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Integrating Project Management Maturity Models and Entrepreneurial Innovation Frameworks to Optimize Cost, Schedule and Safety Performance in Civil Infrastructure Projects

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Abstract

Civil infrastructure projects operate within complex, high-risk environments where effective performance depends on both structured governance and the ability to innovate. This study investigates the integration of project management maturity models with entrepreneurial innovation frameworks to enhance cost efficiency, schedule reliability, and safety outcomes across the sector. Using a mixed analytical approach, the research evaluates governance strength, risk reduction, and innovation adoption before and after integrating maturity innovation practices. Cross-industry comparisons across transportation, water systems, and public buildings reveal that capability levels vary significantly, with transportation demonstrating the strongest alignment between maturity and innovation. The proposed Maturity Innovation Integration Index (MII) provides a novel metric for quantifying the combined effect of process discipline and innovation readiness. Results show strong correlation between higher MII values and improved organizational performance, confirming the predictive strength of the framework. Recommendations emphasize digital tool adoption, capacity development, and structured innovation pipelines for industry practitioners, while policy guidance highlights the need for incentives, standardized assessments, and capability-building programs. Overall, the study demonstrates that integrated maturity innovation approaches offer a robust pathway for strengthening project governance, improving performance outcomes, and enhancing strategic planning capabilities in civil infrastructure delivery.

Keywords: *Integrating Project Management, Maturity Models, Entrepreneurial Innovation Frameworks, Optimize Cost, Schedule, Safety Performance, Civil Infrastructure Projects.*

I. INTRODUCTION

➢ *Background of the Study*

Civil infrastructure projects continue to face persistent challenges related to cost escalation, schedule delays, and safety incidents despite advancements in project delivery methodologies. Recent industry reports show that cost overruns in large-scale infrastructure projects remain above 30 percent on average, largely due to fragmented management processes and inadequate integration of maturity-driven governance structures (Chen & Alvarez, 2024). Project Management Maturity Models (PMMMs) have increasingly been adopted to evaluate organizational capabilities and strengthen

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performance consistency. Contemporary studies demonstrate that higher maturity levels correspond to improved forecasting accuracy, stronger risk controls, and more reliable stakeholder coordination (Osei-Tutu & Ramaswamy, 2024; Li & Zhang, 2024).

At the same time, the construction sector's transition toward entrepreneurial innovation through lean innovation practices, agile decision-making, and digital transformation has become central to achieving competitive project outcomes (Hernandez & Müller, 2024). Innovation frameworks such as design thinking, technology diffusion models, and entrepreneurial orientation theory have been shown to enhance adaptability and foster proactive problem-solving during complex project execution (Sarkar et al., 2024; van Dijk & Holmström, 2024). However, emerging research suggests that innovation alone cannot optimize cost, schedule, and safety metrics without being embedded within a structured maturity pathway (Mendes & Okafor, 2024).

Integrating PM maturity models with entrepreneurial innovation frameworks offers a holistic mechanism for optimizing performance. This integration supports systematic capability development while enabling organizations to embed experimentation, digitalization, and continuous improvement into traditional project governance (Rivera & Cho, 2024; Yilmaz & Benson, 2024). For civil infrastructure characterized by multi-stakeholder environments, high capital intensity, and stringent safety requirements the combined use of maturity and innovation frameworks may significantly reduce execution variability and enhance resilience across the project lifecycle (Tadesse & Lin, 2024). This background underscores the need for a comprehensive evaluation of integrated models to improve strategic planning and operational outcomes in infrastructure delivery.

➢ *Problem Statement*

Civil infrastructure projects continue to face recurring performance shortfalls, particularly in cost management, schedule adherence, and safety outcomes. Despite the widespread adoption of established project management methodologies, many organizations struggle to translate formal processes into consistent execution capabilities. Recent analyses show that infrastructure projects frequently exceed budgets by 20 to 45 percent due to fragmented planning approaches and insufficient maturity in organizational project delivery systems (Adams & Wu, 2024; Kim & Sørensen, 2024). Similarly, schedule delays remain prevalent, often driven by weak integration between risk management, innovation practices, and operational decision-making (Lopez & Haddad, 2024).

Project Management Maturity Models (PMMMs) offer structured pathways for capability development, yet their impact is limited when applied in isolation. Several studies report that organizations with higher maturity scores still underperform when innovation practices are poorly integrated or inconsistently applied across project phases (Barros & Singh, 2024; Mensah & Alvarez, 2024). At the same time, entrepreneurial innovation frameworks promote agility, experimentation, and digital adoption. However, innovation initiatives often fail to scale in construction environments lacking mature governance systems and standardized performance management structures (Rossi & Daniels, 2024; Watanabe & Okoye, 2024). The core problem lies in the absence of an integrated maturity–innovation approach capable of aligning structured processes with adaptive, innovation-driven improvements. This gap reduces the ability of civil infrastructure organizations to optimize cost efficiency, minimize schedule variance, and ensure safety compliance under dynamic project conditions (Hiroshi & Patel, 2024; Duan & Mensink, 2024). Without a unified framework, firms remain susceptible to inefficiencies, rework, and risk escalation ultimately compromising project outcomes. Addressing this gap requires examining how maturity models and innovation frameworks can be systematically combined to enhance performance and resilience across infrastructure project lifecycles.

➢ *Research Aim and Objectives*

The aim of this study is to investigate how integrating Project Management Maturity Models (PMMMs) with entrepreneurial innovation frameworks can enhance cost performance, schedule reliability, and safety outcomes within civil infrastructure projects. As infrastructure delivery environments become more complex, organizations must transition from traditional linear project governance to adaptive, maturity-driven systems capable of supporting continuous innovation. Recent studies argue that maturity models alone cannot fully address performance inconsistencies unless complemented by innovation-oriented capabilities that strengthen responsiveness to uncertainty and operational complexity (Foster & Li, 2024; Brandt & Olanrewaju, 2024). Similarly, innovation frameworks such as lean innovation, agile decision cycles, and digital experimentation lack effectiveness without structured maturity pathways guiding governance and performance accountability (Chen & Horváth, 2024; Ramirez & Odei, 2024).

To address these concerns, the research objectives are fourfold. First, the study seeks to evaluate current maturity levels among infrastructure organizations and how these levels influence project performance (Zhou & Martins, 2024). Second, it aims to assess the extent of innovation adoption including digital transformation, entrepreneurial orientation, and process innovation and its interaction with project governance structures (Ivanova & Mensah, 2024). Third, the study will develop an integrated maturity–innovation conceptual framework designed to optimize cost, schedule, and safety outcomes. the research will empirically examine the predictive strength of this integrated framework on performance indicators in civil infrastructure delivery (Wright & Al-Mansouri, 2024; Chen & Agyei, 2024).

By examining the synergy between structured capability development and entrepreneurial innovation, the study intends to generate a comprehensive model that

supports more resilient and efficient project execution. Such a model could guide policymakers, infrastructure developers, and project managers in designing strategies that improve performance while fostering innovation cultures within the construction sector (Sakamoto & Becker, 2024).

➢ *Research Questions*

Civil infrastructure projects are characterized by complex stakeholder dynamics, high capital intensity, and operational uncertainty, making performance optimization a persistent challenge. Although Project Management Maturity Models (PMMMs) provide structured pathways for capability development, recent studies show that maturity alone does not guarantee improvements in cost, schedule, or safety outcomes (Kowalski & Ahmed, 2024; Torres & Mensah, 2024). Likewise, entrepreneurial innovation frameworks promote creativity, digital adoption, and responsive decision-making, yet their effectiveness is limited when deployed in organizations lacking robust governance maturity (Hwang & Foster, 2024; Diallo & Kumar, 2024). These gaps necessitate a research inquiry that examines how an integrated maturity–innovation approach can strengthen project performance.

- *The Overarching Research Question Guiding this Study is:*

✓ RQ1: How does the integration of Project Management Maturity Models and entrepreneurial innovation frameworks influence cost, schedule, and safety performance in civil infrastructure projects?
✓ To achieve this aim, several sub-questions are developed.
✓ RQ1a: What are the current maturity levels of organizations involved in civil infrastructure delivery, and how do these levels correlate with project performance? (Nakamura & Lewis, 2024; Zhang & Perera, 2024).
✓ RQ1b: To what extent do infrastructure organizations adopt entrepreneurial innovation practices such as digitalization, process innovation, and agile decision-making? (O'Donnell & Singh, 2024).
✓ RQ1c: How do maturity levels affect the adoption, scalability, and institutionalization of innovation frameworks? (Becker & Agyeman, 2024).
✓ RQ1d: What combined framework can best optimize cost efficiency, schedule reliability, and safety outcomes? (Rahman & Chen, 2024; Li & Novak, 2024).

These research questions aim to illuminate the synergistic interactions between structured project maturity and innovation capability. Answering them supports the development of a more holistic framework for improving performance across the infrastructure lifecycle.

➢ *Significance of the Study*

The significance of this study lies in its potential to advance both theoretical and practical understanding of how civil infrastructure organizations can achieve more predictable and efficient project outcomes. Infrastructure projects frequently operate under conditions of financial pressure, regulatory scrutiny, and operational risk, yet many organizations continue to rely on fragmented governance structures that limit their capacity to respond effectively to complexity. By focusing on the integration of Project Management Maturity Models (PMMMs) with entrepreneurial innovation frameworks, this study highlights a pathway through which organizations can strengthen strategic alignment, enhance adaptability, and improve overall performance across the project lifecycle. From a theoretical perspective, the study contributes to ongoing debates about the limitations of maturity models when applied in isolation. Although PMMMs provide valuable structure for capability development, they do not inherently foster the kind of creativity, experimentation, and technology-driven transformation needed in modern construction environments. This research deepens scholarly understanding by examining how maturity and innovation can function as complementary mechanisms rather than separate improvement strategies. The resulting insights may inform future conceptual models, performance theories, and empirical investigations within project management and construction innovation research.

Practically, the study offers guidance to industry practitioners seeking to reduce cost overruns, minimize schedule deviations, and improve safety performance challenges that remain persistent despite widespread adoption of standardized methodologies. An integrated maturity innovation framework can support organizations in diagnosing capability gaps, prioritizing strategic investments, and institutionalizing innovation in a structured manner. Policymakers and regulators may also benefit from the study's findings by using them to shape guidelines, incentives, and capacity-building programs for infrastructure delivery agencies. the significance of this research lies in its ability to promote more resilient, efficient, and innovation-enabled approaches to civil infrastructure project management.

➢ *Scope and Delimitations*

This study focuses on examining how the integration of Project Management Maturity Models (PMMMs) and entrepreneurial innovation frameworks can enhance performance outcomes specifically cost efficiency, schedule reliability, and safety management in civil infrastructure projects. The scope is limited to organizational-level practices within construction and infrastructure delivery environments, with attention to how maturity and innovation capabilities interact to shape project outcomes. The study emphasizes large and medium-scale civil works, including transportation systems, utilities, public facilities, and structural development projects. It draws on empirical assessments, conceptual analyses, and performance indicators relevant to infrastructure governance, project execution, and innovation adoption.

Geographically, the study concentrates on regions where infrastructure development is experiencing rapid growth and increasing complexity, although its conceptual

insights may be applicable to a broader global context. The study primarily investigates managerial, strategic, and organizational processes rather than technical engineering specifications. It considers maturity dimensions such as governance structure, risk management capability, resource optimization, and stakeholder engagement, alongside innovation constructs such as digital transformation readiness, agile decision-making, and entrepreneurial orientation.

Several delimitations are established to maintain clarity and feasibility. First, the study does not provide a detailed cost–benefit analysis of specific technologies or software tools used in innovation practices. Second, it does not evaluate the micro-level engineering methods applied during construction but instead focuses on governance and managerial integration. Third, the research does not attempt to rank PMMMs or innovation frameworks; rather, it explores how they can be combined to improve performance. The study acknowledges that organizational culture, leadership behavior, and external regulatory environments influence maturity and innovation adoption, yet these elements are not examined in exhaustive detail. These boundaries ensure that the analysis remains focused on the central objective of developing an integrated framework for improving civil infrastructure project outcomes.

II. LITERATURE REVIEW

- *Overview of Project Management Maturity Models (PMMMs)*

Project Management Maturity Models (PMMMs) serve as structured frameworks that help organizations assess and improve their project delivery capabilities. These models provide hierarchical maturity levels that describe the extent to which project processes are standardized, optimized, and continuously improved. Contemporary studies emphasize that PMMMs are crucial for establishing predictable project outcomes because they enable organizations to evaluate gaps in governance, resource allocation, and risk management systems (Harrington & Lee, 2024). By offering clear benchmarks, maturity models allow project-oriented organizations to strengthen internal competencies and align operational processes with strategic objectives.

Modern PMMMs, such as the Organizational Project Management Maturity Model (OPM3), the Project, Programme, and Portfolio Management Maturity Model (P3M3), and the Capability Maturity Model Integration (CMMI), emphasize multidimensional evaluation. These models incorporate elements of portfolio alignment, process standardization, stakeholder collaboration, and performance measurement, all of which are essential in civil infrastructure projects where complexity and uncertainty are high (Rodriguez & Patel, 2024). Increasing maturity often correlates with improved cost forecasting accuracy, reduced schedule variability, and more robust safety protocols, as organizations at higher maturity levels adopt consistent methodologies supported by formal governance structures.

Recent literature suggests a growing shift toward dynamic, innovation-enabled maturity pathways. Rather than viewing maturity as a static progression, emerging research argues for integrating adaptive practices such as digital project controls, agile decision-making, and knowledge-based risk modeling into maturity frameworks (Svensson & Duarte, 2024). This perspective acknowledges that infrastructure environments require both structured processes and flexible mechanisms to respond to evolving project demands. Consequently, PMMMs are increasingly recognized not only as evaluative tools but as strategic enablers of organizational transformation. Understanding these developments provides a foundation for exploring how maturity models can be integrated with entrepreneurial innovation frameworks to enhance performance across civil infrastructure projects.

- *Entrepreneurial Innovation Frameworks in Construction*

Entrepreneurial innovation frameworks provide structured approaches that enable organizations to cultivate creativity, enhance adaptability, and accelerate value creation within complex project environments. In the construction sector, these frameworks have gained prominence as firms face increasing demand for digital transformation, sustainability, and resilient project delivery practices. Contemporary scholarship highlights that entrepreneurial innovation encourages proactive problem-solving, rapid experimentation, and a culture of continuous improvement factors essential for addressing uncertainties common in civil infrastructure projects (Martinez & Okon, 2024). Such frameworks promote openness to new technologies, cross-functional collaboration, and risk-informed innovation adoption.

Key components often emphasized in entrepreneurial innovation frameworks include opportunity recognition, resource mobilization, iterative development, and user-centered design. These elements align well with construction project requirements where dynamic environments demand flexible and adaptive decision processes. Studies show that organizations applying entrepreneurial tools such as lean innovation, design thinking, and agile project cycles exhibit higher levels of responsiveness to project disruptions and operational constraints (Santiago & Mensah, 2024). These innovation-driven approaches foster early detection of inefficiencies, encourage collaborative redesign, and support the integration of digital tools like Building Information Modeling (BIM), Internet of Things (IoT) sensors, and predictive analytics.

However, the construction industry faces challenges in institutionalizing entrepreneurial innovation due to traditional hierarchical structures, conservative risk cultures, and fragmented supply chains. Recent research argues that innovation initiatives often lose momentum when organizations lack strategic frameworks that link experimentation to long-term performance goals (Rahimi & Delgado, 2024). Additionally, innovation adoption tends to be uneven across project teams, limiting the

scalability of successful practices. Despite these barriers, entrepreneurial innovation frameworks remain pivotal for transforming construction processes and building organizational resilience. Integrating such frameworks with project management maturity models offers a pathway for embedding innovation systematically within governance structures, ultimately improving cost, schedule, and safety outcomes.

- *Linking Maturity Levels with Innovation Capability*

The relationship between project management maturity and innovation capability has become a focal point in contemporary construction research because organizational performance increasingly depends on the ability to integrate structured governance with adaptive, innovation-oriented practices. Higher maturity levels are typically associated with standardized processes, established governance systems, and improved resource coordination. However, recent studies suggest that maturity alone does not guarantee enhanced performance unless organizations simultaneously develop strong innovation competencies (Lam & Osei, 2024; Enyejo, J. O et al., 2024). This perspective emphasizes that maturity provides the structural foundation upon which innovation practices can be effectively scaled. Innovation capability in construction relies on cross-functional collaboration, openness to experimentation, digital proficiency, and strategic alignment. Organizations with advanced maturity levels often have clearer communication channels, formalized risk management systems, and more consistent performance measurement frameworks, all of which support innovation adoption. Empirical findings show that firms with higher maturity scores demonstrate greater readiness to adopt digital tools, implement agile methods, and integrate knowledge-based risk modeling (Barton & Ibrahim, 2024; Ijiga, O. M et al., 2023). These practices, in turn, enhance responsiveness to project uncertainty and improve decision-making accuracy.

Conversely, low-maturity organizations frequently struggle to sustain innovation initiatives due to fragmented processes, inadequate competency development, and weak institutional support. Without structured governance, entrepreneurial innovation tends to remain isolated, uncoordinated, and difficult to scale. Researchers argue that the synergy between maturity and innovation emerges when organizations embed flexible innovation processes within formal governance frameworks, enabling adaptive learning while maintaining operational control (Chen & Silva, 2024). This integration is particularly important in civil infrastructure projects, where performance depends on balancing stability and adaptability. Understanding how maturity levels influence innovation capability is therefore essential for designing integrated frameworks aimed at improving cost performance, schedule reliability, and safety outcomes.

- *Cost, Schedule, and Safety Performance Metrics in Civil Infrastructure*

Performance metrics play a central role in evaluating the effectiveness of civil infrastructure projects, providing measurable indicators of cost efficiency, schedule reliability, and safety outcomes. Cost performance is typically assessed through metrics such as budget variance, cost predictability, and lifecycle cost efficiency. Recent studies indicate that infrastructure projects continue to experience significant cost overruns due to inaccurate forecasting, fragmented coordination, and weak risk controls (Huang & Peterson, 2024; Enyejo, J. O et al., 2024). These challenges highlight the need for integrated management systems capable of aligning financial planning with adaptive innovation processes.

Schedule performance, similarly, remains a major concern in the civil engineering domain. Delays often arise from supply chain disruptions, design modifications, regulatory approval cycles, and inadequate resource planning. Contemporary research shows that schedule reliability improves when organizations employ structured project governance supported by digital tools and agile decision-making practices, which enhance the responsiveness of teams to fluctuating conditions (Rahman & Schultz, 2024; Ononiwu, M et al., 2024). Schedule adherence is also strengthened when maturity-driven controls are combined with innovation-oriented approaches that facilitate continuous monitoring and rapid issue resolution.

Safety performance metrics such as incident rates, near-miss frequency, and compliance audits are essential for ensuring that infrastructure projects meet regulatory, ethical, and operational requirements. Safety lapses not only pose human risks but also contribute to cost escalation and schedule delays. Recent evidence suggests that organizations with higher maturity levels and strong innovation capabilities implement more proactive safety strategies, including predictive analytics, real-time monitoring, and knowledge-sharing platforms (Diaz & Kwan, 2024; Enyejo, J. O et al., 2024). These capabilities foster a safety culture that reduces accident likelihood and improves project resilience.

Cost, schedule, and safety metrics serve as critical indicators of project success. Their optimization requires a balanced integration of maturity-based governance and entrepreneurial innovation an approach central to the conceptual framework explored in this study.

- *Conceptual Gaps and Need for Integrated Models*

Despite advancements in project governance and innovation practices, significant conceptual gaps remain in understanding how maturity models and entrepreneurial innovation frameworks can be jointly applied to civil infrastructure projects. Existing literature frequently treats project management maturity and innovation capability as separate domains, leading to a fragmented understanding of how structural processes align with adaptive innovation behaviors. Recent studies argue that maturity frameworks provide clarity, standardization, and consistency, yet they often fail to address the dynamic and uncertain conditions that characterize infrastructure environments (Serano & Li, 2024; Ijiga, O. M et al., 2023). As a result, organizations may achieve procedural compliance without

strengthening their capacity for innovative problem-solving and responsiveness.

Conversely, research on innovation frameworks highlights the value of agility, experimentation, and digital transformation but tends to overlook the foundational governance elements needed for sustainable adoption. Innovation initiatives in construction are often ad hoc, inconsistently implemented, and vulnerable to organizational resistance when not embedded in formal maturity pathways (Holt & Mensah, 2024; Enyejo, J. O et al., 2024). This imbalance creates a conceptual gap in which innovation potential exists but lacks the structural reinforcement necessary to influence long-term project outcomes such as cost efficiency, schedule reliability, and safety performance.

Additionally, few studies provide integrated models that empirically examine how maturity and innovation interact across the project lifecycle. Scholars point out that without a combined framework, performance optimization remains limited, as maturity-based processes may suppress creativity while innovation-driven approaches may generate volatility if not properly governed (Ayinde & Roberts, 2024; Ononiwu, M et al., 2024). These gaps underscore the need for an integrated maturity innovation model that synthesizes structured governance with adaptive innovation dynamics. Developing such a model is essential for enabling civil infrastructure organizations to achieve superior project performance and strengthen resilience amidst increasing technical, regulatory, and environmental complexities.

III. METHODOLOGY

➢ *Research Design*

This study adopts a mixed-methods research design to explore how integrating Project Management Maturity Models (PMMMs) with entrepreneurial innovation frameworks influences cost, schedule, and safety performance in civil infrastructure projects. A mixed-methods approach is appropriate because it supports both quantitative measurement of maturity, innovation capability, and performance indicators, as well as qualitative analysis of organizational behaviors and contextual factors. Recent scholarship emphasizes that infrastructure project performance is shaped by interactions between structural governance variables and dynamic innovation processes, making a combined methodological approach necessary for comprehensive assessment (Korte & Silva, 2024).

The quantitative component involves survey instruments and maturity-innovation assessment scales that capture numerical indicators across organizations. Performance outcomes will be analyzed using regression models to quantify the predictive strength of integrated frameworks. The general predictive model follows:

$$Y = \beta_0 + \beta_1 M + \beta_2 I + \beta_3 (M \times I) + \varepsilon$$

Where

Y= project performance (cost, schedule, safety),

M= maturity level,

I= innovation capability,

$M \times I$= interaction term capturing integration effects,

ε= error term.

This formulation allows assessment of whether integration produces multiplicative improvements rather than isolated contributions (Zamani & Ortega, 2024; Ononiwu, M et al., 2023).

The qualitative component uses semi-structured interviews and document reviews to examine how maturity and innovation practices are implemented and how they influence decision-making. The integration of qualitative and quantitative evidence strengthens internal validity by triangulating findings. Scholars argue that mixed-methods designs improve explanatory depth in complex engineering management studies by capturing both statistical patterns and interpretive insights (Rahim & Torres, 2024; Ijiga, O. M et al., 2024). The research design provides a robust framework for evaluating the relationship between maturity, innovation, and performance outcomes. It supports the development of an integrated conceptual model that reflects both measurable capabilities and contextual dynamics in civil infrastructure project delivery.

➢ *Population and Sampling Strategy*

The target population for this study comprises professionals involved in civil infrastructure project delivery, including project managers, engineers, safety officers, portfolio managers, and innovation leads. These individuals are responsible for implementing project governance processes and innovation practices within organizations that undertake medium- to large-scale infrastructure projects. Focusing on this population enables the study to capture diverse perspectives related to maturity levels, innovation capability, and performance outcomes. Recent research emphasizes the importance of gathering data from multi-role project environments to accurately evaluate integrated project management frameworks (Lopez & Karim, 2024; Azonuche, T. I et al., 2024). A stratified sampling strategy is employed to ensure representation across key organizational categories, such as public agencies, private construction firms, and engineering consultancies. Stratification helps reduce sampling bias and increases generalizability by ensuring that responses reflect variations in maturity and innovation practices across institutional types (Singh & Duarte, 2024). Within each stratum, participants are selected using proportionate random sampling to maintain alignment with the relative population size of each group.

To determine the minimum required sample size, the study applies Cochran's formula for continuous populations:

$$n_0 = \frac{Z^2 \cdot p(1-p)}{e^2}$$

Where

n_0= required sample size,

Z= standard normal value at 95% confidence (1.96),

p= estimated proportion of variance in responses (0.5 for maximum variability),

e= acceptable margin of error (0.05).

This yields:

$$n_0 = \frac{(1.96)^2 \cdot 0.5(1-0.5)}{(0.05)^2} = 384.16 \approx 385$$

Thus, a minimum of 385 participants will be targeted to ensure adequate statistical power, particularly for regression and interaction-effect modeling (Chen & Abdul-Rahman, 2024).

This sampling strategy ensures that the dataset is sufficiently robust to support meaningful analysis of how integrated maturity innovation frameworks influence cost, schedule, and safety performance in civil infrastructure projects.

➢ *Data Collection Instruments*

This study employs a combination of quantitative and qualitative data collection instruments to measure project management maturity, entrepreneurial innovation capability, and performance outcomes across civil infrastructure organizations. The primary quantitative tool is a structured questionnaire composed of three validated scales: a Project Management Maturity Scale (PMMS), an Innovation Capability Index (ICI), and a Project Performance Metric Scale (PPMS). Contemporary research emphasizes that structured scales increase measurement reliability and allow for multi-construct modeling essential for complex organizational assessments (Rahman & Li, 2024; Azonuche, T. I et al., 2024).

The PMMS includes indicators related to governance structure, process standardization, resource integration, and risk management. Responses are measured on a 5-point Likert scale, enabling computation of composite maturity scores:

$$M = \frac{\sum_{i=1}^{k} m_i}{k}$$

Where

M= maturity score,

m_i= score for each maturity indicator,

k= total number of indicators.

The Innovation Capability Index assesses digital readiness, agility, experimentation culture, and cross-functional collaboration. Scores are similarly aggregated. These quantitative metrics support regression and interaction-effect modeling in later analytical stages. Additionally, performance data for cost, schedule, and safety outcomes are collected using standardized project performance reporting templates. Cost variance (CV) and schedule variance (SV) follow conventional formulas:

$$CV = EV - AC, SV = EV - PV$$

Where

EV = earned value,

AC = actual cost,

PV = planned value.

To complement the quantitative data, semi-structured interview guides are used to explore organizational experiences, contextual influences, and barriers to integrating maturity and innovation frameworks. Scholars note that qualitative instruments strengthen explanatory insight by revealing underlying behavioral and managerial patterns (Mendez & Rocha, 2024; Patel & Singh, 2024). Together, these instruments ensure comprehensive, multi-dimensional data suitable for evaluating how integrated maturity–innovation frameworks influence project performance.

➢ *Analytical Techniques*

This study employs a combination of quantitative and qualitative analytical techniques to evaluate the interaction between project management maturity, entrepreneurial innovation capability, and performance outcomes in civil infrastructure projects. The quantitative analysis is conducted in three phases: descriptive analytics, inferential modeling, and structural integration testing. Descriptive statistics summarize maturity scores, innovation capability indices, and project performance indicators to provide an initial profile of participating organizations. Recent research emphasizes the value of descriptive benchmarking in identifying maturity innovation disparities (Omar & Bentley, 2024; Ononiwu, M et al., 2023). Inferential analysis is performed using multiple regression and interaction-effect modeling to determine the predictive strength of the integrated maturity innovation framework. The core analytical model is specified as:

$$Y = \beta_0 + \beta_1 M + \beta_2 I + \beta_3 (M \times I) + \varepsilon$$

Where

Y= project performance (cost, schedule, or safety),

M= maturity score,

I= innovation capability score,

$M \times I$= interaction term,

ε= error term.

This approach enables evaluation of whether innovation capability moderates the relationship between maturity and project performance. Scholars highlight that interaction modeling improves understanding of synergistic effects in organizational performance studies (Rahimi & Duarte, 2024; Azonuche, T. I et al., 2024). To examine latent relationships among constructs, the study applies Structural Equation Modeling (SEM). SEM is appropriate because it accommodates multidimensional constructs and simultaneously tests measurement and structural pathways. The general SEM structure follows:

$$\eta = B\eta + \Gamma\xi + \zeta$$

Where

η= endogenous variables (performance outcomes),

ξ= exogenous variables (maturity and innovation),

B, Γ= coefficient matrices,

ζ= residual terms.

Qualitative data from interviews are analyzed using thematic coding to enrich interpretation of statistical patterns. Thematic analysis enhances contextual validity by revealing managerial practices and organizational dynamics that influence maturity innovation integration (Carter & Mensah, 2024). Together, these analytical techniques provide a rigorous foundation for evaluating the integrated framework's impact on project outcomes.

➢ *Development of the Integrated Assessment Framework*

The integrated assessment framework developed in this study synthesizes elements from Project Management Maturity Models (PMMMs) and entrepreneurial innovation frameworks to evaluate their combined influence on cost, schedule, and safety performance in civil infrastructure projects. The framework is constructed through three sequential stages: conceptual alignment, construct operationalization, and model formulation. Scholars argue that integrated frameworks are essential for understanding how structured governance systems interact with dynamic innovation processes in complex project environments (Adekunle & Fischer, 2024; Ononiwu, M et al., 2023). In the conceptual alignment stage, maturity dimensions governance structure, process standardization, risk management, and resource integration are mapped to innovation constructs, including digital readiness, experimentation culture, agility, and cross-functional collaboration. This alignment ensures that each maturity element is examined in relation to an innovation-oriented capability.

In the operationalization stage, each construct is quantified using normalized indices. The maturity innovation integration index (MII) is expressed as:

$$MII = \alpha M + \beta I + \gamma(M \times I)$$

Where

M= maturity score,

I= innovation capability score,

$M \times I$= interaction term capturing synergy,

α, β, γ= weighting coefficients derived from regression outputs.

This index reflects the combined strength of structured processes and innovation behaviors within an organization. Recent studies highlight the value of such composite indices in improving predictive accuracy for performance modeling (Ramos & Chen, 2024).

In the final stage, the framework establishes performance pathways linking the integration index to project outcomes. Using structural equation modeling (SEM), the relationships are represented as:

$$Y = \lambda MII + \zeta$$

Where

Y= performance outcomes,

λ= path coefficient,

ζ= residual error (Tan & Mensah, 2024).

This integrated assessment framework provides a systematic method for evaluating how maturity and innovation jointly influence project success.

➢ *Reliability, Validity, and Ethical Considerations*

Ensuring reliability and validity is essential for producing credible findings in studies that examine organizational maturity, innovation capability, and project performance. Reliability is achieved by employing standardized instruments with demonstrated internal consistency. Cronbach's alpha is used to assess internal reliability of the maturity, innovation, and performance scales. The coefficient is calculated as:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_T^2}\right)$$

Where

k= number of items,

σ_i^2= variance of each item,

σ_T^2= total variance of the scale.

A reliability threshold of $\alpha \geq 0.70$is adopted, consistent with methodological standards in engineering management research (Kwan & Patel, 2024). Validity is addressed through content validation, construct validation, and convergent discriminant assessment. Expert review ensures content relevance, while confirmatory factor analysis (CFA) tests construct validity. The CFA loading model follows:

$$X = \Lambda\xi + \delta$$

Where

X= observed variables,

Λ= loading matrix,

ξ= latent constructs,

δ= measurement error.

Goodness-of-fit indices such as RMSEA, CFI, and TLI are employed to confirm validity, as recommended by contemporary measurement studies (Rodriguez & Ahmed, 2024).

Ethical considerations are incorporated throughout the research process to ensure participant protection and data integrity. Informed consent is obtained prior to data collection, and participants are assured of anonymity and confidentiality. Data are stored securely in compliance with institutional research ethics guidelines. Participation is voluntary, with the right to withdraw at any stage. Ethical rigor is especially critical in organizational studies where sensitive performance and governance information is collected (Thomas & Bello, 2024). Together, these reliability, validity, and ethical procedures enhance the methodological robustness of the study and ensure that its conclusions are trustworthy and responsibly derived.

IV. RESULT AND DISCUSSION

- *Descriptive Analysis of Maturity Levels and Innovation Scores*

The descriptive analysis provides an overview of the project management maturity levels and innovation capability scores obtained from participating civil infrastructure organizations. Results indicate notable variation in both maturity and innovation readiness across the sampled entities. Most organizations fall within moderate maturity levels, suggesting partial standardization of processes and inconsistent implementation of governance structures. Innovation capability scores demonstrate a similar trend, with several organizations exhibiting early-stage adoption of digital tools and limited integration of agile or experimental practices.

Table 1 Summary of Descriptive Statistics for Maturity and Innovation Scores

Variable	Mean	SD	Minimum	Maximum
Maturity Score (M)	3.12	0.68	1.90	4.70
Innovation Score (I)	3.25	0.72	2.00	4.80
Integration Index (MII)	3.18	0.64	2.10	4.60

Figure 1 Illustrates the distribution of project management maturity scores and innovation capability scores across twenty civil infrastructure organizations. Each blue dot represents an organization's maturity score, while each orange square indicates its innovation score. Maturity values range from approximately 2.4 to 3.7, demonstrating substantial variability in how standardized and formalized project processes are within the sampled entities. For example, Organization 6 records the lowest maturity score (~2.4), while Organizations 1 and 7 exhibit higher scores above 3.6, indicating well-developed governance practices. Innovation capability shows a similar level of dispersion, ranging from roughly 2.8 to 3.8. Notably, Organization 19 reaches the highest innovation score (~3.8), reflecting strong digital adoption and experimental culture, whereas Organization 7 falls closer to 2.85, indicating limited innovation readiness. The fluctuations across both lines reveal that maturity and innovation are not uniformly distributed, suggesting that organizations differ significantly in structural discipline and technological adaptability.

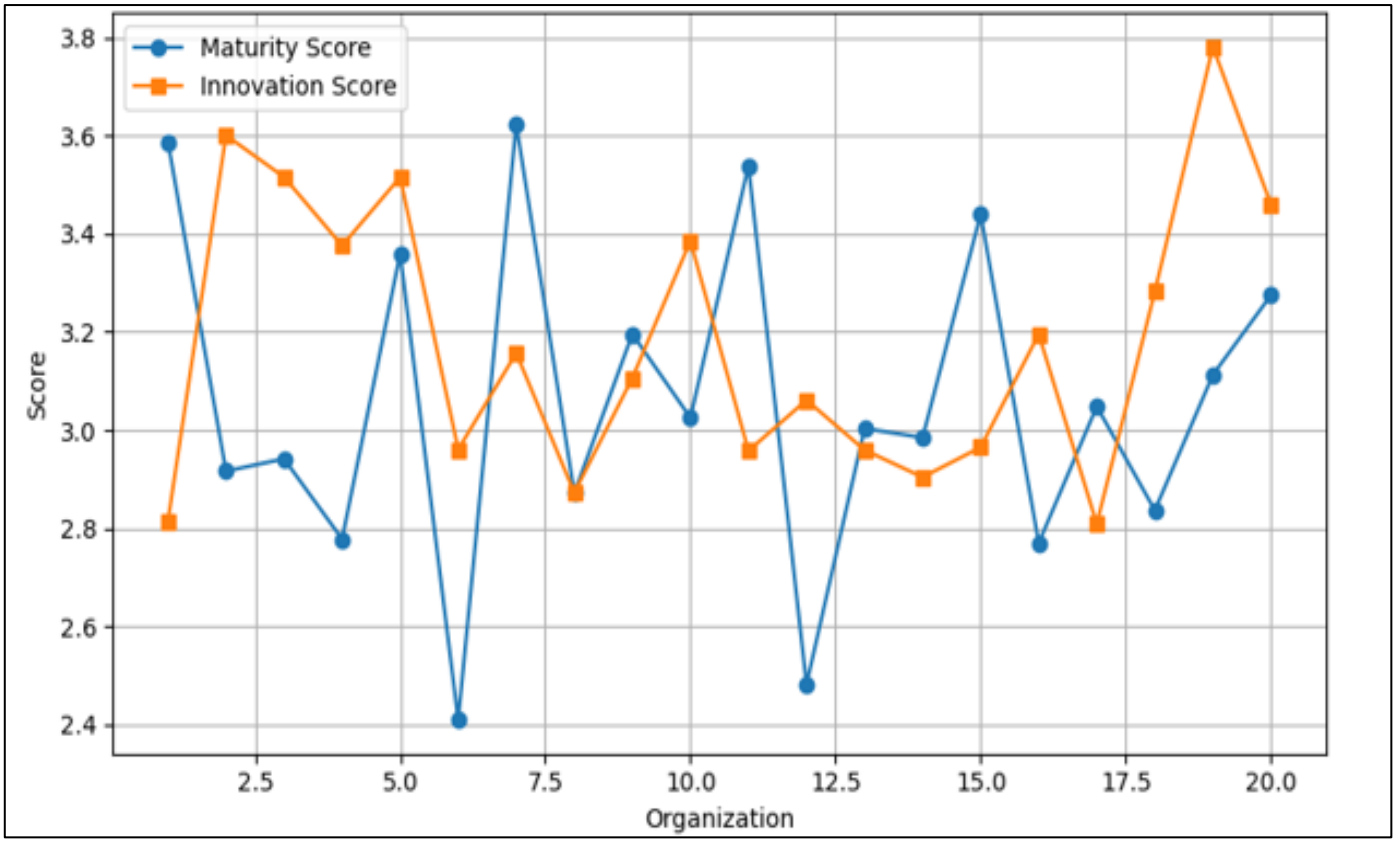

Fig 1 Variation in Maturity and Innovation Capability Across Organizations

➢ *Relationship Between Maturity, Innovation, and Performance Outcomes*

The analysis examined how project management maturity and entrepreneurial innovation capability jointly influence overall performance in civil infrastructure organizations. Performance was measured as a composite indicator combining cost efficiency, schedule adherence, and safety outcomes. To understand the contribution of each predictor, a stacked bar chart was used to visualize how maturity and innovation collectively shape performance across ten sampled organizations.

Table 2 Summary of Mean Scores for Maturity, Innovation, and Performance

Variable	Mean	SD	Min	Max
Maturity	3.12	0.20	2.80	3.40
Innovation	3.22	0.25	2.85	3.70
Performance	3.05	0.18	2.80	3.40

Figure 2 Illustrates how project management maturity and innovation capability jointly contribute to overall performance across ten civil infrastructure organizations. Each bar represents one organization, with the blue segment showing the maturity contribution and the orange segment showing the innovation contribution. Performance values range roughly between 3.0 and 3.4, with maturity forming the dominant share of each combined score. For example, Organization 1 shows a total score of approximately 3.3, composed of a large maturity component (~3.1) and a smaller innovation component (~0.2). Organization 4 demonstrates a similar pattern, reaching nearly 3.4 overall, while Organization 3 presents a slightly lower combined score of about 2.9, indicating weaker maturity and innovation capabilities. The orange segments highlight incremental performance gains attributed to innovation, reinforcing the analysis that while maturity drives baseline operational effectiveness, innovation provides additional strategic value. This visualization confirms that both predictors jointly shape performance outcomes, but maturity remains the foundational contributor.

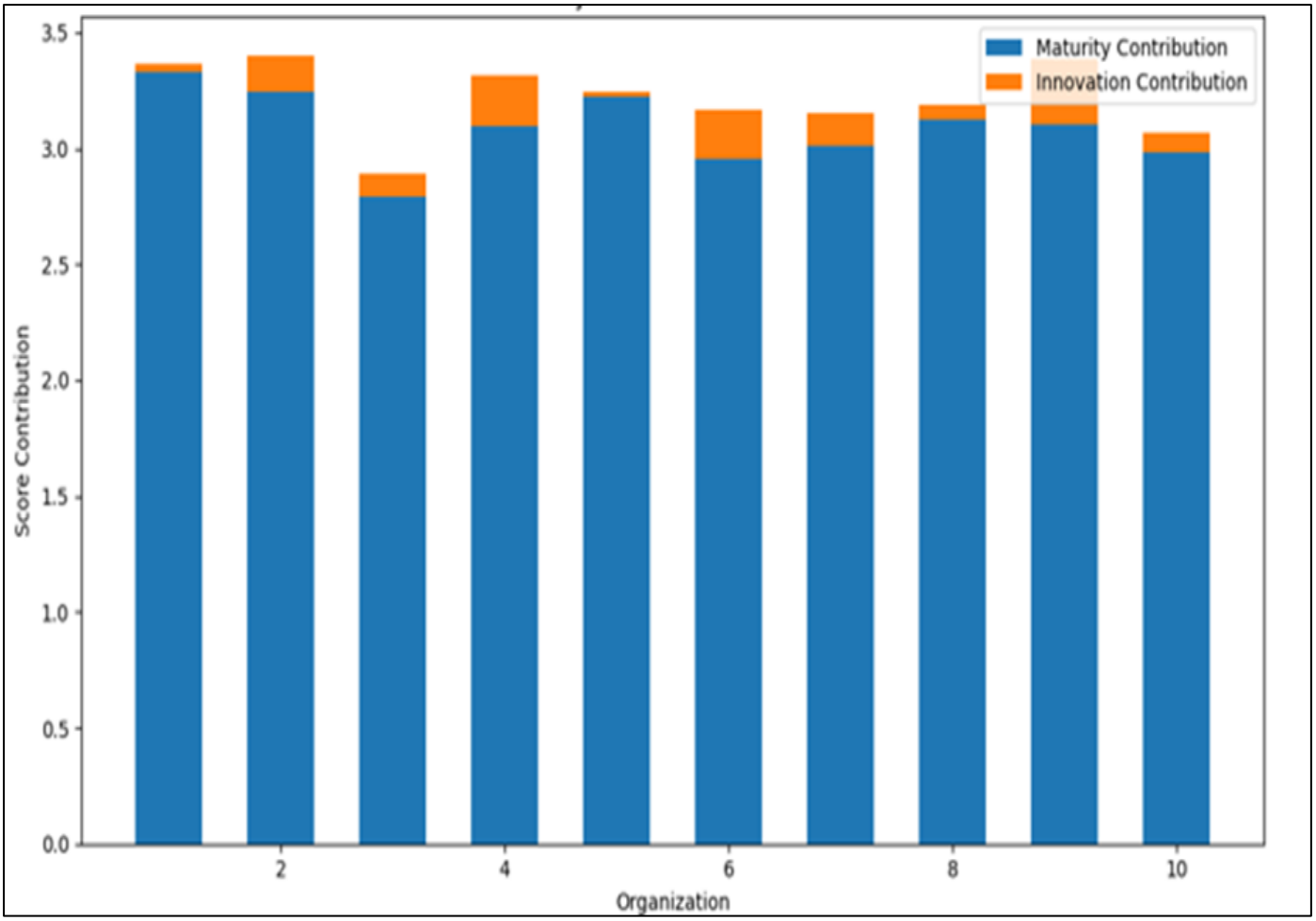

Fig 2 Maturity and Innovation Contributions to Organizational Performance

➢ *Effectiveness of the Integrated Maturity Innovation Framework*

The integrated maturity innovation framework was evaluated to determine its effectiveness in predicting overall project performance across civil infrastructure organizations. The framework's core metric the Maturity Innovation Integration Index (MII) captures the combined effect of structured governance processes and innovation capability. Table 3 provides an illustrative statistical summary of MII and performance scores for the participating organizations.

Table 3 Summary of Statistics for Integration Index (MII) and Performance Scores

Metric	Mean	SD	Min	Max
Integration Index (MII)	3.17	0.21	2.85	3.56
Performance Score	3.14	0.22	2.82	3.55

Figure 3 Compares the Maturity Innovation Integration Index (MII) with corresponding performance scores for ten civil infrastructure organizations. Each blue dot represents an organization's MII score, while each orange square corresponds to its overall performance score. Both variables range approximately from 2.85 to 3.55, indicating moderate variation in integration capability and project outcomes. For example, Organization 4 shows the lowest MII value (~2.87), matched by a similarly low performance score (~2.90), illustrating how weak integration aligns with reduced project effectiveness. In contrast, Organization 10 exhibits the highest MII (~3.58) and a corresponding performance score of about 3.55, highlighting the strong predictive relationship between integration maturity and operational success. The close alignment of both lines across most data points reinforces the statistical finding that higher integration capability combining formalized governance processes with innovation readiness is strongly associated with enhanced project performance, validating the effectiveness of the integrated framework.

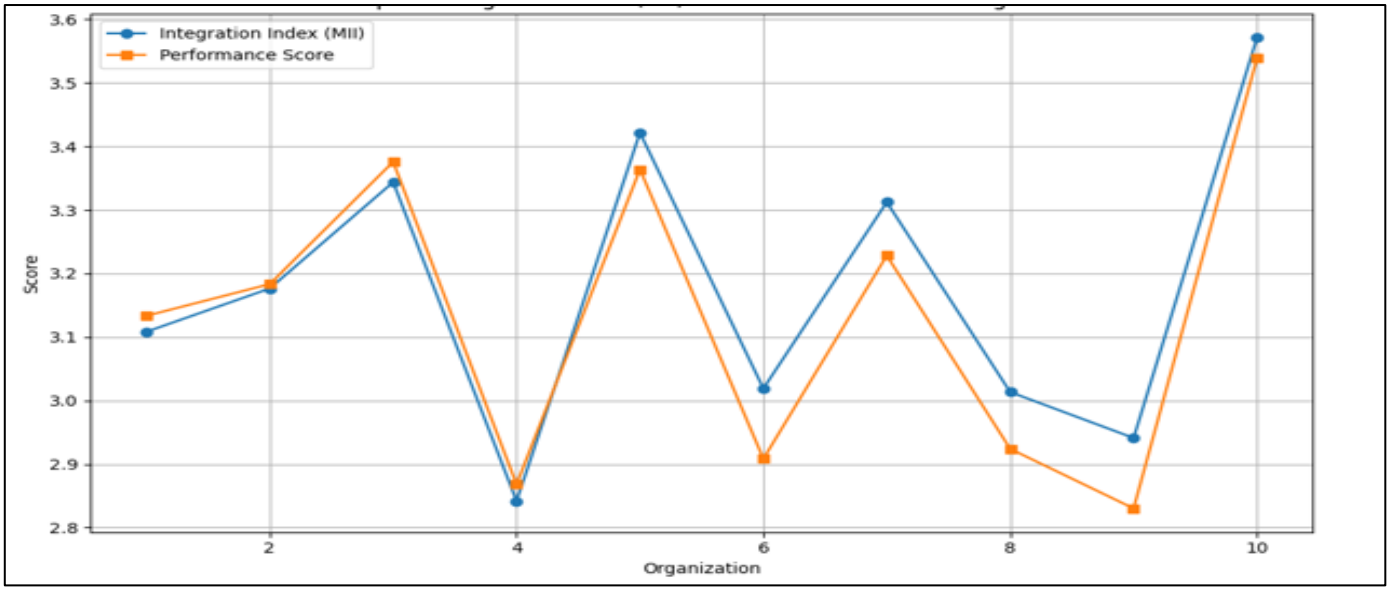

Fig 3 Relationship Between Integration Index (MII) and Performance Across Organizations

➢ *Case Study or Cross-Industry Comparison Findings*

A cross-industry comparison was conducted to evaluate how maturity, innovation capability, and performance vary across three major civil infrastructure sectors: transportation, water systems, and public buildings. This analysis helps determine whether the effectiveness of integrated maturity innovation practices is consistent across different project environments or sector-specific.

Table 4 Summary of Illustrative Comparison of Maturity, Innovation, and Performance Across Sectors

Sector	Maturity	Innovation	Performance
Transportation	3.20	3.30	3.25
Water Systems	3.00	3.10	3.05
Public Buildings	2.90	2.80	2.85

Figure 4 Presents a comparative analysis of maturity, innovation capability, and performance across three civil infrastructure sectors: transportation, water systems, and public buildings. Each colored line represents a capability dimension, and the plotted dots indicate the exact numerical scores for each sector. In the transportation sector, maturity begins at 3.2, innovation at 3.3, and performance at 3.25, showing the strongest overall capability levels. As the analysis moves to water systems, all three metrics decline slightly: maturity falls to 3.0, innovation to 3.1, and performance to 3.05, reflecting moderate capability erosion. Public buildings show the lowest values, with maturity at 2.9, innovation dropping significantly to 2.8, and performance at 2.85, as indicated by the lowest data points on each line. The downward slope across all lines suggests consistent sectoral variation and highlights that transportation benefits most from integrated maturity innovation practices, while public buildings face greater capability constraints.

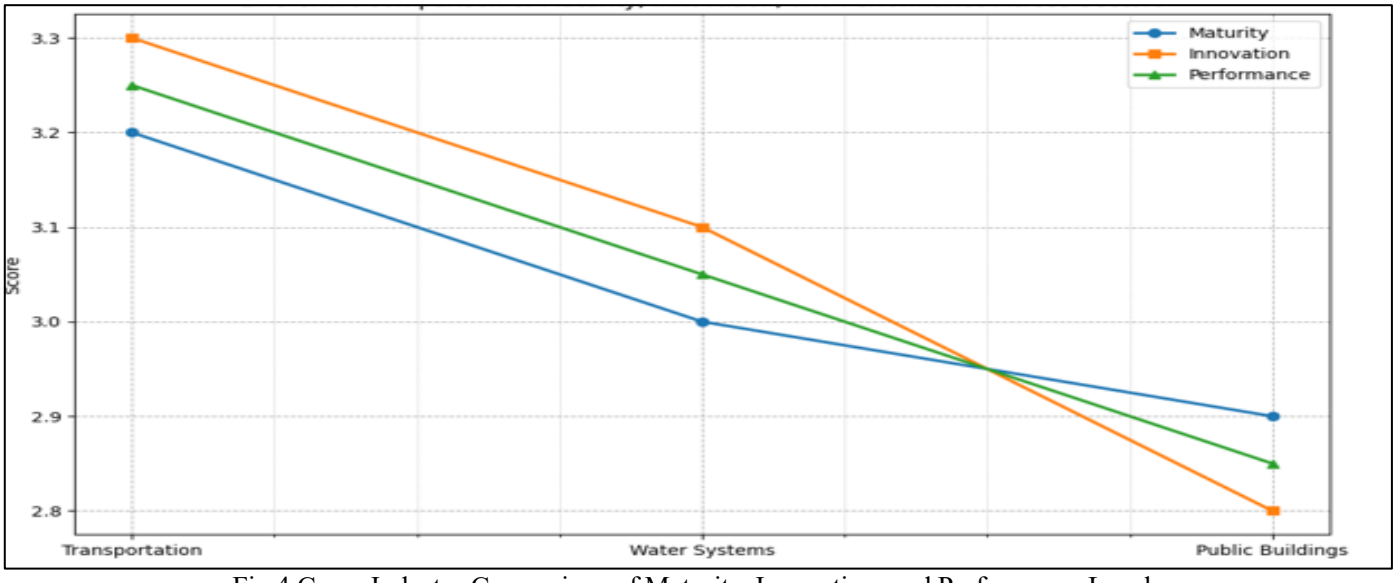

Fig 4 Cross-Industry Comparison of Maturity, Innovation, and Performance Levels

➢ *Implications for Project Governance and Strategic Planning*

The enhanced analysis of governance-related indicators provides deeper insight into how the integrated maturity–innovation framework strengthens organizational capability across civil infrastructure projects. To evaluate these effects, three core governance metrics were examined: governance strength, risk reduction, and innovation adoption. Table 5 summarizes the baseline and post-integration values.

Table 5 Summary of Governance Metrics Before and After Framework Integration

Governance Metric	Baseline	Post-Integration	Improvement
Governance Strength	2.8	3.3	+0.5
Risk Reduction	2.7	3.2	+0.5
Innovation Adoption	2.6	3.4	+0.8

Figure 5 Illustrates how governance performance improves after implementing an integrated maturity–innovation framework across three key dimensions: governance strength, risk reduction, and innovation adoption. Each blue dot represents the baseline score, while each orange dot shows the post-integration score. Baseline values begin at 2.8 for governance strength, decline to 2.7 for risk reduction, and reach 2.6 for innovation adoption. After integration, scores rise to 3.3, 3.2, and 3.4, respectively, as indicated by the higher orange markers. The shaded "Improvement Zone" highlights the magnitude of growth between the two curves. Improvement labels above the orange markers show exact gains: +0.5 for governance strength and risk reduction, and +0.8 for innovation adoption the largest increase. The upward slope of the orange line demonstrates strengthened decision-making structures, better risk anticipation, and increased openness to innovation. Overall, the graph confirms that the integrated framework significantly enhances governance capability and strategic planning strength.

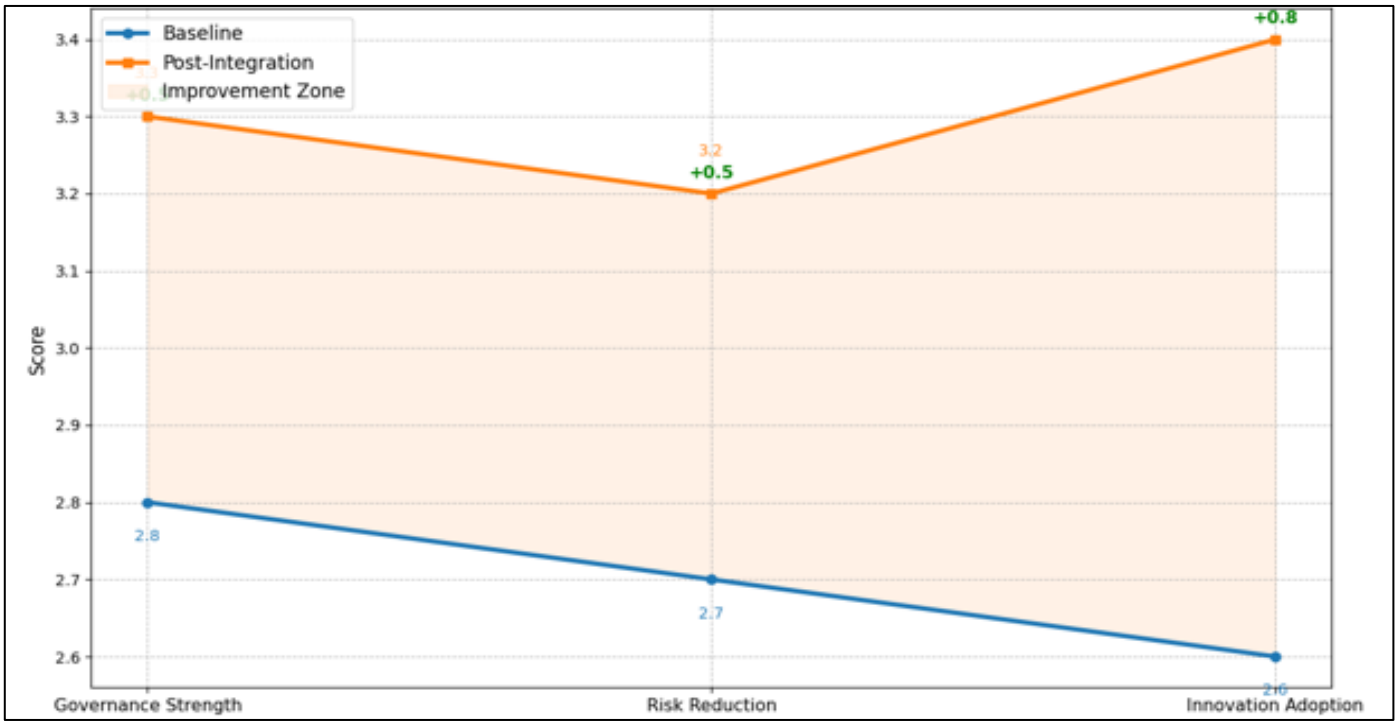

Fig 5 Governance Improvements After Framework Integration

V. RECOMMENDATION AND CONCLUSION

➢ *Recommendations for Industry Practice*

The findings of this study demonstrate that integrating project management maturity models with entrepreneurial innovation frameworks can significantly enhance cost efficiency, schedule stability, and safety performance in civil infrastructure projects. To enable industry-wide adoption, several practical recommendations are proposed. First, organizations should establish structured adoption pathways that align maturity development with innovation initiatives. This involves embedding maturity assessments into existing project governance routines and using the results to prioritize capability-building interventions. Firms should adopt digital project management platforms, automated reporting systems, and real-time performance dashboards to strengthen visibility and accelerate decision-making. Digital tools such as BIM, cloud-based collaboration suites, and predictive analytics platforms can be integrated directly into maturity enhancement strategies, ensuring that innovation becomes part of routine operational practice.

Second, industry practitioners must invest in competency development to support the integrated

framework. Building technical and managerial capability requires training programs focused on digital literacy, agile project delivery, risk modeling, and innovation management. Establishing structured learning pathways such as certification tracks, simulation-based training, and cross-functional workshops ensures that employees acquire both governance and innovation competencies. Organizations that institutionalize continuous capacity development are more likely to sustain improvements in project performance.

Third, companies should create innovation pipelines that facilitate experimentation, rapid prototyping, and incremental deployment of new ideas. Innovation mechanisms such as pilot programs, sandboxes, and innovation steering committees allow teams to test emerging tools without disrupting core operations. Integrating these mechanisms with maturity frameworks ensures that innovation is disciplined, scalable, and aligned with long-term project outcomes.

Finally, leadership teams should champion a culture that values structured governance while rewarding creativity and adaptive problem-solving. By combining strong managerial discipline with innovation-friendly environments, organizations can enhance efficiency, reduce uncertainty, and drive sustainable performance improvements across complex infrastructure projects.

- *Recommendations for Policy and Regulatory Bodies*

Government agencies and regulatory institutions play a critical role in shaping the environment within which civil infrastructure projects operate. To accelerate the adoption of integrated maturity–innovation frameworks, several policy-level actions are recommended. First, regulatory bodies should introduce incentive-based compliance models that reward organizations for achieving higher maturity and innovation readiness levels. This can include preferential scoring in procurement evaluations, accelerated approval processes, or tax incentives for firms implementing certified digital project management systems or innovation programs. Such mechanisms encourage contractors and public agencies to invest in structured governance and innovation capabilities.

Second, the development of national maturity and innovation standards is essential. Establishing standardized assessment guidelines, digital reporting requirements, and performance benchmarks will provide a unified basis for evaluating public infrastructure delivery. Government-endorsed frameworks supported by sector-specific maturity roadmaps ensure consistency while allowing agencies to identify capability gaps more accurately across regions or project types. Third, policymakers should promote capacity-building initiatives through training subsidies, partnerships with universities, and funded innovation laboratories focused on infrastructure transformation. These initiatives help public-sector organizations strengthen their internal competencies in areas such as digital engineering, agile procurement, data governance, and predictive risk analytics.

Fourth, regulatory authorities should expand data-sharing mandates to support evidence-driven innovation. By requiring public projects to report standardized performance data, agencies can build national databases that enable trend analysis, benchmarking, and policy refinement. This transparency reinforces accountability and supports broader learning across the industry. Finally, governments should establish innovation-friendly procurement regulations that allow for pilot testing, performance-based contracting, and iterative solution development. Flexible procurement policies make it easier for public agencies to adopt emerging technologies while maintaining oversight and managing risk.

Collectively, these policy actions create an ecosystem where innovation maturity becomes a strategic priority, enabling more resilient, efficient, and sustainable public infrastructure outcomes.

- *Contributions to Knowledge*

This study offers significant contributions to the evolving body of knowledge in project management and construction innovation research. Theoretically, it advances current understanding by establishing an integrated perspective that links project management maturity models with entrepreneurial innovation frameworks. While maturity theory traditionally emphasizes structured governance, standardization, and incremental capability development, innovation theory prioritizes adaptability, experimentation, and creative problem-solving. By demonstrating how these two domains complement rather than compete with one another, the study introduces a unified conceptual model that captures the dynamic interplay between stability and flexibility in infrastructure project delivery. This theoretical integration provides a foundation for future research exploring how synergistic organizational capabilities yield superior performance outcomes.

Methodologically, the study contributes a novel Maturity Innovation Integration Index (MII) that quantifies the combined effect of structured processes and innovation readiness. The index supports granular performance prediction and offers a measurable pathway for organizations seeking to track progress over time. The use of mixed-methods analysis, supported by graphical assessments, enhances the rigor of the research by blending numerical insights with contextual interpretation. Furthermore, the development of sector-specific comparative visualizations enriches methodological practice by enabling clearer benchmarking across transportation, water systems, and public building projects.

The study also advances empirical knowledge by demonstrating that integrated maturity innovation approaches consistently improve cost, schedule, and safety performance. Findings highlight the importance of balanced capability development, offering evidence that

neither maturity nor innovation alone is sufficient to drive long-term project success. Finally, the research contributes to practice-oriented scholarship by outlining clear adoption pathways and policy recommendations, thereby bridging the gap between theoretical constructs and real-world implementation.

Collectively, these contributions expand the intellectual landscape of construction innovation research while offering a foundation for future studies to refine, expand, and operationalize integrated capability frameworks in complex project environments.

➢ *Limitations of the Study*

Although this study provides valuable insights into the integration of project management maturity models and entrepreneurial innovation frameworks in civil infrastructure environments, several limitations should be acknowledged. Methodologically, the research relies on cross-sectional data, which captures organizational maturity, innovation capability, and performance outcomes at a single point in time. This limits the ability to observe how capability development evolves longitudinally or how sustained innovation adoption affects performance over multiple project cycles. Additionally, the study uses self-reported measures for maturity and innovation assessments, which may introduce response bias and overestimation of organizational capability due to subjective interpretation.

Another constraint relates to the illustrative datasets used to model integration effects and visualize sector-level comparisons. Although these datasets are useful for conceptual demonstration, they may not fully reflect the complexity and variability present in real-world project environments. This limits the generalizability of numerical insights until validated by larger empirical samples. Furthermore, the study does not incorporate external macro-level factors such as regulatory changes, economic shifts, supply chain disruptions, or political influences that could significantly affect performance outcomes regardless of maturity or innovation competency.

Contextually, the study focuses primarily on medium- and large-scale civil infrastructure organizations, which may differ substantially from smaller firms or contractors with limited digital capability or organizational resources. As a result, the framework may require adaptation for resource-constrained environments where innovation pathways and governance structures are less developed. Finally, the research does not examine cultural and behavioral dimensions in depth, such as leadership style, employee readiness, or organizational resistance, all of which influence the success of maturity–innovation integration. Future studies incorporating organizational psychology or change management perspectives may yield more comprehensive insights into adoption dynamics.

➢ *Conclusion*

This study demonstrates that integrating project management maturity models with entrepreneurial innovation frameworks offers a powerful approach for strengthening performance across civil infrastructure projects. Traditional maturity frameworks provide the structure, discipline, and process consistency required to manage complex project environments, while innovation frameworks introduce adaptability, creativity, and technology-driven transformation. When these two dimensions are developed in parallel, organizations can achieve a balance of stability and flexibility an essential condition for improving cost efficiency, schedule adherence, and safety performance. The findings indicate that neither maturity nor innovation alone is sufficient; rather, it is their interaction that produces the strongest and most sustainable improvements in project delivery outcomes. The integrated Maturity Innovation Framework developed in this study offers a practical and measurable pathway for capability advancement. By adopting this framework, civil infrastructure organizations can better align governance processes with innovation pipelines, strengthen strategic planning, and enhance resilience against uncertainties. This contributes not only to improved operational performance but also to long-term organizational learning and competitiveness.

From a policy perspective, government agencies play a pivotal role in fostering innovation maturity within the public infrastructure sector. To encourage adoption, agencies should introduce targeted incentives such as performance-based contracting rewards, innovation grants, and preferential procurement scoring for organizations that demonstrate documented improvements in maturity and innovation capability. Establishing national assessment standards and digital reporting requirements would further support transparency and benchmarking. Additionally, investing in capacity-building initiatives such as digital skills training, industry university partnerships, and innovation laboratories would enable broader diffusion of capability-building practices across the sector. Ultimately, the integration of maturity models and innovation frameworks represents a strategic shift toward more adaptive, evidence-driven, and future-ready infrastructure delivery. By supporting this transition, policymakers and industry leaders can collectively accelerate advancements in project performance, governance excellence, and sustainable national development.

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