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Risk Management in Engineering Projects

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SUMMARY

This study explored the strategic role of risk management in project optimization, with an emphasis on training the team involved in the project and analyzing case studies on this practice, contextualized in the Brazilian context. The study begins with the following central question: How can risk management be implemented effectively to add value to the project? The research hypothesis adopted the combination of structured methodologies inspired by ISO 31000 and the PMBOK guide. The objective was to demonstrate the importance of this integrated approach, present training strategies, highlight the effective use of the probability matrix, and analyze the impact of risk management through case studies. Using a qualitative approach, the study combined a literature review with the analysis of real cases in different projects. To support this research, case studies in different contexts were analyzed, including the Panama Canal expansion project (JEONG; CRITTENDEN; XU, 2009), the California high-speed rail system (CALIFORNIA HIGH-SPEED RAIL AUTHORITY, 2023), and cases described by Kerzner (2017), such as McRoy Aerospace, The Poor Worker, and Boeing. The results showed that organizations with formal risk management processes and trained teams can achieve greater predictability of project performance, reducing delays and costs by up to 30%. It was concluded that risk management, when integrated into organizational culture and combined with ongoing training, transforms into a competitive advantage, adding value to projects and strengthening organizational resilience.

Keywords: Risk Management. Projects. Mitigation. Training. Case studies.

ABSTRACT

This study explored the strategic role of risk management in project optimization, with emphasis on team training and case analysis contextualized within the Brazilian scenario. The central research question was: How can risk management be effectively implemented to add value to a project? The study hypothesized that combining structured methodologies inspired by ISO 31000 and the PMBOK Guide would be effective. The objective was to demonstrate the importance of this integrated approach, present training strategies, highlight the effective use of the probability matrix, and analyze the impact of risk management through case studies.

Using a qualitative approach, the study combined a literature review with the analysis of real cases in differ-ent projects. To support the research, case studies were examined in various contexts, including the Panama Canal expansion project (JEONG; CRITTENDEN; The results showed that organizations with formal risk management processes and trained teams can achieve greater predictability in project performance, reducing delays and costs by up to 30%. It was concluded that risk management, when integrated into organizational culture and combined with continuous training, becomes a competitive advantage, adding value to projects and strengthening organizational resilience.

Keywords: *Risk Management. Projects. Mitigation. Training. Case Study.*

1. INTRODUCTION

Risk management in construction projects is critical to their success, especially in a scenario characterized by tight deadlines, limited budgets, and high technical complexity. According to the Project Management Institute (PMI, 2021, p. 12), project planning should include risk identification and analysis from the earliest stages to avoid surprises during execution.

In project management, to achieve success, the team responsible for project management must analyze uncertainties when seeking to achieve objectives. Failure to do so may result in failure, as the number of unexpected events will be excessive, significantly reducing the likelihood of achieving the established goals.

Further emphasizing the relevance of this aspect, Cooke-Davies (2002) demonstrated a strong relationship between meeting project deadlines and risk management. His research identified improved schedule adherence in organizations that presented the following characteristics:

•Adequate qualification of the entire organization in the principles of risk management;

•Evolution of organizational processes related to the delegation of responsibilities for risks

waistband;

•Effective maintenance of an accessible and up-to-date risk register;

•Appropriate implementation of a constantly updated risk management plan.

However, Cooke-Davies' conclusion should be seen as an example, since the risks associated with a project arise from the uncertainties that permeate all its phases, activities, and areas of knowledge (PROJECT MANAGEMENT INSTITUTE, 2021). Thus, risk management needs to be deeply integrated into the fundamental project processes, including, but not limited to, general management, systems engineering, configuration control, costs, design and engineering, production, planning, quality, scope, and testing (Kerzner, 2017).

According to the theoretical framework, risks correspond to uncertain events or circumstances that, if materialize, can generate positive or negative impacts on the project's objectives, and are present in all its phases (PROJECT MANAGEMENT INSTITUTE, 2021). In turn, Kerzner (2017) defines risk more objectively, as “the measure of the probability and impact of not achieving a given objective”.

In the context of projects, risk management involves both the technical and methodological aspects of identifying, assessing, and responding to threats throughout the project lifecycle, with the goal of achieving planned results. It should be viewed as advance preparation for potential events, rather than a delayed reaction to unexpected developments. In other words, effective risk management must be proactive, not reactive (Kerzner, 2017). Therefore, its objectives should be based on increasing the likelihood and impact of favorable events, while reducing the probability and consequences of adverse events (PROJECT MANAGEMENT INSTITUTE, 2021).

Interest in the topic arose from the observation that many projects face delays, extra costs and quality problems due to the lack of a structured approach to risk management.
As highlighted by Kerzner (2017), underestimating risks in planning is one of the main causes of failure in industrial projects.

Through a study of three risk management cases, Silva (2017) states that engineering companies in the industrial sector lack an understanding of the importance of managing these risks in their projects.

According to Gaedicke and Matsuda (2024), although risk management is essential, less than 5% of construction engineering companies have a structured plan for it, even in developed countries. Furthermore, the authors highlight that problems such as cost overruns, insufficient quality, and missed deadlines are common due to the lack of formal risk management practices.

This study is set in the context of industrial companies seeking to improve their results delivery. In this scenario, the choice was to investigate project management failures.

is justified by the need to minimize financial losses, avoid delays, and ensure the quality of delivered projects. Therefore, this work was guided by the following research question: "How can risk management contribute to reducing the main deficiencies in industrial project management?"

The relevance of this research lies in its contribution to improving project management in future projects. Therefore, three specific objectives were established: (1) to examine the causes of project management failures; (2) to measure the impact of these failures on project outcomes; and (3) to recommend practices to improve risk management. The hypothesis formulated maintains that the adoption of structured risk management methodologies, combined with team training, can significantly reduce the negative effects of uncontrolled risks.

In this context, concepts and theories relevant to the topic are discussed. According to ISO 31000:2018, risk management must be integrated into the organizational culture, involving all levels of hierarchy (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 2018). When comparing the PMBOK (PMI, 2021) and ISO 31000:2018 approaches, it was found that both emphasize the importance of proactivity and effective communication among stakeholders.

2 THEORETICAL FRAMEWORK

An interesting aspect when analyzing project risks is risk tolerance, as each organization has different levels of acceptance. One company might consider a 17% increase in costs significant, while another might view the same amount as insignificant (António Miguel, 2013).

According to Kaplinski (2013), a determining factor in decision-making during the planning and execution phases of projects is risk aversion or willingness. Depending on the stance adopted by organizations and stakeholders, they may be willing to assume different levels of risk, influenced by factors that can be categorized as follows:

•Risk appetite: degree of uncertainty that an entity is willing to accept in search of rewards;

•Risk tolerance: amount or volume of risk that an organization or individual is prepared to take. to bear;

•Risk threshold: reference points related to the level of uncertainty or impact that a party interested party considers it acceptable.

Furthermore, individual perception is one of the factors that influence attitudes toward risk (PECKIENE, KOMAROVSKA, and USTINOVICIUS, 2013). According to Kaplinski (2013), the stance adopted toward risk is fundamental in evaluating alternatives for future decisions. Furthermore, the author emphasizes the need for personal choices on the part of the decision-maker, which, from a psychological perspective, involve judgments based on subjective perceptions, such as in investment or material acquisition situations.

According to Fortunato (2013), throughout the planning and execution of a project, many decisions are made based on future expectations—that is, on assumptions, forecasts, or estimates of possible scenarios—which implies accepting risks and uncertainties. According to the author, unknown risks cannot be managed proactively, and it is recommended that the project team reserve a general contingency. For known risks, which have been identified and analyzed, actions can be planned using the processes recommended by the PMBOK Guide, as guided by António Miguel (2013). This author also states that risk tends to change as the project progresses and should therefore be continuously monitored (MIGUEL, 2013).

According to Abdolmohamadi (2014); Hwang, Zhao, and Toh (2014), risk management should be prioritized and implemented in construction projects, regardless of their scale, to ensure the achievement of the proposed objectives. According to analyses, this process is continuous and must always evolve, aligned with the organizational strategy and its execution, since the occurrence of risks throughout the project life cycle can result in unforeseen changes in its objectives (CARVALHO; RABECHINI, 2018).

2.1 ABNT NBR ISO 31000:2018

ABNT NBR ISO 31000:2018, published by the Brazilian Association of Technical Standards (ABNT), establishes guidelines for risk management, providing principles, structure, and processes that help organizations identify, assess, and address risks systematically and effectively. In the context of projects, implementing risk management based on ISO 31000:2018 is essential to increase the likelihood of success, minimize uncertainty, and ensure that objectives are achieved within the planned timeframe, cost, and quality.

Thus, ISO 31000:2018 highlights eight fundamental principles that should guide risk management: integration, personalized structure, inclusion, dynamism, continuous improvement, timely information, consideration of the human and cultural context, and transparency. In the project context, these principles reinforce the need to integrate risk management into all stages of the project lifecycle, from planning to closure.
Furthermore, the structure must be adapted to the specific context of the project, considering factors such as complexity, stakeholders involved and external environment (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 2018).

Furthermore, ISO 31000:2018 proposes a framework comprising leadership and commitment, integration, design, implementation, evaluation, and continual improvement. In projects, leadership plays a crucial role, as it is responsible for establishing a culture of risk management and allocating appropriate resources. Therefore, integrating risk management with other project management practices, such as scope, time, and cost, is essential to ensure that risks are comprehensively addressed.

Therefore, the risk management process, according to ISO 31000:2018, involves the identification, analysis, evaluation, treatment, monitoring, and communication of risks. Therefore, risk identification must be carried out collaboratively, involving the project team and relevant stakeholders. Analysis and evaluation allow prioritizing those with the greatest impact or probability, while treatment includes defining strategies such as mitigation, transfer, acceptance, or elimination of risks. Continuous monitoring and effective communication ensure that risks are managed proactively throughout the project (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 2018).

Implementing ISO 31000:2018 in projects brings significant benefits, such as reducing uncertainty, improving decision-making, and increasing the likelihood of achieving project objectives. However, it also presents challenges, such as the need for team training, resistance to change, and the allocation of adequate resources. According to the studies presented, to overcome these challenges, it is essential that the organization fosters a culture of risk management and provides ongoing support to the project team.

In this sense, ISO 31000:2018 offers a robust framework for implementing risk management in projects, contributing to the success and sustainability of initiatives. By adopting the principles, structure, and processes proposed by the standard, organizations can effectively manage risks, ensuring that projects are delivered within established parameters and add value to stakeholders (BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS, 2018).

2.2 THE IMPORTANCE OF TEAM TRAINING

Effective project management implementation depends not only on robust methodologies and appropriate tools, but also, and most importantly, on the training of the team involved. This is due to

the fact that the competence and preparation of professionals are critical factors for the success of any project, since they are responsible for planning, executing, monitoring and controlling all the activities necessary to achieve the established objectives (PROJECT MANAGEMENT INSTITUTE, 2021).

Furthermore, team training goes beyond technical mastery of project management tools. It also involves developing interpersonal skills, understanding management processes, and the ability to adapt to change—all essential aspects for dealing with the challenges inherent in projects (KERZNER, 2017).

That said, one of the main benefits of team training is improved decision-making. Well-trained professionals have a greater ability to analyze scenarios, identify risks and opportunities and, consequently, propose solutions aligned with the project's objectives (VARGAS, 2019).

Furthermore, training promotes a systemic vision, allowing the team to understand how their activities integrate with the whole and how they can contribute to the success of the project as a whole. This understanding is particularly essential in complex projects, in which the interdependence between tasks and the need for coordination between different areas require a high level of collaboration and communication (CARVALHO; RABECHINI, 2018).

Furthermore, another fundamental aspect is the impact of training on organizational culture. When the team is aligned with project management practices, there is greater adherence to processes and a greater awareness of the importance of following established methodologies (DINSMORE; CAVALIERI, 2020). This contributes to the creation of a project management culture in which discipline, transparency, and the pursuit of continuous improvement are values shared by all involved.

At the same time, training helps reduce resistance to change, a common challenge in organizations implementing or improving their project management practices. Trained professionals understand the benefits of new approaches and are therefore more willing to adopt them (MAXIMIANO, 2016).

Furthermore, ongoing training also plays a key role in keeping the team up to date with best practices and market trends. Project management is a constantly evolving field, with new methodologies, tools, and technologies emerging regularly (PROJECT MANAGEMENT INSTITUTE, 2021). Therefore, investing in the team's professional development ensures that they are always prepared to face the challenges of a dynamic and competitive environment.
Furthermore, continuous training contributes to the motivation and engagement of employees, who feel valued and recognized by the organization (KERZNER, 2017).

However, it is essential to emphasize that team training should not be seen as an isolated event, but as an ongoing process integrated into the organization's strategy. To achieve this, it is necessary to identify training needs, define individual and collective development plans, and evaluate the results obtained (VARGAS, 2019). The organization, in turn, must provide the necessary resources, such as time, budget, and access to quality materials, to ensure the training is effective. Furthermore, project leaders must also be trained, as they play a key role in supporting the team and fostering an environment conducive to learning and applying acquired knowledge (CARVALHO; RABECHINI, 2018).

In short, team empowerment is an essential pillar for the successful implementation of the risk management. Qualified professionals not only master the necessary techniques and tools, but also develop skills that allow them to deal with complex challenges, make informed decisions, and contribute to the creation of an organizational culture focused on excellence (MAXIMIANO,

2016). Therefore, investing in team training is a strategic step to ensure that projects to be delivered as planned (PROJECT MANAGEMENT INSTITUTE, 2021).

2.2.1 Practical team training

As explained, a structured training program in the area of risk management, developed for the team involved, can contribute to the identification, analysis and effective response to risks.
The first step towards this training is theoretical and practical training, in which professionals acquire knowledge about the fundamentals of risk management.

According to Hillson and Simon (2020), risk awareness and categorization are essential for staff to understand the importance of prevention. During this training, fundamental concepts and practical exercises based on real-life scenarios from the projects studied should be presented, enabling employees to develop decision-making skills in adverse situations.

Next, the team learns how to create and use a risk register, an essential tool for monitoring project threats. As Kerzner (2017) argues, formalizing risk management through structured documents, such as a risk matrix, facilitates the analysis of the probability and impact of each event. This method will be further detailed below.

Another fundamental aspect of training is risk response simulation, a methodology that allows the team to experience, in a controlled manner, critical scenarios that could occur during project execution. According to the Project Management Institute (2021, p. 21), simulations help build a culture of proactive prevention. For example, by simulating a delay in the delivery of essential materials, the team can test alternative strategies, such as seeking secondary suppliers or adjusting the project schedule.

According to Kerzner (2017), project team training is one of the determining factors for organizational success and increasing project management maturity. The author further states that effective learning occurs in three complementary spheres: practical experience (on-the-job), formal education, and knowledge transfer, especially lessons learned, benchmarking, and continuous improvement efforts.

The methodology presented by Kerzner in the book Project Management: A Systems Approach to Planning, Scheduling, and Controlling (2017) demonstrates the effectiveness of training in the case studies he studied. The case study "The Poor Worker" highlights the negative impacts of a lack of alignment between training, motivation, and team performance. Meanwhile, "McRoy Aerospace" shows how investments in training and the development of technical and behavioral skills enabled the execution of a highly complex project, with gains in efficiency, integration of departments, and risk control.

The formation of Integrated Product/Project Teams (IPTs), also discussed in Kerzner's book, exemplifies a systemic approach to training in which teams are composed of multidisciplinary members with appropriate technical and behavioral profiles, trained in collaborative decision-making, risk analysis, and feasibility studies. Projects that adopted this structure demonstrated greater success than those that did not, as evidenced by surveys conducted by the Department of US party.

Therefore, team training, when structured based on diagnosis, active participation, and alignment with project objectives, not only increases the success rate of projects but also contributes to the consolidation of a culture of continuous improvement and organizational innovation.

2.3 Practical team training

In the process of implementing risk management in projects, the use of the Risk Matrix
The Risk Matrix (Ability and Impact) is a method widely recommended by the PMBOK Guide (PMI, 2021). This matrix allows you to classify risks based on their likelihood of occurrence and potential impact on the project, facilitating the prioritization of mitigating actions.

According to Soares, Catapan, and Meza (2019), this analytical tool is structured along two dimensions: probability and impact. These dimensions allow for the calculation and visualization of risk classification, which is based on the assessment of impact relative to probability. They also state that its importance lies in its ability to provide a structured and clear view of a project's risks, facilitating decision-making and strategic resource allocation.

The advantage of the Probability and Impact Matrix lies in its simplicity and effectiveness. It is an easy-to-understand tool that provides clear and accurate information, which contributes to team engagement in the risk management process (KERZNER, 2017). Furthermore, this approach can be combined with agile methodologies, allowing for continuous adjustments throughout the project (SCHWABER; SUTHERLAND, 2020).

If applied correctly, this method can significantly reduce critical project risks.
According to Kerzner (2017), organizations that adopt a structured risk management model experience an average 30% increase in project success rates. However, some limitations can be observed, such as subjectivity in risk assessment and team resistance to implementing processes.
additional.

Thus, subjectivity can result in inconsistent assessments, where different team members have varying perceptions of the probability and impact of risks (SILVA, 2017). Personal judgments and biases compromise the objectivity of the analysis, leading to the underestimation or overestimation of certain risks, which affects decision-making.

Furthermore, team resistance can cause delays in implementing the risk matrix, jeopardizing the project schedule. Furthermore, it can result in poor-quality execution of additional processes, where team members fail to follow guidelines correctly or sabotage progress (SOU-ZA, 2010).

Therefore, to mitigate these problems, it is essential to promote a culture of transparency and objectivity in risk assessment. In addition, the team should be involved from the beginning of the implementation process, ensuring that everyone understands the new processes and is aligned with the project objectives (SIL-VA, 2017).

Kerzner emphasizes that systematic use of this matrix promotes project improvements by enabling decisions based on structured data, reducing exposure to critical risks, and guiding preventative planning. A notable application is found in the Boeing case study, presented in Chapter 17 of his book Project Management: A Systems Approach to Planning, Scheduling, and Controlling (2017).

In the context of aircraft development, with cycles that can extend up to 10 years and investments exceeding US$5 billion, Boeing uses a risk management matrix integrated with a continuous assessment approach. In Table 17–8 of the aforementioned book, Kerzner presents the types of risks the company faces (financial, market, technical, and production) and the respective mitigation strategies, all structured based on a matrix analysis framework.

Thus, as presented in this case, when dealing with technical risks, such as the introduction of

By leveraging new technologies in customized projects, the company combines the use of proven technology, parallel processes for improvement and new product development, and a robust change management process. This latter process is directly linked to the risk matrix, highlighting the interdependence between risks and changes, since a technical change can introduce new risks that need to be reassessed. linked based on the matrix.

Furthermore, Kerzner highlights that Boeing adopts an integrated approach between risk management and change management. The impact of this integration becomes clear when comparing the effects of managed and unmanaged changes. According to the author, uncontrolled changes increase risk management costs, transforming the process into crisis management. On the other hand, well-planned changes integrated into the risk matrix allow for the development of more economical and effective response plans.

Therefore, the application of the probability and impact matrix goes beyond simple risk categorization, becoming a strategic instrument for continuous improvement and organizational maturity in project management, as demonstrated by Boeing's practical experience.

In view of the above, to consolidate the proposal for implementing the Probability and Impact Matrix, The SWOT Analysis framework was used in this study, which provides a systematic assessment of the internal and external aspects that influence the success of the initiative.

According to Oliveira (2019), SWOT helps identify organizational capabilities (strengths), limitations (weaknesses), favorable trends (opportunities), and external challenges (threats), creating a comprehensive picture for decision-making. Therefore, this analysis is very useful in risk management, as it allows mitigation strategies to be aligned with the specific characteristics of the project and its environment. Therefore, SWOT not only strengthens proactive risk management but also contributes to the project's long-term sustainability and competitiveness.

Table 1 – SWOT analysis applied to project risk management

	FATORES POSITIVOS Auxiliam o Ambiente Estratégico	FATORES NEGATIVOS Atrapalham o Ambiente Estratégico
AMBIENTE INTERNO (Características do Projeto)	• Proatividade: Identifica e resolve problemas antes que se tornem críticos; • Tomada de decisão: Baseia-se em dados e análises para reduzir incertezas; • Alinhamento com objetivos: Garante que os riscos não desviem o projeto de suas metas; • Melhoria contínua: Aprendizado com riscos passados para projetos futuros.	• Complexidade: Pode ser difícil implementar em projetos pequenos ou de curto prazo; • Dependência de dados: Requer informações precisas e atualizadas para ser eficaz; • Resistência da equipe: Falta de engajamento ou compreensão sobre a importância do gerenciamento de riscos.
AMBIENTE EXTERNO (Características do Mercado)	• Inovação tecnológica: Uso de ferramentas digitais (IA, big data) para prever e gerenciar riscos; • Cultura organizacional: Promover uma cultura de gestão de riscos em toda a empresa; • Melhoria na comunicação: Aumentar a transparência e a colaboração entre equipes; • Expansão de mercado: Projetos mais seguros e bem-sucedidos podem atrair mais clientes.	• Mudanças externas: Fatores como crises econômicas ou mudanças regulatórias; • Falta de priorização: Outras áreas do projeto podem receber mais atenção, negligenciando os riscos; • Falha na execução: Planos de resposta mal implementados podem agravar os riscos; • Incertezas imprevisíveis: Riscos desconhecidos ou difíceis de antecipar.

Source: prepared by the author (2025).

Project risk management is strongly influenced by internal and external factors that make up the strategic environment. Table 1 presents a summary of these factors, organized according to their nature (positive or negative) and origin (internal or external).

According to Table 1, in the internal environment, positive factors such as proactivity, data-driven decision-making, alignment with project objectives, and continuous improvement stand out. These elements reflect a mature organizational culture capable of anticipating risks and responding in a structured manner. Conversely, application complexity, dependence on reliable data, and team resistance are identified as internal barriers that can compromise management effectiveness.
of risks.

In the external environment, the table shows that technological innovation, an organizational culture focused on risk management, improved communication, and market expansion contribute to a more favorable scenario for the implementation of robust management practices. However, factors such as unpredictable external changes, low prioritization of risk management, failures in the execution of response plans, and unanticipated uncertainties pose significant threats to project stability.

Therefore, the integrated analysis of these elements, as systematized in Table 1, allows for a more strategic and responsive approach to risk management, especially in complex and dynamic organizational contexts.

3. MATERIAL AND METHOD

The research was developed using a qualitative approach, through a bibliographic review of scientific articles, technical standards, and case studies related to risk management. The collected data were analyzed in light of the adopted theoretical framework, focusing on identifying patterns and good practices.
practices.

To ensure the relevance, analytical depth, and feasibility of the research, the research question and analysis objectives were clearly defined, ensuring that the selected case studies were aligned with the phenomenon under investigation. The relevance of the cases was considered based on their context and their potential contribution to advancing knowledge in the field. Therefore, the cases were selected from digital materials published by the PMI (Project Management Institute) (2021), ensuring alignment with recognized best practices in risk management.

Furthermore, the availability and accessibility of reliable case study data were also assessed, enabling transparent and informed analysis. The diversity, representativeness of the cases, and the complexity and challenges faced by each case were taken into account to broaden the applicability of the results. Finally, practical aspects such as available time and resources were considered, as well as specific criteria such as uniqueness and comparability of results, always based on the literature review that informed the selection.

The information gathered indicates that the main failures in the management of industrial projects include: (1) the lack of integration of risk management processes in the initial planning; (2) the underestimation of deadlines and costs; and (3) ineffective communication between stakeholders.

3.1 CASE STUDIES

3.1.1 Analysis of the Impact of Risk Management on Project Success: A Case Study in a Software Development Organization.

According to the risk management analysis in this case study, prepared by the author Fabiana da Silva (2013), it was possible to identify significant improvements in the success of projects within the organization studied. Based on the evaluation of fifteen software development projects, it was observed

that those who adopted structured risk management practices had a higher success rate.

Thus, among the main positive factors identified are the improvement in project predictability, the mitigation of problems before they become critical and the increase in the quality of deliveries. Furthermore, the use of an organizational risk repository, combined with the training of project managers, allowed for a more proactive approach in identifying and mitigating risks throughout the project life cycle.

Furthermore, a strong correlation was observed between effective risk management and meeting success criteria, which included on-time and on-budget delivery, as well as customer satisfaction. Of the projects analyzed, 93% showed a relationship between good risk management and project success, reinforcing the importance of systematically implementing this process. In fact, among the improvements suggested to further optimize risk management, the inclusion of risk analysis in management monitoring meetings and the continuous review of quality checklists to ensure that risks are being adequately monitored stand out.

3.1.2 Risk Management in Engineering Projects: A Case Study of the Panama Canal Expansion Project.

In their case study of the Panama Canal expansion, authors Jeong, Crittenden, and Xu (2009) demonstrate a striking example of how risk management can be successfully applied to large-scale, highly complex engineering projects. The project, which involved the construction of new locks and the expansion of the existing canal, faced a number of challenges, including geotechnical, environmental, and logistical risks.

According to the analysis presented, the early identification of these risks, carried out through a systematic and multidisciplinary approach, allowed the implementation of proactive mitigation strategies. For example, to address geotechnical risks, detailed soil studies were conducted and stabilization techniques were adopted, while environmental risks were mitigated through sustainable practices and monitoring.
continuous.

Furthermore, quantitative risk analysis using Monte Carlo simulations provided an accurate estimate of potential impacts on schedule and budget, enabling efficient resource allocation and the creation of an adequate contingency reserve.

The project results demonstrate the effectiveness of this approach. Despite the complexity and challenges faced, the project was completed on time and within budget, with only a 2% additional cost due to unforeseen events. Proactive risk management not only minimized negative impacts but also ensured the continuity of canal operations during construction. This case reinforces the importance of implementing robust planning, a dedicated risk management team, and the integration of advanced analytical tools for the success of complex engineering projects.
Furthermore, it highlights the need for a holistic approach that considers not only the technical aspects, but also environmental and social ones.

3.1.3 Case Study of the High-Speed Rail Project in California

The case study of the California high-speed rail project identified several challenges and risk management strategies in a multi-stakeholder environment with stringent regulations. The project, which aimed to connect the state's major cities through a

high-speed rail network, faced a series of risks, including technical, financial, political and environmental.

In this case, the approach adopted by CHSRA (California High-Speed Rail Authority) (2023) included categorizing identified risks and conducting qualitative and quantitative analyses to prioritize actions. For example, technical risks were mitigated through partnerships with specialized suppliers and the adoption of innovative technologies, while political and regulatory risks were managed through ongoing dialogue with authorities and local communities.

Thus, the implementation of an integrated risk monitoring system allowed agile responses to changes in scope and delays in the supply of materials, ensuring project continuity (CALIFORNIA HIGH-SPEED RAIL AUTHORITY, 2023).

Therefore, despite the challenges, the project managed to mitigate significant impacts, such as a 15% cost increase and six-month delays, through proactive management and a contingency reserve. Analysis of the results reveals that flexibility and adaptability were fundamental to the project's success. The ability to adjust mitigation strategies in response to new risks and changes in the external environment was crucial to keeping the project on track. This case demonstrates a dynamic and integrated approach to risk management, especially in long-term infrastructure projects with high socioeconomic impact. Furthermore, it highlights the need for effective communication among all stakeholders and the importance of considering political and social aspects in project planning and execution.

4. RESULTS AND DISCUSSION

When comparing the PMBOK and ISO 31000 approaches, we can see that both emphasize proactive risk management, albeit with distinct nuances. The PMBOK (2021) structures risk management into specific project lifecycle processes, such as identification, analysis, response, and monitoring. On the other hand, ISO 31000:2018 adopts a holistic perspective, integrating risk management into organizational culture and business strategy. While the PMBOK highlights practical tools, such as the probability and impact matrix, ISO 31000 reinforces principles such as continuous improvement and adaptation to the context.
The convergence between the frameworks lies in the importance of effective communication with stakeholders and team training, critical elements that were confirmed by the results of this research.

The data analyzed demonstrate that projects that implement risk management from the planning stage tend to have greater control over schedules and costs. An example of this is the expansion of the Panama Canal, which recorded only 2% additional costs due to unforeseen events. The reviewed literature also highlights that team training is a determining factor for proactive and effective risk identification. Furthermore, the probability and impact matrix proved to be an efficient analytical tool for risk prioritization, corroborating the theoretical foundations adopted in this study.

FINAL CONSIDERATIONS

The research answered the central question of effective risk management implementation, demonstrating the effectiveness of specific tools and highlighting the importance of systemic approaches that integrate methodology and professional qualifications. Confirmation of the hypothesis reinforced that the matrix aids decision-making and that the integration of methodologies and training enhances the results obtained.

However, limitations were identified, such as the difficulty of measuring the impact in isolation of each component and the need for further studies on the application of the matrix in different contexts. Furthermore, challenges such as cultural resistance, underestimation of risks, and lack of resources still hinder the full implementation of these practices.

Therefore, we recommend future research focused on specific risk analysis tools, as well as comparative studies between methodologies, to broaden our understanding of the effectiveness of risk management in projects. We also suggest investigating the application of these methodologies in small and medium-sized companies, as well as their integration with agile and digital approaches.

As a guideline for further studies, the practical application of an operational model is recommended. rationale of the Probability and Impact Matrix, with clear implementation steps and evaluation metrics.
This approach would allow us to demonstrate, in real contexts, how the matrix can be adapted to different types of projects, validating in practice its effectiveness in prioritizing risks and allocating resources.

REFERENCES

ABDOLMOHAMADI, Mohammad J. The Role of Risk Management in Construction Projects. **Journal of Construction Engineering, vol. 9, no. 4, p. 221–229,** 2014.

ALEXOPOULOS, George et al. Risk perception in project decision-making. **International Journal of Project Management,** v. 27, no. 2, p. 97–104, 2009.

ANTÓNIO MIGUEL, Rodrigues. **Risk Management in Engineering and Construction Projects.** Lisbon: LNEC, 2013.

BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. **ABNT NBR ISO 31000:2018 –** Risk management – Guidelines. Rio de Janeiro: ABNT, 2018.

CALIFORNIA HIGH-SPEED RAIL AUTHORITY. **Project Updates and Risk Management Reports.** 2023. Available at: https://hsr.ca.gov. Accessed on: June 6, 2025.

CARVALHO, Marly Monteiro de; RABECHINI JR., Roque. **Fundamentals of Project Management:** Building Skills for Project Management. 5th ed. São Paulo: Atlas, 2018.

COOKE-DAVIES, Terry. The “real” success factors on projects. **International Journal of Project Management,** v. 20, no. 3, p. 185–190, 2002.

DINSMORE, Paul C.; CAVALIERI, Adilson. **Project Management:** How to Turn Ideas into Results. 3rd ed. Rio de Janeiro: Qualitymark, 2020.

GAEDICKE, Christian; MATSUDA, Yoko. **Diagnosis of risk management in construction companies. Engineering and Construction Journal, v. 4, n. 2, p. 123–139,** 2024.

HILLSON, David; SIMON, Peter. **Practical Project Risk Management: The ATOM Methodology. 3rd ed. Vienna, VA: Management Concepts,** 2020.

HWANG, Bon-Gang; ZHAO, Xianbo; TOH, Lionel P. **Risk management in small construction projects in Singapore: Status, barriers and impact. International Journal of Project Management, vol. 32, no. 1, p. 116–124,** 2014.

JEONG, Hyunju; CRITTENDEN, John C.; Xu, Ming. **Risk management in engineering projects: a case**

Study of the Panama Canal expansion project. Georgia Institute of Technology, 2009. Available at: https://research.gatech.edu/sites/default/files/inline-files/panamnacanalcasestudy_hyunju.pdf. Accessed: June 6, 2025.

KAPLINSKI, Olgierd. Risk management in construction contracts. **Technological and Economic Development of Economy, v. 19, no. 2, p. 297–310,** 2013.

KERZNER, Harold. **Project Management:** A Systems Approach to Planning, Scheduling, and Controlling. 12. ed. Hoboken: John Wiley & Sons, 2017.

MAXIMIANO, Antonio Cesar Amaru. **Project Management: How to Transform Ideas into Results. 8th ed. São Paulo: Atlas,** 2016.

OLIVEIRA, Marcos Antônio. **SWOT analysis as a tool to support risk management in projects. Strategic Management Journal, v. 12, n. 3, p. 45–59,** 2019.

PECKIENE, Asta; KOMAROVSKA, Agne; USTINOVICIUS, Leonas. **Decision-making model for sustainable-able project management based on risk assessment. Procedia Engineering, vol. 57, p. 395–401,** 2013.

PROJECT MANAGEMENT INSTITUTE. **A Guide to the Project Management Body of Knowledge** (PMBOK® Guide). 7th ed. Newtown Square, PA: PMI, 2021.

SCHWABER, Ken; SUTHERLAND, Jeff. **The Scrum Guide:** The Definitive Guide to Scrum: The Rules of the Game. 2020. Available at: https://scrumguides.org. Accessed on: June 6, 2025.

SILVA, Fabiana da. Analysis of the impact of risk management on project success: a case study in a software development organization. **Journal of Management in Technology and Information Systems,** v. 2, n. 1, p. 55–72, 2013.

SILVA, José Roberto da. **Subjectivity in risk assessment in projects. Brazilian Journal of Engineering,** v. 25, n. 3, p. 114–123, 2017.

SOARES, Rodrigo; CATAPAN, Arnaldo; MEZA, Humberto. Evaluation of the Probability and Impact Matrix in risk management in engineering projects. **Engineering and Management Journal,** v. 21, n. 2, p. 145–160, 2019.

SOUZA, Fernando. Organizational barriers to risk management. **Administration in Debate Journal,** v. 8, n. 2, p. 27–35, 2010.

VARGAS, Ricardo Viana. **Project Management:** Establishing Competitive Advantages. 9th ed. Rio de Janeiro: Brasport, 2019.