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Mitigating Technical Risks in School Construction Projects through a Risk Notification and Impact Estimation System

Valeria Del Castillo[1], Giuliana Barraza[2]
[1]Universidad Peruana de Ciencias Aplicadas
Av. Alonso de Molina 1611, Santiago de Surco, Lima, Peru
u201913981@upc.edu.pe; pcargbar@upc.edu.pe

Abstract **-** The construction of schools faces technical risks that, if not managed properly, can generate delays and cost overruns, negatively impacting beneficiary communities. Previous studies highlight that early and proactive management of these risks, combined with appropriate strategies, can improve project efficiency and results. However, the lack of systematic approaches and advanced tools remains a major obstacle. In this context, this article proposes a potential risk notification system based on the principles of the Project Management Body of Knowledge (PMBOK) Guide and the latest version of the New Engineering Contract (NEC4) to facilitate the early identification of said risks, the qualitative and quantitative evaluation of their impact, and better communication and collaboration between those involved in the project. The contribution of the system lies in its ability to structure technical risk management in a precise and collaborative manner to mitigate its possible impacts on project deadlines and costs.

Keywords**:** risk management, delays, cost overruns, school construction, civil engineering

1. Introduction

Worldwide, the construction of educational infrastructure is crucial to improve access to education and the socioeconomic development of the population. However, in several developing countries such as Peru, the execution of these projects faces significant challenges that translate into delays and cost overruns. The materialization of unidentified or poorly managed risks negatively impacts the planning and execution of projects, since, if not managed properly, these risks can generate additional costs, failure to meet deadlines and even affect the quality of the infrastructure, impacting the well-being and satisfaction of the community that is intended to benefit. According to Wylie et al [1], technical risks are one of the main causes of delays in the execution of construction projects and, therefore, require special attention. These risks can range from structural design failures to geotechnical unforeseen events. Therefore, Bhardwaj [2] points out that addressing them early and effectively allows mitigating their impact and contributing to a more efficient execution, guaranteeing compliance with the planned budget and schedule.

Numerous previous studies have shown that early risk identification and mitigation are key to significantly reducing potential delays or cost overruns during the execution of construction projects. Wylie et al [1] indicate that the lack of a systematic approach to risk management contributes to the increase of adverse events that can affect the progress of projects. Furthermore, research conducted by Doe [3] where the impact of proactive risk management in educational infrastructure projects was analyzed, concluded that implementing adequate strategies can reduce the occurrence of setbacks, which translates into better results in terms of cost and time.

Brown and Eisenhasrt [4] identified several critical success factors in project management, highlighting the importance of effective communication and active participation of all stakeholders involved in the process. This collaborative approach not only helps to identify risks at early stages but also fosters an organizational culture that values transparency and information sharing. Similarly, other studies [5] on risk management in construction projects emphasized the importance of integrating qualitative and quantitative approaches in risk assessment. This dual approach allows for prioritizing more effective response actions, ensuring that resources are directed to the risks that have the greatest potential impact on the project.

Additionally, research by Lee et al. [6] on the implementation of predictive monitoring technologies in infrastructure projects identified that the use of digital platforms and notification tools allows project managers to anticipate critical events. This anticipation significantly reduces the risks associated with technical issues that may arise during the project lifecycle.

This research suggests that the use of technology and advanced risk notification methods not only improves the accuracy in detecting potential problems but also facilitates a more agile and coordinated response among project stakeholders.

This paper proposes a potential risk notification system specifically designed for school construction projects. Based on the principles of the Project Management Body of Knowledge (PMBOK) Guide and the latest version of the New Engineering Contract (NEC4) procurement framework, this system establishes a structured sequence for the identification, assessment and control of technical risks in school construction projects. The assessment includes both a qualitative and quantitative analysis of the impact of the most common risks identified in previous projects to prioritize risks and allow project managers to allocate resources efficiently and effectively. Likewise, control is managed through continuous monitoring and the application of response strategies adapted to each risk. Finally, a notification system is incorporated for any new risks that may arise during the execution of the project.

The proposal seeks to facilitate the early identification of technical risks in school construction projects, allowing project teams to not only anticipate problems, but also to proactively respond to them. In addition, the system combines knowledge from PMBOK and NEC4, promoting collaborative and accurate risk management. The use of technological tools for risk notification is also contemplated, which improves accessibility and immediacy in the communication of potential risks among all project stakeholders to mitigate their possible impacts on the project's timeline and cost.

2. Tools and Methodology

For the design of the notification system for potential technical risks, advanced macros were created in Microsoft Excel to automate processes. The structure of the proposal was developed considering the management framework of the NEC4 standardized contract family and the Project Management Institute standards defined in the PMBOK guide. In addition, technical risks were collected from 5 public school construction projects in Peru. With this information, a list of 8 columns was created in a first Excel sheet named “LIST”. The columns were named as follows:

- ID: unique code that identifies each risk.
- Type: According to the PMBOK guide, risks can be considered opportunities or threats.
- Category: According to the PMBOK Guide, risks can be classified as technical, management, commercial and external.
- Risk: Title of the risk.
- Description: Additional or more detailed information about the risk.
- Causes: Possible identified causes of the risk such as customer requests, design errors, supplier delays, etc.
- Consequences: Possible consequences if the risk materializes, such as delays in activities, additional costs, etc.
- Add: Drop-down list with 2 options (YES and NO).

On the other hand, in the same sheet, an interface was designed so that, depending on the particular characteristics of the project, the user can search and select the risks that he considers relevant. The user can search by ID, type, category and/or keyword. In addition, he must select “YES” in the “Add” column of all the risks that he wants to consider to generate the initial risk management matrix.

Once the risks have been selected, users can generate the risk management matrix by pressing the “Create Matrix” button. This button allows all the information of the selected risks to be automatically transferred to a new sheet named “MATRIX”. In this sheet, the selected risks are presented and the following columns are enabled for each one:

- Probability: This column allows the user to select the probability of occurrence of the risk (Very low, Low, Moderate, High, Very high).
- Qualitative Impact: This column allows the user to select the qualitative impact of the risk (Very Low, Low, Moderate, High, Very High).
- Priority: This column automatically defines the priority level of the risk depending on the selected probability and impact, according to the probability and impact matrix based on the PMBOK guide.
- Quantitative Impact (Cost): This column automatically defines an estimate of the quantitative impact of the risk in terms of cost. For this purpose, the percentages with respect to the total project budget used in the projects mentioned above were considered.

• Quantitative Impact (Timeframe): This column automatically defines an estimate of the quantitative impact of the risk in terms of timeframe (weeks). For this purpose, the percentages relative to the total project duration used in the projects mentioned above were considered.

• Strategy: Allows you to choose the most appropriate response strategy: Escalate, Avoid, Transfer, Mitigate or Accept (for threats), Exploit, Share or Enhance (for opportunities).

• Actions: This column allows the user to add the actions to be taken in more detail.

• Responsible: This column contains the name and/or position of the person who will be in charge of managing the risk.

• Notes/Updates: This column allows the user to add comments about actions taken, updates, etc.

• Status: In this column the user can define the status of the risk (active or inactive), which allows the user to monitor risks in real time.

As a sign of commitment to collaboration between the parties, Medina [8] indicates that NEC includes an "early warning" regulation that indicates that any of the parties that identifies a problem that may affect the project must notify the other. In order that both parties can work together to determine how to avoid or mitigate the identified risk. Based on this provision, a format was designed for the notification of those risks that may arise during the execution of the project so that, in turn, they can be automatically added to the previously generated matrix. This format was called "Potential Risk Notification (PRN)" and consists of the following parts:

• Organization details: Name and address of the organization to which the applicant belongs.

• Applicant's details: Name, surname, position and contact information (telephone number and email) of the person who identifies the risk, completes the form and sends it.

• Recipient details: Name, surname and position of the person receiving the notification.

• Risk data: Title, type, category, description, causes, consequences and proposed actions.

Once the PRN form is completed, the applicant can convert it into a PDF file by pressing the “Create PDF” button and save it in the folder of their choice. They can also add the new risk to the existing matrix by pressing the “Add Risk” button. This allows the newly recorded risk information to be transferred to the previously generated matrix, thus keeping it up to date throughout the project. Whenever new risks are identified, they can be recorded in the same way.

On the other hand, to send the PDF file of the generated PRN, the Click Up project management program was used. This program allows work teams to be formed and tasks to be assigned to their members. Using this function, the applicant can send the NRP to inform the other party of the identified risk and, if necessary, request a meeting to coordinate actions and designate those responsible. To do this, the applicant must create the task by attaching the PDF file, assign the recipient and define a date as the maximum response deadline. Once created, the recipient will be automatically notified.

Click Up also allows for detailed monitoring of task progress, offering the option to view its status in real time. This includes whether the recipient has reviewed the document, left comments or proposed changes. Thus, both the applicant and the recipient can exchange information in an organized and transparent manner, minimizing the possibility of misunderstandings. In addition, one of the advantages of this program is that reminders can be set to alert the team when a task is approaching its deadline or if no responses have been received. This ensures that action is taken in the established times, facilitating risk management and quick decision-making. Additionally, the platform offers the option to generate activity and statistics reports, allowing the applicant to keep track of the actions taken and document communications and interventions related to the PRN. This becomes a valuable tool for audits and for the continuous improvement of risk management processes.

3. Results

Several authors claim that having the favourable opinion of at least eight out of ten experts would provide a reliable estimate of the validity of the tool [9]. Therefore, to validate the designed proposal, surveys were conducted with ten professionals with experience in public school construction projects under NEC4.

The results showed that 90% of experts consider that the system for reporting potential technical risks would be useful for their management during the execution of school construction projects.

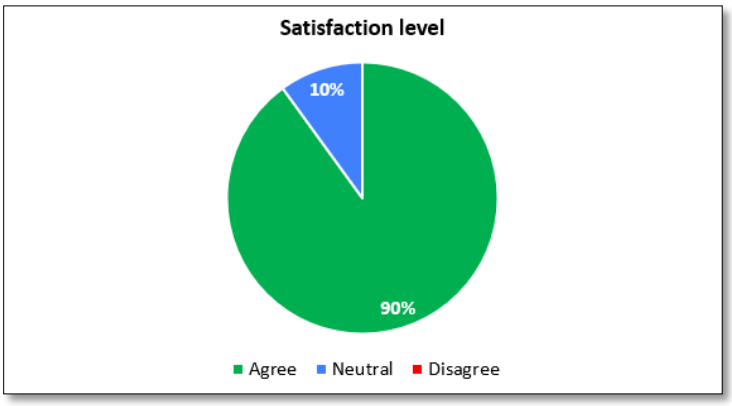

Fig. 1: Satisfaction level of experts regarding the matrix with notification of potential risks designed.

It was also found that 100% of the experts believe that the impact of technical risks on project time and cost could be significantly reduced if they were identified and managed through this system. 80% estimate that the impact on time as a percentage of the schedule would be low (less than 5%), while the other 20% estimate that the impact would be moderate (between 5% and 10%). None stated that the impact would be high (greater than 10%).

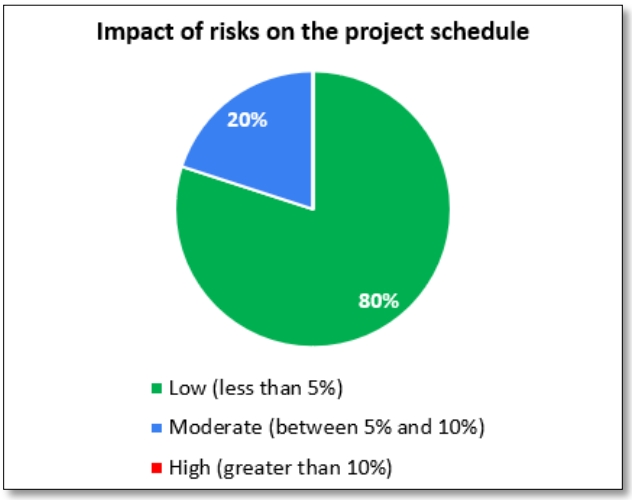

Fig. 2: Impact of technical risks as a percentage of the schedule when using the matrix with notification of potential risks designed.

On the other hand, 70% of the experts estimate that the impact on the cost as a percentage of the budget would be low (less than 5%), while the other 30% estimate that the impact would be moderate (between 5% and 10%). None of them stated that the impact would be high (greater than 10%).

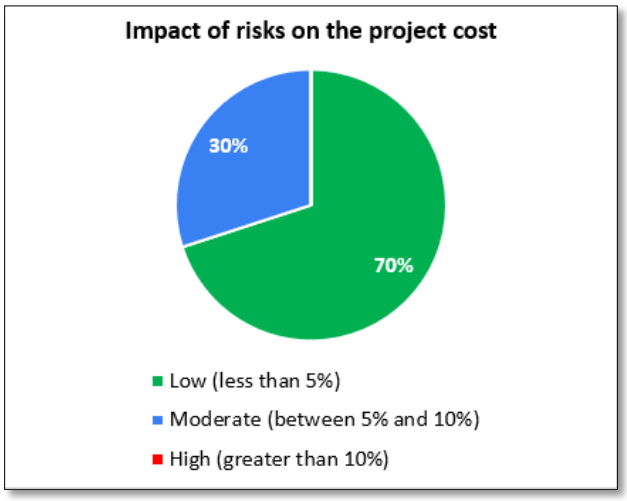

Fig. 3: Impact of technical risks as a percentage of the budget when using the matrix with notification of potential risks designed.

The positive opinion of experts on the subject offers an encouraging outlook for school construction projects, since, if this system is implemented, the impact of technical risks that may arise during the execution of the project could be mitigated, and thus, ensure compliance with the planned deadlines and costs.

4. Conclusion

This article demonstrates the effectiveness of a potential risk notification system in the management of school construction projects, especially in the context of public infrastructure projects in Peru. Through the implementation of a system based on PMBOK principles and the NEC4 procurement framework, the identification and mitigation of technical risks is facilitated, allowing for better resource management and a reduction of negative impacts on project timelines and costs. Four contributions are highlighted:

Efficiency in identifying and mitigating technical risks: The proposed system allows project teams to identify and manage technical risks early, which, according to the experts consulted, contributes to reducing cost overruns and delays. This finding is particularly relevant for the educational infrastructure construction sector, where resources and execution times are limited and often compromised.

Using technological tools to improve communication and risk monitoring: The article highlights the importance of using technologies for risk notification, which improves communication between the parties involved. The experts validated the functionality of the automatic notification system and highlighted its usefulness for real-time monitoring, which translates into a more agile and coordinated response to unforeseen events.

Positive impact on costs and execution schedules: According to the results obtained from the surveys of experts, the implementation of this system can significantly reduce the impact of technical risks on the cost and schedule of projects, with a majority indicating that the impact on the schedule would be low or moderate (less than 10%) and a similar effect on the budget. This result suggests that the proposed system is not only effective in mitigating the identified risks, but also in keeping the projects within the planned time and cost margins.

Contribution to knowledge in risk management in educational infrastructure: The methodology contributes to the scientific field by combining qualitative and quantitative approaches in risk assessment, a feature that improves the accuracy in prioritization and resource allocation. This dual approach, based on the integration of PMBOK and NEC4, provides a solid and adaptable framework that could be applied in future educational construction projects, providing a basis for further research.

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