International Journal of Applied Research in Business and Management (ISSN: 2700-8983)
an Open Access journal by Wohllebe & Ross Publishing, Germany.
Volume: 06 Issue: 01 Year: 2025
https://doi.org/10.51137/wrp.ijarbm.2025.msut.45698

Unpacking the Influence of Risk Management Culture within the Built Environment Projects

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Abstract:

This study investigates the practical implementation and effectiveness of risk management tools and techniques in construction projects, with a particular focus on how organizational culture influences their success. Through qualitative research, including semi-structured interviews with professionals in the construction industry, the study explores the challenges and best practices in risk identification, assessment, and mitigation. Findings reveal that traditional tools such as checklists, risk registers, and brainstorming remain widely used, though their application is often limited by a lack of formal education and training in risk management. While quantitative methods, such as Monte Carlo simulations, are recognized for their predictive capabilities, they are underutilized, particularly for non-financial risks. The study highlights significant gaps between theory and practice, particularly in the integration of advanced data-driven approaches, which could improve the accuracy of risk assessments for high-risk tasks. Furthermore, the research identifies the absence of structured knowledge transfer mechanisms as a barrier to effective risk management. The study concludes that while risk management frameworks are theoretically sound, their practical implementation is often hindered by organizational barriers, including inadequate training, poor communication, and the failure to incorporate emerging technologies. The results suggest that future research should focus on developing standardized, technology-integrated risk management frameworks and fostering a culture of continuous improvement to enhance project success.

Keywords:

Risk Management, Construction Environment, Project Safety, Tools, Risk Mitigation.

Submitted: 2025-02-10. Revised: 2025-02-18. Accepted: 2025-02-21.

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Introduction

Risk management plays a crucial role in the successful delivery of projects within the built environment, where construction and infrastructure projects face numerous uncertainties and complexities. These risks can range from financial and operational challenges to environmental and safety hazards, which can significantly impact the overall project outcome. Given the scale and complexity of modern built environment projects, it is essential to explore how risk management practices are applied and whether the tools and techniques used effectively address the risks encountered throughout the project lifecycle (Zou, Zhang, & Wang, 2019; Flanagan & Norman, 2020). This study examines the influence of risk management culture within built environment projects by exploring the tools and techniques adopted and evaluating their effectiveness. Understanding how these tools are implemented in practice and how they contribute to the success of a project is critical for improving risk management strategies in the industry. While numerous risk management tools, such as risk registers, Monte Carlo simulations, and risk matrices, are widely used in the construction industry, there is ongoing debate about their practical effectiveness. Some scholars argue that while these tools provide valuable insights into potential risks, they often fail to capture the organizational and cultural factors that are integral to successful risk mitigation (Kwak & Ibbs, 2020; Aven, 2021). For example, while quantitative tools can help project managers estimate risk probabilities, they do not necessarily reflect the way risks are perceived and managed by different stakeholders involved in the project. Additionally, the integration of these tools into an organization's risk management culture—where proactive risk identification and decision-making are encouraged—has been identified as a key factor influencing the success of risk management strategies (Hillson, 2019). This paper aims to explore two central objectives, namely, to investigate the practical implementation of risk management tools in built environment projects and to examine the effectiveness of these tools in reducing risks and improving project outcomes. This study is guided by the hypothesis that the effectiveness of risk management tools is influenced not only by their technical capabilities but also by the organizational culture and how these tools are integrated into day-to-day project management practices. To explore this hypothesis, a qualitative research approach will be employed, using in-depth interviews with project managers, risk managers, and other key stakeholders involved in built environment projects. The qualitative method will allow for a deeper understanding of how these professionals perceive, adopt, and implement risk management tools, as well as how these tools influence their decision-making and risk mitigation practices. By capturing the experiences and insights of industry practitioners, this study aims to offer a rich, detailed analysis of the real-world applications of risk management in the built environment. This paper is structured as follows: following this introduction, the second section presents a literature review, discussing theoretical and empirical studies that highlight the linkage between risk management theory and practice. The third section outlines the research methodology, detailing the qualitative approach used to collect and analyze data. After

presenting the study's findings, the paper discusses the implications of the results for improving risk management practices in the built environment. Finally, the paper concludes with a summary of key findings, practical recommendations, and suggestions for future research.

Literature Review

The study review critically examines the existing knowledge on risk management in the built environment, focusing on tools, techniques, and cultural factors that influence their effectiveness. The review aims to explore the theoretical and conceptual frameworks, the practical application of risk management tools, and the impact of organizational culture on their success. It synthesizes empirical research, highlighting how risk management tools are implemented in practice and their effectiveness in real-world construction projects. The review concludes by justifying the study's hypothesis, which posits that organizational culture significantly influences the success of risk management strategies in the built environment. The study will place a fundamental focus on the stakeholder theory that is complemented by the agency theory and the critical success factors theory, while the balanced scorecard (BSC) will also be taken into account as a measuring yardstick in an effort to curtail risk management avenues with the construction sector that involves billions of investments by the policymakers and public practitioners on behalf of the citizens. The integration of the theoretical embeddedness will elucidate the stakeholder theory with its three pillars, namely the descriptive approach, the instrumental approach, and the normative approach, which advocate the intimate affinity of this theory to strategic management and contingency theoretical orientation (Mahajan et al., 2023). The concept of risk management occurs within the context of both organizational sustainability, which is grounded on governance, and organizational management, which is anchored on business ethics (Schaltegger, Hörisch, and Freeman, 2019). The main challenge of the risk context and reality is that it has diverse and a variety of critical success factors that go beyond the resources and capabilities of those entrusted by both primary and secondary stakeholders to be accountable and civil in their application, behaviour and deliverables (Kannan, 2018). Stakeholder theory is also closely aligned with the agency theory, which focuses on the professional transactional relationship between the principal (investor) and the agent (executor) of the aspirations of the former (Panda & Leepsa, 2017). The integration of technological-based risk mitigation techniques has entrenched the strategic tool of the business scorecard as a multidisciplinary intervention in an attempt to reinforce and guard against deviations to the risk-averse initiatives in a variety of sectors that incorporate the safeguard of resources and capabilities (Yang & Lee, 2020). While the study embraced the stakeholder theory, the assimilation of the balanced scorecard could act as a catalyst in the adaptation of the enterprise resource management that is bespoke and addresses the clear and present risk headwind that could be experienced within the construction sector (Suttipun et al., 2018). Risk management in construction can

be understood from two main perspectives: normative and descriptive. The normative approach emphasizes structured, quantitative methods such as risk registers, matrices, and Monte Carlo simulations, which provide objective data to assess and mitigate risks (Zou et al., 2019; Flanagan & Norman, 2020). These tools assume risks can be quantified and controlled through formal processes. In contrast, the descriptive approach focuses on the human and organizational dimensions, suggesting that cognitive biases, social dynamics, and organizational culture influence decision-making in risk management (Kwak & Ibbs, 2020). Hillson (2019) argues that risk management is not merely technical but involves leadership and communication within the organization. Aven (2021) integrates both approaches, proposing that risk management frameworks should balance technical solutions with the cultivation of proactive risk culture within organizations, aligning with the study's hypothesis that organizational culture influences the effectiveness of risk management tools.

Risk Identification Tools and Techniques

Effective risk identification uses diverse methods tailored to project needs and resources. Popular techniques include brainstorming, checklists, interviews, and system analysis (Mhetre, Konnur, & Landage, 2016). These methods help identify and prioritize risks early, ensuring comprehensive risk management (Cerezo-Narváez, Pastor-Fernández, Otero-Mateo, & Ballesteros-Pérez, 2022).

Tools for Risk Identification:

- Brainstorming and Checklists: These common methods are used to list potential risks based on past experiences or predefined guidelines (Gido, Clements, & Baker, 2018).
- Assumption Analysis: Examining underlying assumptions through Assumption Analysis uncovers latent risks (PMI, 2017).
- Cause and Effect Diagrams: These diagrams help visualize the relationships between causes and effects, facilitating the identification of underlying risk factors (Cerezo-Narváezet al., 2022).
- Nominal Group Technique: This structured method helps prioritize risks by gathering input from stakeholders (Cerezo-Narváez, et al., 2022).
- Interviews: Direct discussions with project stakeholders provide deep insights into potential threats and opportunities (Gilbert, 2024). For larger, complex projects, HAZOP and system modelling are used to analyze risks in depth (Schwalbe, 2020).

Risk Assessment and Analysis

Risk assessment involves prioritizing risks based on probability and impact. Qualitative Risk Analysis ranks risks using a matrix that assigns priority levels such as low, medium, or high (Turner, 2009). Quantitative Risk Analysis uses statistical models and simulations, such as Monte Carlo analysis and

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decision trees, to quantify the impact of risks on project outcomes (Biggins, Truelove, & Lawlor-Wright, 2016). These tools are essential for high-stakes projects where precision in forecasting is critical.

- Analyzing qualitative risks: This method involves ranking hazards based on their likelihood and impact before further investigation or action.
- Analyzing quantitative risks: This method calculates how identified risks will impact the overall project goals.

Although both methods can be used together or independently, quantitative risk analysis often follows qualitative risk analysis. Depending on the project's scope, complexity, and available resources, a team may choose to conduct qualitative risk analysis only for specific projects (Turner, 2009). The selection of risk analysis techniques is influenced by the project's nature and available time and budget. Common tools for qualitative risk analysis include the probability/impact matrix and the Top Ten Risk Item Tracking approach (Testorelli, Ferreira de Araújo Lima, & Verbano, 2022). For quantitative analysis, tools such as Monte Carlo simulations and decision trees are widely used. Decision trees, for example, calculate the expected monetary value (EMV) to assess potential project outcomes. Sensitivity analysis is another technique that analyzes how changes in input variables affect outcomes (Schwalbe, 2020).

Qualitative Risk Analysis

To differentiate between significant and minor risks, project teams must assess the likelihood of a risk occurring and the potential consequences should it occur. According to Kloppenborg (2015), the evaluation of risk involves assigning probabilities and impacts for each risk, which can be categorized as high, medium, or low, as illustrated in Figure 1.

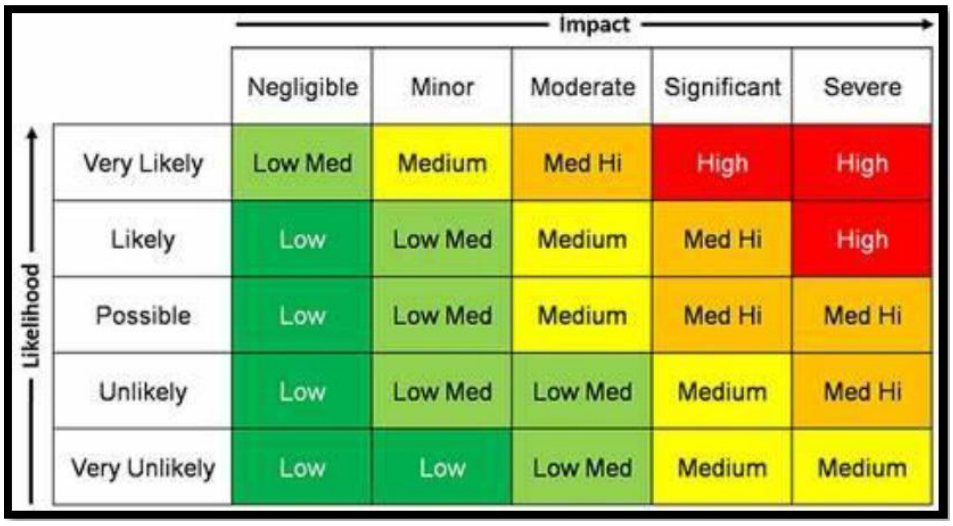

Figure 1: Probability/impact matrix example

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Probability/Impact Matrix

The probability/impact matrix or chart is commonly used to visualize and categorize risks based on their likelihood and impact. This matrix helps project managers determine which risks require the most attention. In this technique, risks are categorized according to their likelihood of occurrence on one axis and the potential consequences on the other (Schwalbe, 2020). To use this approach, project stakeholders compile a list of risks that may affect the project, categorizing each risk based on its probability of occurrence and potential impact (Testorelli, et al., 2022). The project manager then summarizes the findings in a probability/impact matrix, assigning numerical scores to quantify the likelihood and impact of each risk. This method helps prioritize risks based on their potential to disrupt the project, guiding the development of contingency plans for high-priority risks (Mhdawi, 2020). These prioritized risks are listed in the updated risk register, and less critical risks may be tracked in a risk watch list (Testorelli, et al., 2022).

Top Ten Risk Item Tracking

The Top Ten Risk Item Tracking approach is another qualitative risk analysis tool that tracks and monitors risks throughout the project lifecycle. It helps ensure that the most significant risks are continuously reviewed and managed. This technique involves listing the top ten risks, their current and prior rankings, and the progress made toward mitigating them since the last review (Testorelli, et al., 2022). During periodic reviews, project managers and stakeholders evaluate the top risks and take actions as needed to address emerging threats. This technique also allows for tracking risks over time, helping to identify persistent or evolving risks that could have a significant impact on project success. For example, some organizations focus on tracking risks that are highly likely to materialize soon, while others prioritize risks that are challenging to detect or mitigate (Turner, 2009).

Risk Register Updates

An essential outcome of qualitative risk analysis is the updating of the risk register. This document is updated with detailed information about each identified risk, including a numerical or qualitative ranking for the probability and impact of each risk. The rankings, typically categorized as high, medium, or low, provide project managers with a structured approach to prioritize risks (Martinelli & Milosevic, 2016). Additionally, the risk register may include a watch list for risks deemed low-priority but still significant enough to warrant attention. These risks are periodically reviewed, ensuring they are addressed if their likelihood or impact increases over time. Risks requiring further quantitative analysis are also flagged for additional evaluation (Burkov, Burkova, Barkhi, & Berlinov, 2018). By continuously updating the risk register, project teams ensure that risk management efforts are focused on the most pressing threats, helping to mitigate potential project disruptions (Jahan, Khan, Thaheem, Ullah, Alqurashi, & Alsulami, 2022).

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Quantitative Risk Analysis

While qualitative risk analysis is an essential part of all projects, quantitative risk analysis is applied more formally in large, complex, or high-risk projects (Biggins, et al., 2016). It provides a higher degree of rigour, enabling project teams to assess the likelihood of meeting critical project objectives such as time, budget, scope, and quality (Testorelli et al., 2022). Quantitative risk analysis becomes particularly valuable when precise predictions about project performance are needed.

Selecting a Suitable Quantitative Risk Technique

When selecting an appropriate quantitative risk technique, several criteria should be considered (Kloppenborg, 2015):

- The expertise of project team members should align with the chosen technique.
- The methodology should facilitate prompt responses to emerging risks.
- The technique should support the determination of project cost and schedule contingencies.
- The method should enable effective communication among stakeholders.
- The technique should be simple to apply and understand.

Quantitative Risk Techniques

Some commonly used quantitative risk techniques include:

- Decision Tree Analysis: This technique uses diagramming and computation to evaluate the effects of different options under uncertainty. The Expected Monetary Value (EMV) is commonly used to calculate the financial value of various decisions (Kloppenborg, 2015). Decision trees help assess the risk associated with potential project paths and select the best course of action based on expected outcomes.
- Failure Mode and Effect Analysis (FMEA): FMEA is a systematic method that evaluates the potential failure modes of a project or system. By analyzing each component's failure mode and its impact on the project, teams can prioritize risks based on their severity and likelihood (Mhetre, Konnur, & Landage, 2016).
- Sensitivity Analysis: This technique identifies the key risks that could have the most significant impact on a project. It examines the degree to which uncertainties in project parameters affect outcomes, often displayed in a tornado diagram (Kloppenborg, 2015). Sensitivity analysis is particularly useful for understanding the sensitivity of project goals to changes in input variables.
- Simulation: Simulation models, such as Monte Carlo analysis, convert uncertainties into potential outcomes. By using probability distributions for project parameters like cost and

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time, simulation techniques provide insight into the likelihood of achieving project objectives under different scenarios (Mhetre, Konnur, & Landage, 2016).

Risk Register Updates

As quantitative risk analysis techniques are applied, the risk register is updated with new information, such as the probability and impact of each identified risk. This document now reflects both qualitative and quantitative analyses, helping project teams make more informed decisions. The register also prioritizes risks based on their likelihood and severity, sometimes highlighting the most critical risks using a Top Ten Risk List (Mhetre, Konnur, & Landage, 2016). Furthermore, organizations may place more emphasis on risks that are likely to materialize soon or on those that are difficult to detect early. These risks are clearly documented in the risk register, ensuring that appropriate actions can be taken as the project progresses (Jahan, et al., 2022). The risk register remains a dynamic tool, frequently updated to track risks, their mitigation, and any changing project circumstances (Testorelli, et al., 2022). It is an essential document for continuous monitoring and management throughout the project lifecycle (Schwalbe, 2020).

Methods and Data

A qualitative research methodology predicated on the interpretivism philosophy that posture theory construction and meaning generation has been pursued by the researchers Bryman & Bell (2015), which is particularly suited for exploring the complexities within the broader field of management science and business discipline such as risk management in construction projects. The phenomenon in the study seeks a deep examination and assessment of stakeholders' perceptions, experiences, and attitudes, including those of project managers, contractors, and clients (Cresswell & Cresswell, 2017). The inductive-oriented approach immerses the researchers in the integral component of research instrumentation due to the agility and flexibility of the qualitative epistemological and ontological perspective Sekaran & Bougie. (2016which utilizes methods such as interviews, focus groups, and observations to uncover how risk management practices are implemented and understood within the unique contexts of construction projects, which are influenced by factors such as scope, budget, regulations, and stakeholder relationships (Butler-Kisber, 2018). Qualitative research is especially beneficial for exploratory studies, enabling the identification of emerging themes and offering insights that quantitative methods may overlook, such as the influence of risk management on project success (Charmaz, 2014). This flexible methodology supports the discovery of practical strategies and lessons learned from real-world examples, which can help improve risk management practices and project outcomes in the construction industry (Patton, 2015; Cresswell & Cresswell, 2017). The study in affirming the inductive approach employed allows for adaptation in data collection and pursues a thematic analysis (Braun and Clarke, (2017), which facilitates the encapsulation of dominant and

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emergent themes in the meaning generation within the auspices of coding, which is complemented by inferring of categories and patterns. The population for this study's inclusion criteria was informed by the selection of participants who are in the construction industry and who will share plausible reflections and contributions to the empirical data collection. The selection of this population ensures that the participants possess sufficient practical knowledge to provide valuable insights into the complex dynamics of risk management in construction projects, which are shaped by various project-specific factors such as scope, budget, and regulatory constraints (Busetto, Wick, & Gumbinger, 2020). This focus on experienced personnel is critical to ensuring the reliability and credibility of the data, as junior staff with less than three years of experience are excluded to maintain the validity of the research findings (Merriam & Tisdell, 2015). The sample size selected in the study is sufficient for gathering rich, contextual data while maintaining close relationships with participants, which enhances the quality of the findings (Cresswell & Cresswell, 2017). Non-probability purposive sampling is particularly effective for qualitative research, as it allows for a focused selection of individuals who can provide detailed perspectives on the phenomena under study (Merriam & Tisdell, 2015). In terms of data collection, the interview guide will feature open-ended questions focusing on risk management practices, perceptions, and challenges encountered in construction projects, informed by literature on risk management (Kendrick, 2015; Burger, Verster, & Zulch, 2015) and qualitative methodologies (Braun & Clarke, 2019). Informed consent was obtained from all participants, and interviews were audio-recorded and transcribed verbatim for thematic analysis to explore patterns and themes related to risk management's impact on project success.

Results

The findings of this study explore the practical implementation and effectiveness of risk management tools and techniques in construction projects. Through the analysis of participant insights, the research identifies key challenges and successful practices in risk identification, planning, and communication. These findings contribute to understanding the critical role of systematic risk management in enhancing project success and business sustainability in the construction industry (Kallow, Bodla, Ejaz, & Ishaq, 2023; Bahamid, et al., 2022). The following are the demographics of the selected participants:

Pseudonym	Position	Gender	Years of Experience
Participant 1	Contracts Manager	Male	29
Participant 2	Construction Manager	Male	21
Participant 3	Site Agent	Male	12
Participant 4	Site Agent	Male	6
Participant 5	Quality Manager	Male	5
Participant 6	Quality Manager	Male	5
Participant 7	Site Engineer	Male	10

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Participant 8	Senior Health and Safety Officer	Male	22
Participant 9	Site Engineer	Male	22
Participant 10	Site Agent	Male	17
Participant 11	General Foreman	Male	16
Participant 12	Site Agent	Male	11

Table 1: Participants Demographics

Objective 1: Explore the practical implementation tools and techniques adopted in relation to risk management

The study identifies the integration and synthesis of risk mitigation strategies, which are employed in a systematic and holistic manner. This is achieved through consistent investment in risk identification control measures and diagnostic tools.

Emerging Themes

Participants highlighted several issues in the practical implementation of risk management, including the lack of formal education and a focus on overall risk management training, which are seen as significant disadvantages. Tools such as risk matrices, risk registers, and checklists were identified as the most common methods for risk management. Participant 3 noted, "Past construction experience and engaging with all levels of people on site to identify potential risk items", which is consistent with literature suggesting the use of brainstorming sessions, Delphi methods, and Failure Mode and Effect Analysis (Aven, 2015). Participant 7 supported the use of risk matrices by stating, "We do use the risk matrix where we identify hazards and quantify the risks." The planning phase was overwhelmingly considered the most critical phase for risk management, as supported by Bahamid et al. (2022) and Participant 7's statement, "The planning phase is the first opportunity to start identifying risks and implementing preventative measures." Participants also emphasized the importance of ongoing risk monitoring and review, acknowledging that risk assessments can often be forgotten post-evaluation. Participant 7 noted, "Risk reviews are often forgotten after the initial assessment, and the risks aren't updated." This aligns with Aaltonen et al. (2015), who stress the importance of regular risk reviews. Other participants highlighted the barriers to effective knowledge sharing and skill transfer, which hinder the development of a strong risk management culture.

Objective 2: Examine how effective the tools and techniques that exist in relation to risk management

The findings from this objective reveal a focus on risk impediments and constraint identification, which is crucial for augmenting business sustainability and project success.

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Emerging Themes

The study found that experience is the most commonly cited tool for learning from past projects, with several participants highlighting its significance. Participant 10 mentioned, "Experience is the most efficient method because you know where the risks will come from." Additionally, risk registers were acknowledged as valuable tools in identifying and tracking risks. Participant 3 explained, "We draw up risk registers for each project and track risks by severity levels to ensure they are addressed in subsequent projects." This aligns with research by Kallow et al. (2023), which underscores the effectiveness of learning from case studies to improve future risk management. While most participants indicated that the standard of risk management at Raubex KZN is good or very good, some, like Participant 11, expressed concerns over the effectiveness of risk resolution, stating, "We're good at identifying risks, but resolving them effectively is a challenge." This echoes Hillson and Murray-Webster's (2017) assertion that risk management tools are effective only when consistently used and shared within the organization. Furthermore, participants discussed the importance of effective risk communication, with many stating that communication within Raubex KZN is good, but Participant 11 noted, "Risk communication isn't prioritized enough in meetings, and risks aren't always addressed as central issues." Mhetre, Konnur, and Landage (2016) highlight the barriers in risk communication, such as information distortion and varying stakeholder priorities, which can hinder the overall effectiveness of risk management efforts.

Discussion

The study highlights key insights into risk management practices in the construction industry. Traditional strategies like risk identification and mitigation remain crucial; however, the need for flexibility and adaptability in response to technological advancements and global uncertainties is evident. The study found that while tools like checklists and brainstorming are commonly used for risk identification, the adoption of more advanced, quantitative methods is limited, particularly for non-financial risks (Kallow, et al., 2023). This gap between theory and practice in risk assessment techniques aligns with prior research that emphasized the importance of predictive analytics in risk management (Green, & Dikmen, 2022). Despite using qualitative risk assessment methods, the research reveals that construction projects could benefit from more data-driven approaches, particularly for high-risk tasks. While challenges like time constraints and skill gaps remain, the study suggests the integration of advanced technologies could improve the accuracy of risk assessments and decision-making (Reddy, 2015). Additionally, the research points to the lack of formalized knowledge transfer mechanisms as a barrier to effective risk management, consistent with Fadun & Saka (2018), who highlighted the importance of systematic knowledge sharing in risk management practices. Future research should explore how emerging technologies can bridge these gaps and improve risk management strategies in the industry.

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The study, in its diagnostic of the techniques for dealing with risk, project managers apply strategies to handle both negative and positive risks. These strategies include avoiding, transferring, mitigating, or accepting risks, depending on the nature of the threat or opportunity. When contextualizing such Strategies to be efficacious, proactive, and adaptive when tackling Dealing with Negative Risks risks and headwinds, it is critical that the delineation of the real-time challenge explicitly describes clear and present articulation of adhering to safety measures. The risk avoidance culture also facilitates a critical dynamic that could be associated with the mitigation contribution. Huemann & Turner (2024) articulated that risk can often be eliminated by altering project designs or processes. For example, modifying a parade route to avoid dangerous traffic areas eliminates the risk. With alignment to the designed transfer of risk, contracts, such as insurance or fixed-price agreements, project risks can be shifted to third parties (Mhetre, Konnur, & Landage, 2016). However, transferring risk does not eliminate it, but rather shifts the burden. The alleviation, mitigation and ultimate eradication of risk should be embraced by all and sundry within the organization which should also cascade down to those in the construction site environment. The likelihood and impact of risks can be reduced through careful planning, testing, or designing prototypes (Abdul-Rahman, Wang, & Sheik Mohamad, 2015). There should be a probability of accepting that risk will time and again emanate. For low-impact or unlikely risks, the best strategy may be to accept them and develop plans to manage them if they occur (Kendrick, 2015). Hence, it is critical to always have a checklist and protocol adherence of reacting and responding timeously and expedited when this abnormal reality transpires, not only for resource optimization but also for the prevention of the dreaded safety concerns of the personnel within the construction site. The systematic and comprehensive evaluation, assessment and examination of risk should be the responsibility and accountability of everyone within the organization and should be entrenched in the DNA and be adopted as the business practice, culture and execution and not only the responsibility of those at the higher echelons of the organization. : Investigating further into the nature of the risk or testing assumptions can provide clarity, allowing for better management of both threats and opportunities (Ahmad, Thaheem, & Maqsoom, 2018). While strategies, contingencies or tactics for dealing with positive risks, it is incumbent on the personnel to exploit risks in order to maximize the opportunity, resources are allocated, and actions are taken to ensure the opportunity materializes (Jepson, Kirytopoulos & London, 2020). Co-sharing of risk presents the opportunity with partners who are both primary and secondary stakeholders through joint ventures or licensing agreements, which helps to maximize its potential benefit (Gilbert, 2024). The augmentation and enhancement of risk translate into the offering of positive outcomes, and efforts are made to increase their probability or improve their impact (Testorelli et al., 2022). Empirical studies show that risk management tools such as risk registers, Monte Carlo simulations, and risk matrices are widely used but have varying degrees of effectiveness in practice. Risk registers enhance risk awareness and decision-making, but their success relies on continuous engagement from senior

management throughout the project lifecycle (Zou et al., 2019; Aven, 2021). Monte Carlo simulations, although highly sophisticated, are underutilized due to their complexity and the need for technical expertise (Kwak & Ibbs, 2020). Furthermore, these simulations are not always integrated into decision-making, especially in organizations with weak risk cultures (Hillson, 2019). Risk matrices, while useful for risk prioritization, can oversimplify risks or lead to misclassification if not used correctly (Flanagan & Norman, 2020). Several studies emphasize the importance of organizational culture in the successful application of these tools. A proactive risk culture, where risk management is embedded into decision-making, leads to better outcomes (Hillson, 2019; Kwak & Ibbs, 2020). Aven (2021) argues that an organization's willingness to engage in risk management directly affects the effectiveness of its tools. These findings support the hypothesis that the success of risk management tools is influenced by an organization's risk culture and its integration into day-to-day project practices. The designed adherence and compliance to risk mitigation measures, specifically within the construction environment and in this study on the built environment of national roads and highways, makes provision for the acceleration of economic transportation and mobility, but it also plays a critical role in ensuring that this undertaken is premised on safety and anchored in legal, financial, reputational seamless operational execution mandate by the implementing agents on behalf of the principals. The findings in the study could ascertain trustworthiness through the application of the following hallmarks of the interpretivism qualitative study relative to transferability by uncontrived assumptions based on the theoretical assumptions, empirical data inventory and contextual extrapolations of the research setting from respondents' insights, views and experience that has been solicited. This is also corroborated by the need for infrastructure and facilities within the construction sector, which continues to make unspoken contributions to the country's economic prosperity and safer roads for all users.

Conclusion

The study confirms that effective risk management is essential for successful construction projects but reveals gaps in its practical implementation. While risk management frameworks are robust in theory, their application is often hindered by a lack of structured processes, advanced tools, and knowledge transfer mechanisms. One major contribution of this study is the identification of the need for more tailored and flexible risk management strategies that account for the unique characteristics of each project. These findings contribute to the current understanding of risk management, particularly in aligning tools and techniques with project-specific needs (Firmenich, 2017). The study's limitations, including its qualitative nature and context-specific findings, suggest that future research should include quantitative studies to capture a broader spectrum of experiences in the construction industry. Additionally, future work should focus on developing standardized risk management frameworks incorporating technological solutions for real-time monitoring and decision-making. Encouraging a

culture of continuous improvement through feedback loops and better communication channels can significantly enhance the effectiveness of risk management practices (Divya Sankar, Shashikanth, & Mahender, 2022). Such advancements will help move the industry toward proactive risk management, fostering better decision-making and project success. In this study, in bolstering the risk-mitigating culture, the multilevel and multi-hierarchical approach is recommended, and the spreading of awareness could have a multiplier effect on the integration of the construction project workflows based on the continual review and update of risk mitigation and workflow scheduling by applying information flow intra and from the external project participants or secondary stakeholders (Zhong et. al, 2017). Therefore, over and above the establishment of the strategic state-of-the-art risk assessment techniques communication through the application of ICT-oriented interventions such as Radio Frequency Identification (RFID) technology, Radio Frequency Identification (RFID), or even Google Maps, which could also extend the assessment and the complementary impact with the project workflow (Kasim, et. al, 2019).

Practical Implications

- With inference to the practical implications, the study accentuates and demonstrates the significance of real-time and pragmatic continuous learning and adaptation in the face of evolving project dynamics within the construction sector that has an avalanche of risk-prone scenarios. The construction sector in managing risks is inherently tied to the capability of stakeholders, with specific mention of project managers, to participate in open dialogues, share insights, and collaboratively navigate the uncertain terrain of risks with primary and secondary stakeholders (Yuan et. al, 20221).
- The qualitative findings communicate establishing regular knowledge-sharing mechanisms, such as forums and communities of practice, to facilitate the dissemination of experiences and lessons learned that continually promote safety checks and balances.
- Therefore, the management and leadership team should also promote the integration of technological interventionist solutions for existential risk assessment, monitoring and decision-making as a risk mitigation business practice. These managerial implications emphasize the agility and adaptive approach to risk control and management while espousing an intrinsic and dynamic aspect of project development and execution in the construction industry.
- Practical applications of advanced risk assessment tools in complex construction projects make an optimal contribution to cost overrun and unbudgeted variation orders that increase and escalate the snag list inventory and incorporate simulation for the assessment and

International Journal of Applied Research in Business and Management (ISSN: 2700-8983)
an Open Access journal by Wohllebe & Ross Publishing, Germany.
Volume: 06 Issue: 01 Year: 2025
https://doi.org/10.51137/wrp.ijarbm.2025.msut.45698

evaluation of interdependent construction scheduling of complex risks of capital assets and infrastructures under uncertainty could be optimally minimized (Pehlivan & Öztemir, 2018).

- The integration of similar risk evaluation techniques such as Program Evaluation and Review Technique (PERT), Monte Carlo Simulation (MCS) technique and Critical Path Method (CPM) could also be incorporated within the construction programs, thus advancing the dashboard view of project headwinds (Huynh & Nguyen, 2020; Chen et. al, 2023).
- Incremental gravitation towards integrating the digitalization-oriented assessment tools that Artificial Intelligence propelled will, in future, deliver a comprehensive and clear line of sight relative to risk control and management (Afzal et al., 2021).
- The other technologically based risk assessment to be considered in complex construction sites from the Bayesian belief network (BBN); Fuzzy hybrid methods (FHMs) coupled with Fuzzy Set theory (FST); Fuzzy-artificial neural network (FANN); Fuzzy-analytical network processing (FANP) which require dynamic capability-oriented approach from the decision makers in dedicated monetary resource investments in such risk interventionist prevention (Zhang, et. al, 2017).
- From a practical standpoint, these assessment techniques may support seamless construction project management by reducing complexity and safety anomalies, thus preempting pandemonium. Furthermore, construction personnel, engineers and site accountants should deliberate and communicate the significant complexity and risk features for the successful project completion.

Further Related Research

- The strategic documentation in the decision-making and problem-solving within the construction sector is to be extended to the basic public especially the motorists and pedestrians as they traverse around these construction sites.
- The role of technology in broadening transparency, such as the use of cameras and drones on construction sites, could benefit the policy-makers and authorities when undertaking the oversights of these complex projects.
- The earlier introduction of risk management and construction management as a pedagogical curriculum within the earlier educational years and later as the essential research discipline that plays a critical role in keeping personnel, assets, resources and basic public safe within the vicinity of construction sites.

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