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Impact of Communication on Capital Project Performance: A Mediated Moderation Model

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Abstract: Many studies demonstrate the importance of communication in project performance. However, little is known about how project communication exerts its effects on the outcomes of capital projects that have a large impact on environmental and economic sustainability. Using a longitudinal survey and bootstrap-based structural-equation modeling, this study uncovers how project competencies and team innovative behavior affect the relationship between project communication and capital project performance. This study collects repeated measures from project managers at two time points: immediately after the initiation and planning stages end and immediately after project completion. Excluding responses with missing data, this study's sample includes 108 capital projects. This study finds that project technical and managerial competencies completely mediate the relationship between project communication and project performance. This study also finds that team innovative behavior affects project performance through the mediating effect of project technical competence. Team innovative behavior also moderates the relationship between project technical competence and project performance. Project communication has the largest effect on project performance despite having the smallest direct effect; project managerial competence possesses the next-largest effect on project performance despite having the largest direct effect. This study discusses the managerial and research implications.

Keywords: project communication; project performance; technical competence; managerial competence; innovative behavior; longitudinal research

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1. Introduction

Communication is critical in organizational life [1]. Similarly, business management literature shows the importance of effective communication in cultivating and sustaining value-enhancing organizational relationships [2]. One executive even asserts that "communication is as fundamental to business as carbon is to physical life" [3].

Research also documents how important effective communication is to project performance (e.g., Chandrasekaran et al. [4]; Chbaly et al. [5]; Chen [6]; Diegmann et al. [7]; Manata et al. [8]; Nunes and Abreu [9]). For example, Badir et al. [10] employ case research to investigate a focal company in the alliance and subsequently develop a conceptual project framework. They conclude that a project's team and leader empowerment have a significant impact on communication performance with strategic partners. Additionally, based on a study of 68 supply chain projects employing the partial least squares (PLS) approach, Brinkhoff et al. [11] note that trust between supply chain project partners is a strong predictor of effective project communication.

Subsequent work by Paik et al. [12] identifies four communication behaviors (monitoring, managing, challenging, and negotiation) that are essential to communication performance. They are based on a content analysis of an industry report and two case studies. Manata et al. [8] develop a measurement model for assessing communication behaviors among 202 team members in 21 capital project teams using confirmatory factor analysis. Dinis et al. [13] show that project communication in the capital-projects industry improves by expediting information flows among project parties via virtual reality and laser-scanning technologies.

Although many studies acknowledge the importance of communication in project outcomes, these studies focus mainly on which factors influence communication (e.g., Brinkhoff et al. [11]: Paik et al. [12]; Oke and Idiagbon-Oke [14]; Sosa et al. [15]). Some studies investigate the relationships between communication and project performance, but they focus on the extent to which communication affects project performance (e.g., Chandrasekaran et al. [4]; Cui et al. [16]; Diegmann et al. [7]; Yan and Dooley [17]). For example, using an in-depth case study of 13 outsourcing projects, Cui et al. [16] conclude that trust and effective communication between project teams and stakeholders drive the success of outsourcing projects.

Subsequent work by Yan and Dooley [17] analyzes 214 buyer–supplier product-development projects using the structural equation modeling (SEM) technique and notes that communication intensity significantly affects project performance if task or relational uncertainty is high. They also find that communication intensity reduces project performance when task uncertainty is low. Chandrasekaran et al. [4] combine cross-case comparison and agent-based simulation experiments to investigate how high-tech organizations manage shifts in research and development (R&D) projects. Using a sample of 142 informants from 12 R&D projects, they note that frequent cross-level communication between top management and R&D project teams improves project performance.

Based on an analysis of 74 information system (IS) project managers, Diegmann et al. [7] note that clients' subjective perceptions of project performance are positively associated with client–vendor communication (CVC), and thus, improved CVC, likely affects the course of projects. Recently, using the multivariate partial least-squares modeling technique to analyze 130 project professionals, de Oliveira and Rabechini [18] demonstrate the importance of infusing communication with empathy with project stakeholders, which significantly enhances project performance.

In sum, studies (e.g., Brinkhoff et al. [11]; Dinis et al. [13]; Paik et al. [12]; Oke and Idiagbon-Oke [14]; Yan and Dooley [17]) that investigate the relationships between communication and project performance focus principally on what factors affect project communication and/or the extent to which communication influences project performance. Relatively few focus on how project communication exerts its impacts on project performance. A few studies investigate communication's mediation variables in a project environment (e.g., Henderson et al. [19]; Lee et al. [20]), but they mainly focus on the relationships between communication and team performance. Additionally, they use cross-sectional research designs to draw inferences from data collected at a single point in time.

As a result, there is a lack of novel research longitudinally investigating what mediates and/or moderates the relationship between communication and capital project performance, as well as the extent to which the constructs influence capital project performance. Understanding the factors through which project communication influences project outcomes and the extent to which each factor's impact on project performance is essential to enhance the relationships between communication and capital project performance. Such understanding is important, as it increases capital project performance and hence reduces the likelihood of project rework that causes more resource consumption and environmental burden. Ultimately, better sustainable practices in project management could be achieved.

Research also shows that project performance is associated with project teams' abilities to create or introduce beneficial new ideas and solutions in work groups, as well as apply new practices and technologies, project knowledge and skills, and effective project managerial practices (Hsiao et al. [21]; Janssen [22,23]). This study broadly classifies these capabilities into three dimensions (factors): team innovative behavior, project technical competence, and project managerial competence. In other words, this study examines whether raising a project's communication effectiveness increases, for example, technical competence, which in turn enhances the odds of the project's favorable outcome over time.

Longitudinal research that collects repeated measures over time from the same individuals and examines changes in the observations is essential to explore the causal properties of these constructs as they manifest and affect project outcomes over time [24].

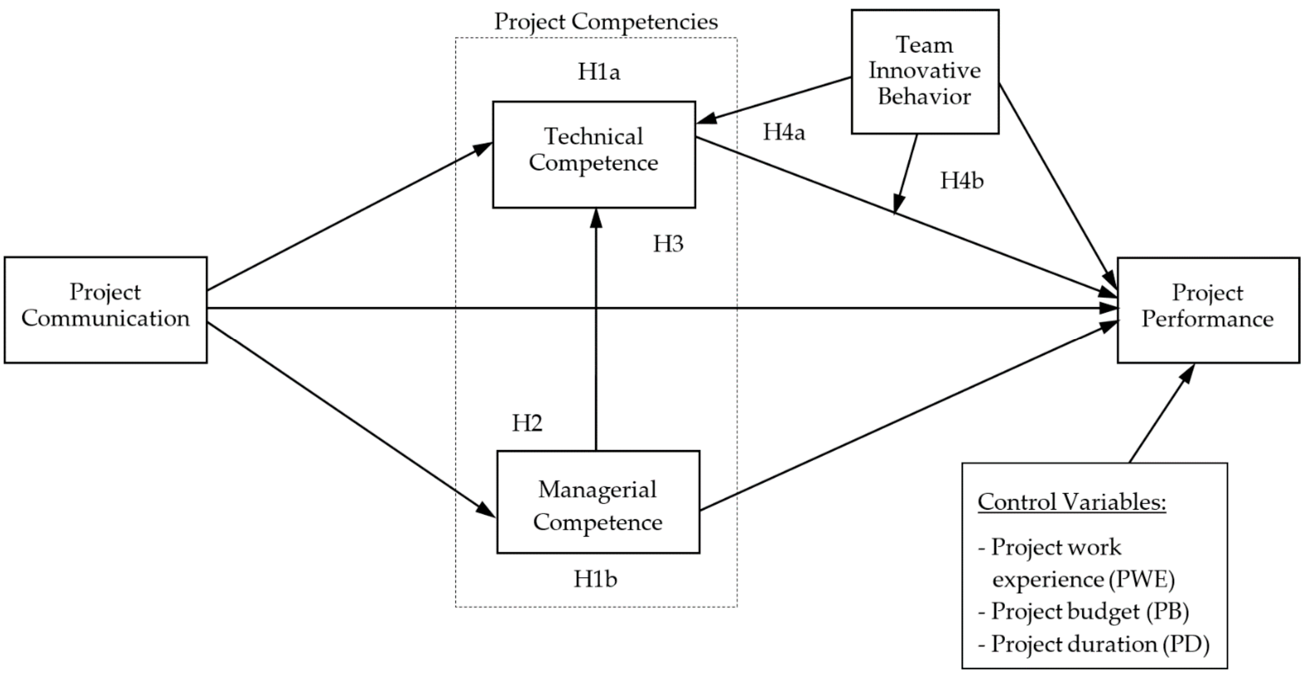
The main objective of this research is, therefore, to analyze longitudinally how, through project technical competence, project managerial competence, and team innovation behavior, project communication affects capital project performance. This study uses the longitudinal survey method, the bootstrap-sampling method, and structural-equation modeling to examine the hypothesized five-dimension research model.

The structure of the present work is as follows. "Theoretical Development" offers a theoretical background for this study's research hypotheses. "Research Methodology" describes this study's research methods. "Research Results" delineates the statistical tests of the hypotheses. "Discussion and Conclusion" presents the implications of the study findings and concludes this study.

2. Theoretical Development

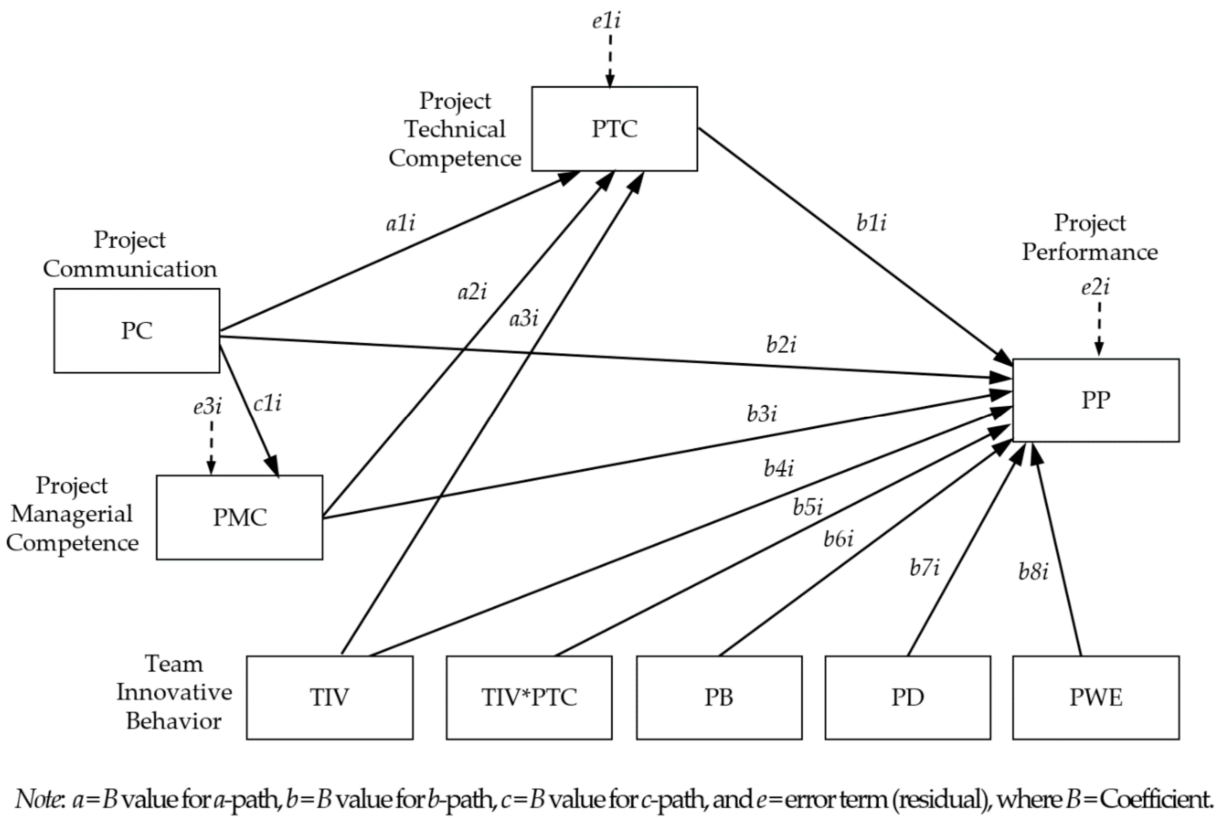
To investigate how project communication—through project technical competence, project managerial competence, and team innovation behavior—affects project performance, this study proposes a mediated moderation model, shown in Figure 1a, where Figure 1b shows the model's statistical diagram. The model extensively reviews interdisciplinary literature and looks to several experienced practitioners and researchers. A key tenet of the model is that effective project communication facilitates high-quality technical competence and managerial competence, which in turn raises project performance. Team innovative behavior partially moderates that performance.

The conceptualization of project performance includes project outcome and customer satisfaction. Project outcome refers to whether the team finishes and delivers the project according to contracted requirements and specifications within the budget estimates and scheduled time frame (Chen and Lin [25]; Hwang et al. [26]). Customer satisfaction refers to how satisfied customers are with how the team handles the job (Chen [27]).



(**a**)

Figure 1. *Cont.*



(**b**)

Figure 1. (**a**) Hypothesized relationships among project communication, project core competencies, team innovative behavior, and project performance. (**b**) Model statistical diagram.

2.1. Project Communication, Project Competencies, and Project Performance

Communication is the process by which information transfers from one individual to another [1]. More specifically, communication is the act or process of transmitting information, ideas, emotions, and skills via words and data visualizations [28]. Communication is central to the performance of temporary organizations (e.g., Brinkhoff et al. [11]; Manata et al. [8]; Sosa et al. [15]; Yan and Dooley [17]). Starting with Allen [29], scholars and practitioners extensively investigate the impact of communication flows on project performance [14].

Project team members' communication effectiveness is the first element of project performance (e.g., Chandrasekaran et al. [4]; Chen [30]; Cui et al. [16]; Diegmann et al. [7]; Yan and Dooley [17]). Effective communication is also an essential antecedent of technical and managerial capabilities [27].

In this study, *project communication* is the exchange of project-specific information between project stakeholders. *Project technical competence* describes the technology, knowledge, and skills team members possess to elaborate on their project tasks, whereas *project managerial competence* is a project team's facility/capability to bring together and utilize project resources to fulfill responsibilities and achieve project objectives [21]. When team members communicate effectively, they share timely and important information formally and informally within and across the project, thereby enhancing project competencies.

Project competencies, in turn, are a possible mediating path through which team members' effectiveness in project communication affects project performance. Hsiao et al. [21] support the existence of a strong connection between a firm's core capabilities and the performance of its new products. That study analyzes 80 managers at 80 manufacturing companies using regression analysis. As Chen [27,30] summarizes, the key determinants of project performance include the project team's use of new technologies and practices, the knowledge and skills the team employs, and the extent to which the team plans, organizes, and uses project resources to carry out responsibilities. High-quality project competencies mean team members apply new project practices and technologies, project knowledge and skills, and project managerial practices that result in higher performance. This study thus hypothesizes:

Hypothesis 1a. *Project technical competence mediates the positive relationship between project communication and capital project performance.*

Hypothesis 1b. *Project managerial competence mediates the positive relationship between project communication and capital project performance.*

Researchers observe that high-quality team performance improves the potency of the technology, knowledge, and skills required for executing project tasks [30]. Studies suggest that team outcomes at least partially mediate the relationship between project communication and project technical competence (e.g., Ancona and Caldwell [31]; Patrashkova-Volzdoska et al. [32]). Nevertheless, there is a lack of research investigating the potential mediating role that project managerial competence could have in relation to project communication and technical competence.

This study suggests that project managerial competence conveys at least part of project communication's influence on project technical competence. Effective communication enhances a team's ability to gather and employ resources to fulfill responsibilities and accomplish project goals, thereby reflecting managerial competence (Chen and Lin [25]; Henderson et al. [19]). High-quality managerial competence also promotes the effective use of project resources, such as new practices, technologies, and skills, which in turn increases project technical competence [27]. As such, effective communication promotes managerial competence, which tends to advance technical competence. This study therefore hypothesizes:

Hypothesis 2. *Project managerial competence mediates the positive relationship between project communication and project technical competence.*

Studies also suggest that project technical competence may mediate the link between project managerial competence and project performance, given that it captures the technology, knowledge, and skills that teams need to complete their tasks [21,27]. High managerial competence allows teams to integrate, organize, and reconfigure project resources and competencies more effectively, resulting in better technical competence for team members to develop and implement their tasks. In fact, when project complexity increases, effective technical competence depends more on well-developed managerial competence to enable efficient integration and use of various resources in the project delivery process [21]. In conjunction with hypothesis 1, which posits that project technical competence and managerial competence are positively associated with project performance, this study hypothesizes:

Hypothesis 3. *Project technical competence mediates the positive relationship between project managerial competence and capital project performance.*

2.2. Innovative Behavior, Project Technical Competence, and Project Performance

People demonstrate innovative behavior when they create, introduce, or apply beneficial new ideas and solutions in work groups or organizations [23]. Examples include developing new strategies for job improvements; suggesting innovative work systems, tactics, or tools; and finding original solutions to problems [22]. Whilst the importance of innovation for organizational competitiveness and efficiency is widely recognized (e.g., Janssen [23]; Yuan and Woodman [33]), innovative employee behavior has become an especially important corporate asset in business environments characterized by ever-increasing competition (e.g., Madrid et al. [34]; Ng and Lucianetti [24]; Scott and Bruce [35]).

For example, drawing on prior studies (e.g., Scott and Bruce [35]), Yuan and Woodman [33] conclude that innovative employee behavior has a critical impact on corporate success in modern dynamic business environments. Based on an analysis of 216 employees and managers in four large corporations, they developed a model to explain innovative employee behavior using performance and image outcome expectations. Similarly, Romero and Martínez-Román [36] report the important repercussions of innovative employee behavior in the early stages of small business creation and development on their subsequent economic success. They conclude that employee education and training are key factors of innovative behavior. Their findings are based on a factor analysis of survey responses from 700 small-business workers.

Furthermore, based on a study of 300 employees from a large automotive corporation using multivariate regression analysis, Leong and Rasli [37] show how employees apply innovative behaviors to achieve performance goals. They conclude that innovative and creative behavior influences overall performance in manufacturing and quality settings. Additionally, Kang et al. [38] analyze 39 chief executive officers (CEOs) and 105 employees from 39 small companies using the multilevel structural-equation modeling (MSEM) technique and note that innovative climate is positively associated with employee innovative behavior, which affects corporate performance.

In addition, research finds that aside from its significant role in corporate performance, innovative work behavior influences technology capacities, technical knowledge, and skills that offer competitive advantages (e.g., Chen [27]; Hsiao et al. [21]; Yuan and Woodman [33]). Along these lines, individual innovative behavior involves idea dissemination and implementation that motivates and inspires teammates to work innovatively over time [39]. In teams, innovative work behavior introduces and applies new technologies and methods that improve technical competence over time, boosting firm performance [33]. In that context, innovative behavior that creates and promotes new ideas and original solutions [23,34] in the workplace may affect not only project performance but also may act as a precursor to project technical competence. This study thus hypothesizes:

Hypothesis 4a. *Project technical competence mediates the positive relationship between team innovative behavior and capital project performance.*

Further, studies indicate that innovative work behavior affects the strength of the relationship between technical capacity and organizational performance [27]. For example, Madrid et al. [34] note that innovative work behavior often helps businesses function more effectively by strengthening technical competencies. They offer a multilevel and interactional model of individual innovation that explains innovative employee work behavior. The work is based on a study using a structural equation modeling analysis of 92 individuals from 72 companies.

Based on a sample of 267 employees from 60 corporations, the moderated mediation model in Ng and Lucianetti [24] explains what motivates employees to improve organizational performance via innovative work behavior that cultivates growth in innovation and technology that enhances corporate performance. Using a hierarchical regression analysis of 86 teams in the Intelligent Ironman Creativity Contest, Fan et al. [40] further note that innovative and creative work behavior strengthens the use of technology, employee knowledge, and employee skills, which in turn affects team performance. Recently, using a SEM analysis of 340 managers in the banking sector, Kör et al. [41] conclude that managers' innovative behavior encourages innovation performance in technology-driven businesses and thus helps innovation and technology improve business performance.

Thus, this study expects project technical competence to affect project performance to a degree that depends upon team innovative behavior. That is, the relationship between project technical competence and project performance strengthens when team innovative behavior rises. This study hypothesizes:

Hypothesis 4b. *Team innovative behavior moderates the relationship between project technical competence and capital project performance.*

3. Research Methodology

3.1. Participants

This study uses capital projects to examine the hypotheses. Capital projects are long-term projects requiring large investments to develop, add to, or improve a capital asset, such as an industrial or environmental facility, transportation project, or building [30]. This study chooses the capital project industry because it contributes significant growth to the economy but receives less research interest than processing or manufacturing sectors [27,42]. In particular, prior studies (e.g., Chen [6,30]; Dinis et al. [13]) demonstrate that the success of a capital project largely lies in effective communication between project stakeholders owing to its size and complexity. Yet, little is known concerning how communication exerts its impact on capital project performance.

The sampling frame is the National Association of General Contractors (NAGC). Of the 500 members this study randomly invited, 117 participated in the survey—a 23.4% response rate. This study solicited collaboration from human resource managers at those 117 firms. Each firm had a project manager who had just finished or was about to finish the initiating and planning phases of a capital project they expected to complete in the subsequent two years.

This study involves two stages of data collection over two years. This study collects repeated measures from each project's manager at two time points: immediately after the initiation and planning stages end and immediately after project completion. In other words, this study measures the constructs of project communication, project technical competence, project managerial competence, team innovative behavior, and project performance at two different points in time. This longitudinal design that focuses on changes over time is essential to explore the causal properties of the variables under investigation [24].

To reduce potential common-method variance (CMV), this study incorporates several recommendations from Podsakoff et al. [43]. Specifically, this study uses survey measures from previous research to generate quality scales and mix the order of the survey questions. This study also confirms to informants that their identities and responses are kept anonymous.

After removing survey responses with incomplete information, the sample includes 108 capital projects—a 21.6% response rate. These 108 capital projects fall into four categories: industrial facilities (20 projects), environmental facilities (17 projects), transportation facilities (16 projects), and buildings (55 projects). The respective project contract prices, budgets, and actual costs range (in U.S. dollars) from USD 47.47 million to USD 0.01 million, USD 47.17 million to USD 0.01 million, and USD 46.80 million to USD 0.01 million, respectively. Project contract durations, scheduled durations, and actual durations are 730 days to 15 days, 728 days to 15 days, and 720 days to 18 days, respectively. Project managers have between 1 and 30 years of project work experience. A total of 20 respondents have fewer than 3 years' experience; 29 have 3–5 years of experience; 32 have between 5 and 10 years; 13 have 10–15 years; 6 have 15–20 years; 5 have 20–25 years; and 3 have between 25 and 30 years.

3.2. Measures and Analysis

The survey questionnaire is based on a five-point Likert scale on which 5 means "strongly agree", and 1 means "strongly disagree". Table 1 describes the measures, constructs, and reliability test results.

Table 1. Scales and reliability measures.

Construct	Subconstruct	Overall Item Description	Reference	Subconstruct α	Construct α
Project communication	Communication planning	CP1: Key stakeholder identification CP2: Communication needs of the stakeholders	Barclay and Osei-Bryson (2010) and Emhjellen (1997)	0.86	0.94
	Information distribution	ID1: Information gathering and sharing ID2: Quality of project status reports ID3: Communication within project team members and with the customer	Henderson (2008) and Narayanan et al. (2011)	0.92	
Project performance	Project outcome	PO1: Within the budget estimate PO2: Within the scheduled time frame PO3: Meeting customer budget, scheduled time, and quality requirements	Chen and Lin (2018)	0.84	0.92
	Customer satisfaction	CS1: Meeting customer budget, scheduled time, and quality requirements CS2: Responsiveness to customer requests/complaints CS3: Satisfaction with the way your team handles the job	Chen (2014)	0.87	
Project technical competence	Research & development	RD1: Team education and confidence RD2: Financial and physical resources adequate	Chen (2014)	0.92	0.96
	Technology management	TM1: At the leading edge of project practices/technologies TM2: Acquiring project technological capabilities in advance of needs TM3: Evaluation of new project practices and technologies	Prajogo and Ahmed (2006)	0.92	
	Knowledge management	KM1: Quality of intellectual capital build-up KM2: Regular upgrades in project-related knowledge and skills KM3: Sharing and disseminating project-related information and knowledge KM4: Managing project-related intellectual assets	Prajogo and Ahmed (2006)	0.93	
Project managerial competence	Scope	Sc1: Scope definition Sc2: Scope verification	Chen (2013)	0.82	0.95
	Quality	Qu1: Quality planning Qu2: Quality assurance Qu3: Quality control	Chen (2015)	0.84	
	Team	Te1: Motivation for achieving the objectives of the project Te2: Team-building Te3: Conflict resolution and problem-solving	Bendoly and Swink (2007) and Thamhain (2004)	0.91	
	Inventory	In1: Inventory planning In2: Quality of inventory management In3: Coordination of inventory management between the project level and the company level	Luu et al. (2008)	0.91	
	Change	Ch1: Quality of change control Ch2: Bringing the appropriate parties into the discussion	Luu et al. (2008) andChen (2013)	0.84	
Team innovative behavior		TIB1: Creating novel ideas for job improvements TIB2: New working methods, techniques, or instruments TIB3: Producing original solutions to problems	Janssen (2001)		0.86

Project Communication. Five-item scales in Barclay and Osei-Bryson [44], Henderson [45], and Narayanan et al. [46] measure project communication as communication planning and information distribution, with two- and three-item scales, respectively. This study uses Cronbach's α to assess the internal consistency of a set of item scales of a construct, where a value of 0.70 or above suggests internal consistency in that construct [47]. The Cronbach's α for communication planning and information distribution are 0.86 and 0.92, respectively. For project communication, it is 0.94. The values are all larger than the threshold value of 0.70, indicating internal consistency in these constructs.

Project Performance. Six-item scales in Chen [27,48] and Chen and Lin [25] measure capital project performance as project outcome and customer satisfaction with three- and three-item scales, respectively. The Cronbach's α for project outcome and customer satisfaction are 0.84 and 0.87, respectively. The Cronbach's α for project performance is 0.92.

Project Technical Competence. Nine-item scales in Chen [27] and Prajogo and Ahmed [49] measure project technical competence as research and development, technology management, and knowledge management with two-, three-, and four-item scales, respectively. The Cronbach's α for research & development, technology management, and knowledge management are 0.92, 0.92, and 0.93, respectively. For project technical competence, it is 0.96.

Project Managerial Competence. Multi-item scales in Bendoly and Swink [50], Chen [27], and Luu et al. [51] measure project managerial competence as scope, quality, team, inventory, and change with two-, three-, three-, three-, and two-item scales, respectively. The Cronbach's α for scope, quality, team, inventory, and change are 0.82, 0.84, 0.91, 0.91, and 0.84, respectively. The Cronbach's α for *project managerial competence* is 0.95.

Team Innovative Behavior. Janssen's [22] three-item scale measures team innovative behavior (Cronbach's α = 0.86). In addition, this study controls for the potential impact of project budget (*PB*), project duration (*PD*), and the manager's project work experience (*PWE*), because these variables may influence project performance [52]. That is, it is plausible that a project manager's work experience affects the extent to which team members complete tasks [25]. Project duration and budget are control variables in many studies [52] based on the premise that longer duration and larger budget are indicators of time, cost, and effort needed to finish the project. This study measures *PWE*, *PB*, and *PD* in years, millions, and working days, respectively.

The survey data are from the project managers of capital project teams, making it necessary to determine whether any general factor explains most of the covariance between the forecaster and criterion variable. This study applies Harman's single-factor test [43] to evaluate the impact of CMV on the sample data. The test results show no single dominant factor. The largest accounts for 21.66% of the total variance, implying that CMV is not a pervasive problem in this study.

This study uses a twofold process to test the hypotheses regarding how project communication, via project technical competence, project managerial competence, and innovative behavior, affects capital project performance. First, this study develops and validates the measurement model using confirmatory factor analysis (CFA) [53] for testing the hypothesized model presented in Figure 1. Second, this study utilizes the bootstrap-based SEM [54,55] to test the hypothesized model and estimate the effects of project communication, project technical competence, project managerial competence, and team innovative behavior on project performance.

4. Research Results

4.1. Measurement Results

Prior to testing the hypotheses, this study uses a rigorous approach to confirm and validate the measurement model based on the CFA technique [53] using analysis of moment structures (AMOS). This study utilizes the standardized factoring loadings, average variance extracted (AVE), and composite creditability (CR) to evaluate the measurement model's convergent validity. The results of CFA indicate that all the standardized factor loadings range from 0.71 to 0.96, which are greater than the recommended threshold (0.5) and significance ($p < 0.001$), implying the existence of convergent validity.

Table 2 reports the measurement model's descriptive statistics, CRs, AVEs, and average shared squared variances (ASVs). As shown in Tables 1 and 2, the Cronbach's α and CR values for *project communication*, *project technical competence*, *project managerial competence*, *team innovative behavior*, and *project performance* are (0.94, 0.83), (0.96, 0.90), (0.95, 0.92), (0.86, 0.86), and (0.92, 0.75), respectively, and are all greater than the threshold values (0.70, 0.60) [53]. In addition, Table 2 shows that the AVE values for each construct are 0.66–0.80, which are all above the recommended threshold (0.50) [54]. This further confirms the existence of convergent validity for all the constructs.

Table 2. Results of convergent and discriminant validity.

Construct	Mean	Standard Deviation	CR	AVE	ASV
Project communication	2.94	1.08	0.83	0.78	0.63
Project technical competence	2.71	1.10	0.90	0.80	0.59
Project managerial competence	2.98	0.95	0.92	0.71	0.68
Team innovative behavior	2.84	1.14	0.86	0.66	0.64
Project performance	3.25	0.97	0.75	0.68	0.54

As also shown in Table 2, the ASV values of project communication, project technical competence, project managerial competence, team innovative performance, and project performance are 0.63, 0.59, 0.68, 0.64, 0.54, respectively. They are all smaller than their corresponding AVE values of 0.78, 0.80, 0.71, 0.66, and 0.68. This suggests discriminant validity exists among these constructs [56,57]. The measurement model's overall fit also suggests a reasonable fit with the data, where chi-square/degree of freedom is 2.354, incremental fit index (IFI) is 0.921, Tucker–Lewis index (TLI) is 0.907, comparative fit index (CFI) is 0.920, and root mean square error of approximation (RMSEA) is 0.079 [53].

4.2. Hypotheses Testing

Following Chen [27], Prajogo and Ahmed [49], and Wiengarten et al. [58], this study converts the scales in each construct into a single composite score subsequent to the validation of the measurement model. The five constructs show that their AVEs and Cronbach's α values are larger than 0.5 and 0.7, respectively. The standardized factor loadings of all items in each construct are also larger than the threshold value of 0.5. These results support the validity of the five constructs [53,59].

Table 3 presents the results of the hypothesized mediated moderation model's unstandardized regression weights using the bootstrap-based SEM [54,55] with 1000 bootstrap samples. The RMSEA for the model is 0.038, and the respective chi-square/DF, IFI, TLI, and CFI are 1.306, 0.980, 0.965, and 0.979, indicating a good fit [54]. As Table 3 shows, the significance of the unstandardized path coefficient (i.e., direct effect) at $p < 0.001$ indicates that project communication greatly affects project technical competence. In addition, the bootstrapping bias-corrected 95% confidence interval (CI) excludes zero, which confirms a statistically significant direct effect.

Table 3. Unstandardized structural model: results of 1000 bootstrap samples.

Sources		Parameter Estimates				BBC 95% CI		
Dependent	**Independent**	**B**	**SE**	**CR**	**P**	**LB**	**UB**	**P**
Project technical competence	Project communication	0.482	0.070	6.907	<0.001	0.325	0.648	
Project technical competence	Project managerial competence	0.229	0.091	2.502	0.012	−0.020	0.456	0.069
Project technical competence	Team innovative behavior	0.239	0.065	3.662	<0.001	0.086	0.410	
Project performance	Project technical competence	0.196	0.056	3.508	<0.001	0.067	0.347	
Project performance	Project communication	0.084	0.057	1.466	0.143	−0.041	0.210	
Project performance	Project managerial competence	0.471	0.068	6.927	<0.001	0.310	0.638	
Project performance	Team innovative behavior	0.152	0.051	2.976	0.003	0.044	0.293	
Project performance	Team innovative behavior * Project technical competence	−0.090	0.027	−3.389	<0.001	−0.164	−0.037	
Project performance	PB	−0.001	0.000	−2.855	0.004	−0.001	0.001	0.067
Project performance	PD	−0.001	0.000	−0.675	0.500	0.000	0.000	
Project performance	PWE	0.007	0.005	1.449	0.147	−0.005	0.017	
Project managerial competence	Project communication	0.975	0.038	25.431	<0.001	0.892	1.083	
Chi-square		27.431						
Degree of freedom		21.000						
IFI		0.980						
TLI		0.965						
CFI		0.979						
RMSEA		0.038						

Note: The respective units of PWE, PB, and PD are years, millions, and working days for all the following analyses. B = Coefficient, SE = standard error, CR = Critical ratio, P = Probability, BBC 95% CI = bootstrapping bias-corrected 95% confidence interval, LB = lower bound, UP = upper bound, IFI = incremental fit index, TLI = Tucker–Lewis index, CFI = comparative fit index, and RMSEA = root mean square error of approximation.

This study makes similar conclusions about the significant direct effects of team innovative behavior on project technical competence at $p < 0.001$, project communication on project managerial competence at $p < 0.001$, project technical competence on project performance at $p < 0.001$, project managerial competence on project performance at $p < 0.001$, and team innovative behavior on project performance at $p < 0.050$, as well as the significant interaction effect of team innovative behavior and project technical competence on project performance at $p < 0.001$. The non-significant direct effect of project communication on project performance is also confirmed by the bootstrapping bias-corrected 95% CI that contains zero.

In addition, although the CR value shows a significant direct effect of project managerial competence on project technical competence at $p < 0.050$, the bootstrapping bias-corrected 95% CI contains zero, indicating an inconclusive result. However, a bootstrapping analysis shows a mildly significant direct effect at $p = 0.069$. Figure 2 structurally presents the mediated moderation model with 1000 bootstrap samples. Path values are standardized coefficients.

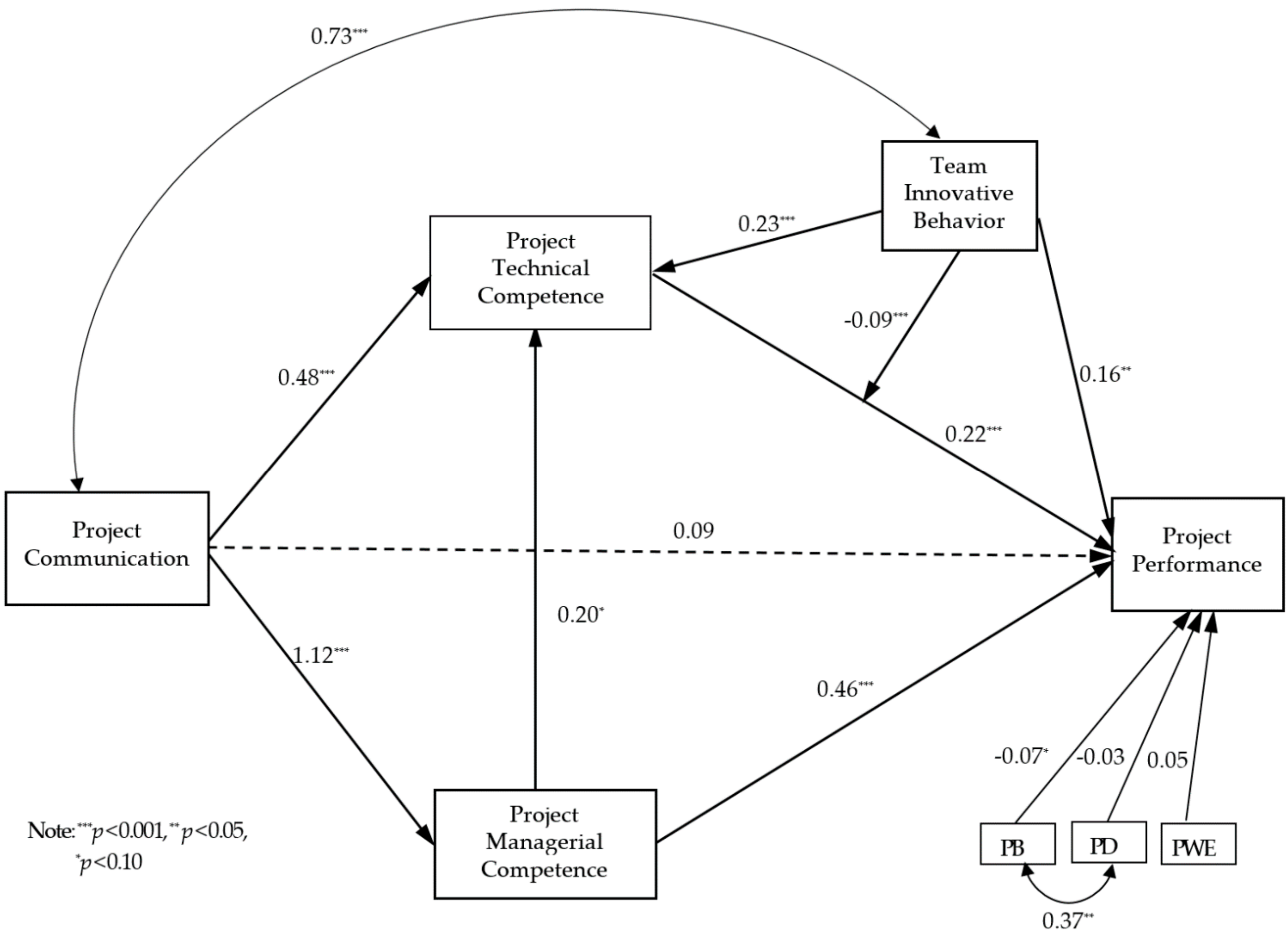


Figure 2. The standardized mediation model (1000 bootstrap samples). Chi-square/DF = 1.306, IFI = 0.980, TLI = 0.965, CFI = 0.979, and RMSEA = 0.038.

Table 4 shows the results of bootstrap-based SEM analysis and Sobel test for the mediations. As the table shows, the significance of the indirect effect (Hypothesis 1a) at $p = 0.002$ by the Sobel test indicates that project technical competence mediates the relationship between project communication and project performance. The bias-corrected 95% CI excludes zero, which confirms a statistically significant indirect effect [60] (Preacher and Hayes, 2008). This supports Hypothesis 1a, which states that project communication is positively related to project performance through the mediating influence of project technical competence.

This study makes a similar conclusion about the significance of the indirect effect at $p < 0.001$ by the Sobel test and the bias-corrected 95% CI that excludes zero. This supports Hypothesis 1b, which suggests that project communication is positively related to project performance through the mediating influence of project managerial competence. Similarly, the significance of the indirect effect (see Hypotheses 3 and 4a) by the Sobel test, as well as the bias-corrected 95% CI excluding zero, supports Hypothesis 3. That hypothesis states that project managerial competence is positively related to project performance via the mediating influence of project technical competence. Hypothesis 4a states that team innovative behavior and project performance are positively related through the mediating influence of project technical competence.

Table 4. Results of bootstrap-based SEM analysis and Sobel test for the mediations with 1000 bootstrap samples.

Hypothesized Path	Indirect Effect		Sobel Test		BBC 95% CI		
	B	**SE**	**Z**	**P**	**LB**	**UB**	**P**
Hypothesis 1a Project communication → project technical competence → project performance	0.094	0.041	3.120	0.002	0.031	0.208	
Hypothesis 1b Project communication → project managerial competence → project performance	0.460	0.093	5.337	<0.001	0.291	0.639	
Hypothesis 2 Project communication → project managerial competence → project technical competence	0.223	0.117	2.504	0.012	−0.013	0.459	0.065
Hypothesis 3 Project managerial competence → project technical competence → project performance	0.045	0.025	2.043	0.041	0.008	0.129	
Hypothesis 4a Team innovative behavior → project technical competence → project competence	0.047	0.023	2.535	0.011	0.013	0.121	

Note: B = coefficient, SE = standard error, Z = z score based on the Sobel test, P = probability, BBC 95% CI = bootstrapping bias-corrected 95% confidence interval, LB = lower bound, and UP = upper bound.

Table 4 also reveals project managerial competence to be a significant mediator of project communication—project technical competence at p = 0.012, as evaluted by the Sobel test (Hypothesis 2). However, the bootstrapping bias-corrected 95% CI includes zero, suggesting an inconclusive result. Further bootstrapping analysis indicates a mild significance at the p = 0.069 level. This study thus concludes that project communication is mildly positively related to project technical competence through the mediating influence of project management competence.

Moreover, as shown in Table 3, the regression coefficient for the interaction term (*team innovative behavior* × *project technical competence*) is statistically different from zero at the 0.001 level. The bootstrapping test generates a bias-corrected 95% CI from −0.164 to −0.037, which suggests the interaction term is significant by excluding zero. These results support hypothesis 4b, which states that team innovative behavior moderates the relationship between project technical competence and project performance.

5. Discussion and Conclusions

Scholars extensively investigate the influences of communication on project performance, but few explore what variables transform project communication into project performance and to what extent each of these variables influences project performance. This study develops and examines the theory that effective project communication facilitates high-quality technical competence and managerial competence, which in turn raises project performance. This study also argues that the relationship between project technical competence and project performance depends on team innovative behavior.

The results of the bootstrap-based SEM analyses reveal that combined project managerial and project technical competencies fully mediate the relationship between project communication and project performance. This is because the direct effect of project communication on project performance is non-significant (see Figure 2).

In addition, the results of the bootstrap-based SEM analyses show that project managerial competence partially mediates the relationship between project communication and project technical competence due to the significance of project communication's direct effect on project technical competence (see Figure 2). They also show that project technical competence partially mediates the relationship between project managerial competence and project performance as project managerial competence's direct effect on project performance is significant (Figure 2). Furthermore, this study finds that project technical competence partially mediates the relationship between team innovative behavior and project performance owing to the significance of team innovative behavior's direct effect on project performance (Figure 2) and the degree to which project technical competence influences project performance is contingent upon team innovative behavior.

A graphical representation of the moderating role of team innovative behavior in Figure 3 reveals interesting nuances in the relationship. Project performance is lowest when there is poor performance in project technical competence and a low level of team innovative behavior. Further, high team innovative behavior has a negative slope. This indicates that the positive relationship between project technical competence and project performance becomes weaker when team innovative behavior strengthens.

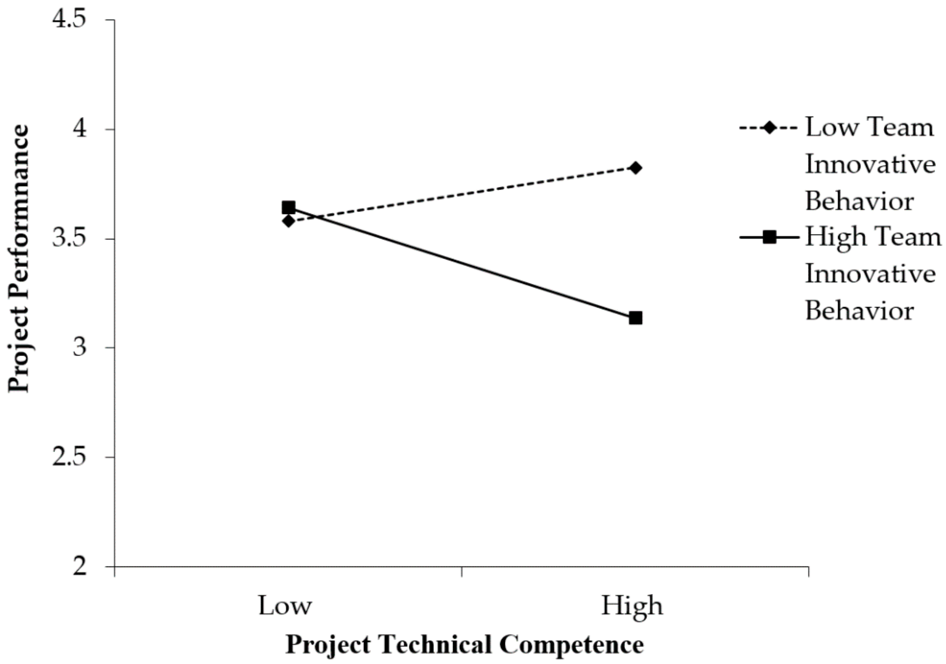


Figure 3. Relationship between project technical competence and project performance at low and high levels of team innovative performance (1000 bootstrap samples).

Further, the research shows that both team innovative behavior and project technical competence positively affect project performance. However, their interaction on project performance is negative (see Table 3 and Figure 2). In other words, team innovative behavior negatively moderates the relationship between project technical competence and project performance. This negative moderation further echoes the indication in Figure 3 that the positive link between project technical competence and project performance strengthens when team innovative behavior weakens. This indication is somewhat unexpected, given that the general perception in the literature (e.g., Ng and Lucianetti [24]; Yuan and Woodman [33]) is that technical competence best promotes organizational performance when innovative behavior is high.

One possible explanation for such a negative moderating influence on the relationship between project technical competence and project performance is that project performance grows faster when team innovative behavior is lower. This may be due to Spearman's Law of Diminishing Returns (SLODR), which states that the effects of human cognitive ability strengthen for lower-ability subjects [61]. Another explanation is that project technical competence and team innovative behavior do not have a linear relationship; rather, it is curvilinear (such as an inverted u-shaped relationship). As a senior project manager said in a post-survey interview:

> *"In the capital projects industry, team innovative behavior is definitely an important driver for improving technology, knowledge, and skills required for team members to do their jobs. However, if team members are continuously trying and experimenting new ideas, working methods, or techniques, this could increase our project cost and slow down our project progress, which in some cases even causes delay and cost overrun in the process of project delivery."*

More research is necessary to clarify this unexpected result regarding the negative moderating influence of team innovative behavior. Nonetheless, there is a direct managerial implication for project practitioners: to improve project performance effectively during the project delivery process, project practitioners should establish a mechanism for monitoring and controlling team innovative behavior and not excessively promote the importance of team innovative behavior.

In addition, as shown in Figure 2, the combined project technical competence and project managerial competencies fully mediate the relationship between project communication and performance. This suggests that project communication only indirectly influences project performance, whereas project technical competence and project managerial competence exert direct effects. Another managerial implication is, therefore, that for effective capital project delivery, project managers who want to enhance project performance by improving project communication should also target improving project technical competence and project managerial competence.

This study's research methodology provides a practical way to understand the potential quantitative impacts of project communication and its mediating and moderating variables. Table 5 summarizes the SEM analysis quantitative results (Figure 2) for direct, indirect, and total marginal physical product (MPP) effects based on the hypotheses' test results, where MPP is the percentage change per input resulting in percentage change in output. In particular, a 1% increase in team innovative behavior means a 0.230% increase in project technical competence and a 0.216% increase in project performance. This suggests that team innovative behavior has a total MPP effect of 0.216 on project performance. Additionally, a 1% increase in project technical competence produces a 0.220% increase in project performance, suggesting an MPP effect of 0.220. Likewise, a 1% increase in project managerial competence produces a 0.199% increase in project technical competence, creating a 0.506% increase in project performance. This suggests that project managerial competence has a total MPP effect of 0.506 on project performance, the second-largest effect despite having the highest direct MPP effect on project performance.

Table 5. Results of the bootstrap-based SEM analysis for direct, indirect, and total marginal physical product (MPP) effects.

Variable	**Project Communication**			**Project Managerial Competence**			**Project Technical Competence**			**Team Innovative Behavior**		
	DME	**IME**	**TME**	**DME**	**IME**	**TME**	**DME**	**IME**	**TME**	**DME**	**IME**	**TME**
Project Technical Competence	0.482	0.223	0.705	0.199		0.199				0.230		0.230
Project Managerial Competence	1.120		1.120									
Team Innovative Behavior												
Project Performance	0.094	0.673	0.767	0.462	0.044	0.506	0.220		0.220	0.165	0.051	0.216

Note: 1000 bootstraps. DME = direct MPP effect, IME = indirect MPP effect, and TME = total MPP effect.

Further, a 1% rise in project communication means 0.705% and 1.120% increases in project technical competence and project managerial competence, respectively, which generate a 0.767% increase in project performance. The total MPP effect is 0.767, the highest among the variables despite having the smallest direct MPP effect on project performance. This indicates that indirect MPP effects may produce an interaction chain effect that is more substantial than direct MPP effects. A more subtle implication is that project practitioners should not downplay a seemingly negligible effect on project performance, because, through chain effects, it may become significant.

Finally, this study hopes that it simulates further investigations of the relationship between project communication and project performance from a dynamic perspective. Most of the literature related to project communication and performance is based on cross-sectional research designs (i.e., static research designs) (e.g., Dinis et al. [13]; Paik et al. [12]; Oke and Idiagbon-Oke [14]; Yan and Dooley [17]). However, the static research designs that collect data at one point in time may not truly reflect what would happen in practice because it invariably indicates that when one variable changes, the other variables also change [24]. This study relaxes that assumption by collecting repeated measures at two different points in time, enabling one to observe and measure whether one variable changes if another changes. Such a dynamic perspective on the relationship between project communication and performance is more practical and informative, providing solid evidence that the dynamic mediation effects of project managerial and technical competencies, as well as the dynamic moderation effect of team innovative behavior, occur in practice.

In sum, the research findings regarding the importance of project communication to project performance align with other research (e.g., Brinkhoff et al. [11]; Chandrasekaran et al. [4]; Cui et al. [16]; Diegmann et al. [7]; Oke and Idiagbon-Oke [14]; Yan and Dooley [17]). This study adds to the literature's understanding of how project communication, through project competencies and team innovative behavior, influences project performance. Nevertheless, the direct effects of project communication on project technical competence, project managerial competence on project performance, and project technical competence on project performance are significant, suggesting the existence of potential mediators. This calls for more research on those possible mediators.

In addition, this study examines how project communication affects project performance via capital projects. The results might not apply to all other project types (e.g., R&D projects and NPD projects). However, future research could triangulate the findings using different types of projects, thereby providing a more complete picture. Further, although this study provides possible explanations for the negative moderating influence of team innovative behavior on project performance, more research should clarify it. Furthermore, although a high response rate does not necessarily mean free from nonresponse bias, future research may utilize response-enhancing techniques (e.g., social networks) in the capital projects industry.

This study uses project managers to report on project team capabilities. When performing their work, project managers do not act alone; they interact with team members. This enables project managers to evaluate average team member capabilities. This study, however, does not consider the potential effects of capability variability among team members. This, too, calls for more research to study how capability variability among team members influences project competencies and performance. Finally, this study measures capital project performance based on project budget, project schedule, project quality, and customer satisfaction [25,27,48]. Future research could further triangulate the research findings by including more measures of sustainability factors such as the project's social, environmental, and economic impacts.

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