TI → PM → COP is proven to be significant, and project management acts as a partial mediator in strengthening the effect of Technological innovation on the operational performance of contractors.

Explanatory Power

The R-square (R^2) value is used to measure how well the independent variables in the model explain the variability of the dependent variable. An R^2 value of 0.25 is categorized as weak, 0.50 as moderate, and 0.75 as strong in the context of social science research [17]."

Table 9. R-square

	R-square
COP	0.246
PM	0.200

The R-square test result for the Contractor Operational Performance (COP) variable is 0.246, so that 24.6% of the variation in COP consists of Technological Innovation (TI) and Project Management (PM). Meanwhile, the R^2 for the PM variable is 0.200, meaning that 20% of the variation in PM can be explained by TI. Thus, the explanatory power in this model falls into the weak to moderate category, but it still provides meaningful and significant information in the context of construction project management, which naturally involves many external factors outside the model.

Predictive Ability

The Q-square value is used to measure the model's predictive ability for endogenous variables through the blindfolding method. If the Q-square value greater than 0, this indicates that the model has good predictive relevance, with general categories: $Q^2 > 0.00$ = low, > 0.25 = moderate, and > 0.50 = strong [17]. Q^2 serves as a complement to R^2 in evaluating how well the model can predict observed data.

Table 9 – Q-square

	Q^2 (=1-SSE/SSO)
COP	0.134

PM	0.121

In these results, the Q^2 value for COP is 0.134 and for PM is 0.121. Although Q^2 is still at a low level, the model is still considered to have adequate predictability, especially for initial studies or studies with complex managerial constructs.

IPMA Analysis

Importance-Performance Map Analysis (IPMA) aims to identify which variables have a significant influence (importance) on the target variable, in this case Contractor Operational Performance (COP), but still have a relatively low level of performance. This analysis not only helps in understanding the strength of causal relationships but also maps out areas that require further attention in efforts to enhance the effectiveness of organizational strategies. As such, IPMA provides a more practical and applicable foundation for managerial decision-making, particularly in the context of optimizing airport construction projects in Indonesia.

"The value of IPMA lies in recognizing that the variable with the greatest impact does not necessarily warrant the most attention. If the performance of a given variable is already high compared to the other explanatory variables, improving it further may require substantial effort. Thus, it may be more effective to focus on variables with lower importance but where performance improvements are more feasible, potentially generating a greater overall impact on the target variable" [19].

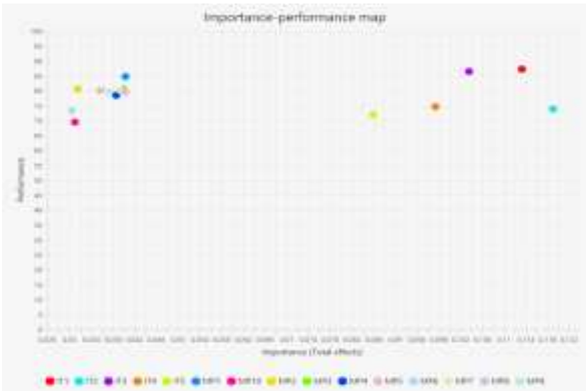

Fig. 6. IPMA for Contractor Operational Performance

The results of the IPMA on COP show that the TI2 indicator (Process Digitization) holds the most important position with a total effect of 0.119, but its performance is still relatively moderate (73.855), making it the top priority for improvement. Inadequate digitization in project work processes can reduce operational efficiency and performance quality, despite its high potential impact on work outcomes. Interestingly, the PM10 indicator (Stakeholder Engagement) has the lowest impact (0.031) and the lowest performance among all indicators (69.466). This is an important signal that stakeholder engagement is still suboptimal, even though this aspect is crucial in ensuring alignment with the project vision and smooth implementation.

DISCUSSIONS

Technological innovation has a direct impact on the effectiveness and efficiency of project management in various sectors. This is reinforced by [20], who show that the integration of technology in innovation projects enables more structured decision-making within limited time and budget constraints. Additionally, a technology-based sustainable project management approach can enhance the economic impact of implemented innovations [21].

Technological innovation directly has a positive impact on improving contractors' operational performance. Technology can accelerate work processes, enhance accuracy, and reduce human errors in construction project operations. Who found that technological innovation improves productivity and the quality of work procedures, although its financial impact tends to be long-term [22]. Technological capabilities drive open innovation that directly impacts the improvement of operational performance perceptions in the SME contractor sector [23].

Effective project management can directly improve contractors' operational performance in the implementation of construction projects. Project management strategies such as comprehensive project planning and the use of digital technology have a positive impact on contractors' operational performance [24]. On the other hand, contractors' managerial capabilities do not always significantly influence road infrastructure project performance, indicating that the influence of project management needs to be supported by other factors [25]. “Through precise performance evaluation, managers can make optimal decisions regarding resource use, ultimately increasing project productivity and overall performance” [26]. “To achieve high competitiveness in the global market, construction companies need to focus on improving their performance. Key factors that influence construction performance are time, cost, quality, safety and health, client satisfaction, environment, financial performance, internal stakeholders, external stakeholders, and information technology and innovation" [27].

Technological innovation can have an indirect influence on improving contractors' operational performance through effective project management. In other words, project management is an important channel in transforming technological potential into operational efficiency and productivity. Technological innovation in the construction sector improves project productivity and quality through improvements in project management practices [22]. In line with this, Technological innovation is implemented through a systemic project management approach that focuses on the successful implementation of innovative strategies in projects [20]. Thus, technology not only has a direct impact but also significantly strengthens project management as the main intermediary in improving contractor operational performance.

CONCLUSION

First, the results of this study indicate that technological innovation plays a significant role and has a significant impact on project management for airport contractors in Indonesia. For example, the use of digital planning software, BIM (Building Information Modeling) technology, and cloud-based monitoring systems has been proven to improve the effectiveness of project management, such as project planning, project control, and inter-team coordination. This indicates that the more accurately technological innovations are applied, the more optimal the project management performance of contractors. “The integration of BIM technology facilitates effective management and sharing of cost segregation data among stakeholders, enhancing collaboration and decision- making throughout the project lifecycle” [28].

Second, the findings also show that project management acts as a mediator in the relationship between technological innovation and contractor operational performance. This mediating role can strengthen project management to maximize the use of technological innovation in field operations. In other words, technological innovation does not directly improve work efficiency or productivity, but rather strengthens the project management system, thereby supporting improved operational performance. “Project planning can indeed improve knowledge inte- gration and, in turn, facilitate construction project success in which knowledge integration plays a mediating role” [29] .

Third, technological innovation acts as a driver of work efficiency, while project management functions as a structure to manage and direct the effective use of technology. Thus, technological innovation and project management have been proven to simultaneously influence the operational performance of airport contractors in Indonesia. The combination of both can have a positive impact on project timeliness, cost control, and work quality, which are highly complex in medium to large-scale infrastructure projects such as airport construction and development in Indonesia. “Better productivity and the ability of the workforce lead to improved performance. With the improvement in performance, the contractor will enjoy better business results over the long run” [30].

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