RISK AND UNCERTAINTY IN ENGINEERING PROJECTS:

A SURVEY OF PROFESSIONALS

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Abstract: Engineering projects tend to present numerous uncertainties due to a lack of information or unreliable information, new technologies, project complexity or even unpredictable factors. These uncertainties can affect the project´s success. This paper aims to investigate the level of knowledge and adoption of risk management practices in engineering projects. Moreover, the paper aims to explore the perception of the influence of risk management on project success. The methodological approach was a survey-based study with a sample of 596 respondents. The results indicated that most professionals (61.6%) know of the PMBoK® and try to partially or totally apply it, followed by ISO 31000 (24.7%) and ICB/IPMA (13.6%). Considering the success dimensions, the most frequent consequences associated with risk were delayed schedule, increased cost, damaged client reputation, and decreased quality.

1 Introduction

The roles and contributions of risk management within organizations have evolved and grown over the years. Because of challenges that impact supply chains, assets, earnings and operations, more enterprises have recognized the importance and value of firm-wide risk management, and risk managers have both fueled and responded to rising expectations. Increased expectations generally bring new challenges. Since organizations are increasing their overall expectations of the risk management function, it is important to explicitly define a framework for measuring the performance of risk management [1].

According to [2], most projects deal with uncertainties, and many projects depend, to a certain extent, on unforeseen circumstances that are beyond the control of the owners, stakeholders, project managers, contractors and suppliers. Risk should be routinely considered from the very beginning in all aspects of the project, including its development (to update risks, incorporate new risks or eliminate those already identified), and the project should be oriented towards managed risks, but studies have shown that risk management practices are poorly adopted by project managers [3]. Although project management has expanded into engineering projects, many companies still do not value it and consider it only as a cost. Given this scenario, risk management deserves more space and attention in the context of project management, and this is due, among other factors, to its impact on the overall results. The success of a project, when considering time, cost and quality, largely depends on how management addresses the risks involved [4].

According to [5], many projects have been delayed or have exceeded their budgets because project managers cannot effectively manage risk. Currently, projects are considerably more exposed to risks and uncertainties due to factors such as complexity in planning and design as well as the number of stakeholders.

Engineering project organizations face a very dynamic business environment; therefore, establishing an appropriate risk management system is of crucial importance. However, due to the lack of practices in this field, it is still necessary to explore this important knowledge area to achieve better results in projects [1].

Due to the importance of risk management in engineering projects, this research aims at investigating the level of knowledge and adoption of risk management practices by exploring the following research questions: (RQ1) Which are the main frameworks and guidelines applied in engineering projects? (RQ2) Are project managers and team members proficient in risk management methods, tools and practices? (RQ3) What are the perceptions of the influence risk management on project success? The survey focused on practices and results related to risk management in engineering projects and their impact on various project success dimensions. The main findings aim to identify the risk management approach in the professional environment in different countries and industries. The data analysis will be evaluated to identify possible gaps and contribute to project management practices as well as to academic knowledge. Therefore, a questionnaire was developed to examine the major environmental features of engineering projects companies.

The paper is structured as follows: Section 2 provides a literature review of the main theme concepts. Section 3 describes the exploratory study composed of the survey method. Section 4 presents the results and discussion. Section 5 concludes the paper.

2 Literature Review

2.1 Risks in Engineering Projects

In project management, uncertainties can affect the necessary information during decision making. From the beginning of a project, it is necessary to obtain relevant and necessary information for its development. However, not all the information required is provided, and often, much of the information received contains missing documentation, creating uncertainty. Considering that uncertainty and risk are inevitable in such projects, they should be managed, minimized, accepted, shared and transferred but should not be ignored [6]. The most common interpretation of uncertainty in the extant literature on projects is the risk and/or uncertainty caused by unreliable information or a lack thereof [3, 7, 8]; novel, immature or unproven technology [9]; project complexity [10–13] and other unpredictable factors. In projects, these risks are overcome by proactively employing project managers' and team members' combined knowledge and judgment based on experience and creativity, e.g., [14–16].

Despite the extensive research conducted in this field, there is a gap concerning the analysis and identification of risks in practice from the earliest phases of projects [17, 18].

Regarding risk identification, many techniques require deep knowledge of previous projects and rely on retrospective analysis by subject matter experts. The development of more predictive risk identification techniques could provide tremendous insight to project managers, particularly if likely risks can be identified in early design phases [19].

A case study developed by [20] in three Brazilian construction companies identified that national companies do not have formal procedures for risk management. The authors attributed the inexistence of these practices to the size, limited resources and less formal culture of the companies. Reducing uncertainty means greater project maturity and a higher level of information available for its implementation as well as the enhancement of the project manager's ability to make decisions and anticipate a series of typical problems in project development. Industrial projects are included in this scenario since most Brazilian companies that develop projects in this segment do not have adequate risk management in their processes.

2.2 Risk Management Methods

Risk management frameworks and processes need to reflect the characteristics of the project environment and organization. In dynamic and complex project deliveries, this requirement implies the well-organized use of collective knowledge and coordinated responses, which are often spread among several participant organizations [21].

Complexity and project diversity have led to varied communities of practice and bodies of knowledge and have been a challenge to reaching a common and workable understanding of project management best practices. The same problem has occurred in the project risk management field, where some popular guidelines exist for implementing risk management in engineering project domains [22].

Managing risks on construction projects is a process that includes a risk assessment and a mitigation strategy for those risks. A risk assessment includes both the identification of a potential risk and the evaluation of the potential impact of the risk. A risk mitigation plan is designed to eliminate or minimize the impact of the risk events—which are occurrences that have a negative impact on the project.

The guide to the project management body of knowledge (PMBoK®), the most widely distributed of the available knowledge guides [23], proposes project risk management that is in accordance with the following processes: a) plan risk management; b) identify the risks; c) conduct the qualitative risk analysis; d) carry out the quantitative risk analysis; e) plan the responses to the risks; f) monitor and control risks [24]. This guide is one of the most used technical developments for controlling risks [25], and it is widely used for training and underpins the development of competency standards [26]. The International Project Management Association (IPMA) is a more

accepted and recognized association in European countries, and it also developed a guide for best practices in project management that is similar to the PMBoK® and is called the IPMA Competence Baseline (ICB®). The latter has some peculiarities and allows each country to make necessary process adaptations and changes and provides flexibility to meet local standards. Introduced in 2009, the ISO 31000 standard is intended to help organizations manage diverse types of risk in a systematic and comprehensive manner by offering a universal framework 'to assist the organization to integrate risk management into its overall management system' [27]. The standard quite clearly defines the main responsibilities of organizations, including establishing a policy on risk management, communicating its beneficial effects to the various stakeholders, and ensuring that sufficient resources are in place [28].

Most project risk management research is presented from a very restrictive perspective considering a single-organizational project delivery team and covering limited risk perceptions and risk management approaches. Therefore, some traditional approaches based on risk management best practices deal with only two aspects of risk, probability and impact, considering the occurrence possibility of certain events and how the risks impact project objectives [21].

According to Carvalho and Rabechini Junior [18], there is a convergence in the literature with regard to these best practice processes, but there is growing interest in others that involve not only risk management but also uncertainties such as "context and the strategic approach to risks/uncertainties", "relationship with stakeholders" and "crisis management".

Moreover, [27] affirm that these guidelines generally consist of a list of so-called "best practices" in risk management, which is assumed to be captured from experience and lessons learned over time; however, the guidelines fail to include evidence to support the effectiveness of their prescriptions. It appears that, even though project managers might be aware that risk management practices exist, project managers fail to implement these practices. [3] argue that, despite a great number of risk management guidelines, little work exists to reveal what risk management is actually accomplished (or not accomplished) by project managers and why. The adoption of a risk management guideline is not as important as the actions risk managers take [28].

2.3 Risk Management and Project Success

Project success includes the classical success criteria, which are also called the iron triangle: budget, schedule, and quality adherence, as well as customer satisfaction with regard to all the projects in the portfolio [29]. Constantino et al. [30] argues that these factors are not always enough to consider a project successful. Well-defined objectives, the communication of a project's aims to team members and the approval of deliveries by a multiplicity of stakeholders are crucial. Another important and critical issue that must be considered is scope management as well as project managers' competence. A study developed by Rabechini Junior and Carvalho [31] shows that uncertainties and individual business knowledge have a significant impact on project success. In considering this scenario, the conceptual understanding of uncertainty and risk is important.

The critical success factors (CSFs) are the main factors that increase the ability of organizations to carry a project through to its full implementation. A continuous assessment of all the decisions made during the project life cycle that impact project risks and CSFs allows managers to set priorities and determine the actions that can drive the project towards success [30].

According to [32], the importance of managing risk in projects attests to the recognition and importance of requisite variables that affect business effectiveness at the operational and strategic levels. As a consequence, risk management is one of the most important tools a project manager has to increase the likelihood of success.

3 Research Method

Due to the nature of the research questions that drive this research, a survey-based approach was selected. According to [33], one of the main survey challenges is the difficulty of attracting individuals to complete the questionnaire and obtaining significant samples for the research. The author suggests that attention should be paid to certain issues when developing questionnaires, such as considering only questions related to the research proposal, writing clearly and accurately, allowing only one interpretation, and writing questions that do not lead the respondents to a particular response. Therefore, writing the questions requires attention to how survey constructs are conceptualized and how questions must be phrased to obtain information that respondents are willing and able to provide [34].

3.1 Sampling Process

The survey sampling process was carried out through a list of approximately 5,500 professionals from the LinkedIn® platform for engineering, construction and architecture and professional contacts from different countries. A pilot test was performed with a short list of Brazilian and international professionals as a facial test of the questionnaire in English and Portuguese. The intention was to ensure the understandability and interpretability of the questions and to make adjustments if necessary.

3.2 Data Collection and Analysis

In line with the conceptual basis derived from the literature review discussed in Section 2, the questions and the questionnaire were structured and established in a way that would draw out the necessary data from the respondents in a direct, clear and synthetic way. Based on the proposed aim, the questionnaire was developed in four main sections: introduction, participant context, professional education, and risk management knowledge and experience or perceptions regarding risk management (**Figure 1**). The survey was disseminated online through the SurveyMonkey® platform.

The descriptive statistics and the cross-tabulation analysis of the variables were performed using IBM SPSS software and Minitab.

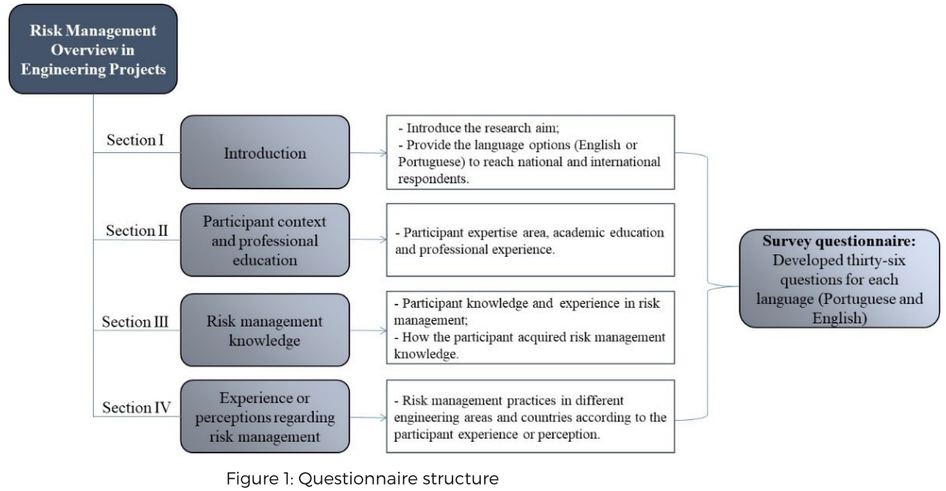


Figure 1: Questionnaire structure

4 Results and Discussion

4.1 Sample Demographics

The survey has 668 answers in total, and 72 responses were discarded due to incomplete answers. Hence, 596 valid answers were considered (**table 1**).

Parameters	Value
Total Questionnaires	668
Discarded Questionnaires	72
Validated Questionnaires	596

Table 1: Valid answers

Figure 2 shows the countries of origin of the professionals who responded to the questionnaire.

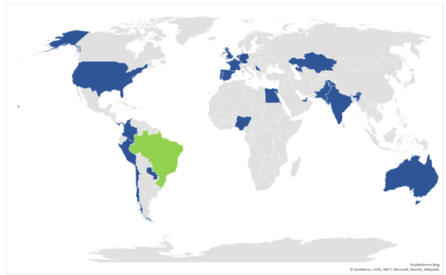


Figure 2: Countries of origin of the survey data

4.2 Participant Context and Professional Education

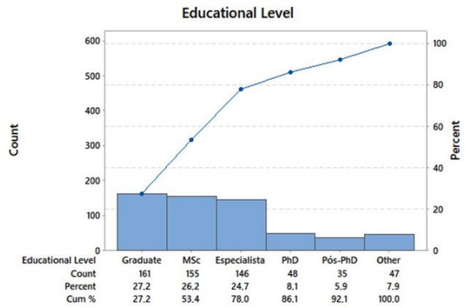
The relevant information regarding the participants' contexts and education levels is presented through an analysis of the data on their sex, education level and age.

Most of the professionals who responded to the questionnaire were female, representing 51.8% of the total (**Table 2**).

Sex	Female	Male
Count	305	284
Percentage	51.8	48.2
Cum (%)	51.8	100.0

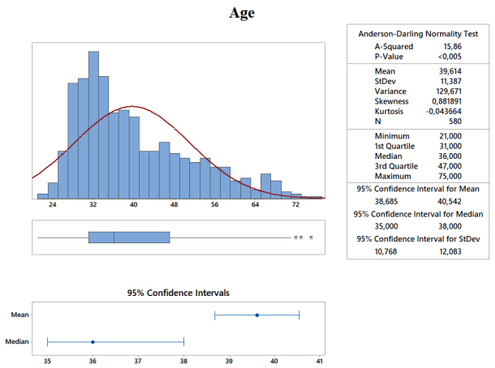
Table 2: Respondents' sex

Regarding the education level, **Graph 1** demonstrates that most of the respondents have a graduate level education, representing 27.2% of the total, followed by MSc professionals (26.2%) and specialists (24.7%). The number of PhD professionals represents 8.1% of the respondents.



Graph 1: Respondents' education level

Thus, we can assume that the professionals who participated in the survey are well qualified and have a good conceptual background since 64.9% of them have a post-graduate education.



Graph 2: Respondents age

Most of the respondents are between 30 and 34 years old, and the majority are 32 years old (**Graph 2**).

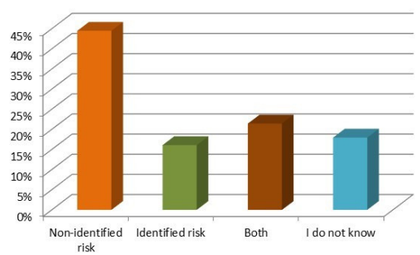
4.3 Knowledge, Experience or Perceptions Regarding Risk Management

In asking the respondents about their experience in risk management, 56.2% of the professionals answered that they had never worked with risk management, and 43.8% had experience being responsible for risk management or working with it in an indirect way (**Table 3**).

	Have never worked	Have experience
Count	329	256
Percentage	56.2	43.8
Cum (%)	56.2	100.0

Table 3: Distribution of answers to the question: have you ever worked with risk management?

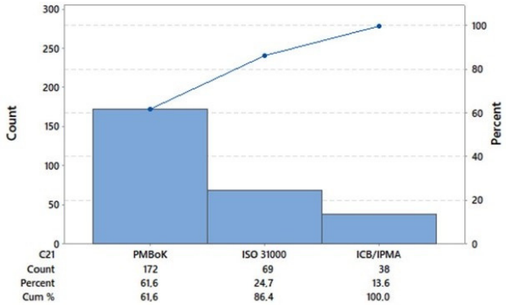
Regarding identified and nonidentified risks, the research showed that professionals have more difficulty facing nonidentified risk than identified risk, with 44.5% and 16.1%, respectively. Additionally, 21.4% of the respondents indicated that both are difficult to face, and 18% did not know which one they had more difficulty facing (**Graph 3**).



Graph 3: Distribution of answers to the following question: Over your career, have you had more difficulty facing identified risks or nonidentified risks?

Furthermore, there is an interesting finding regarding professionals' uncertainties in projects. The data indicated that professionals have experienced situations in which many risks were not previously identified, and they had more difficulty in dealing with nonidentified risks than identified risks. The data indicate the lack of information or knowledge regarding the result of an action or decision making in projects. These data confirm the importance of studies concerning how the professional environment addresses risk and uncertainty. Against this backdrop, dealing with uncertainty has an embracing and determinant significance for the project as a whole [35].

The professionals were about a good reference to a risk management method, and Graph 4 illustrated that most professionals (61.6%) recognized the PMBoK® as the best practice, followed by ISO 31000 (24.7%) and ICB/IPMA (13.6%).



Graph 4: Distribution of answers to the following question: What is a good reference for a risk management method?

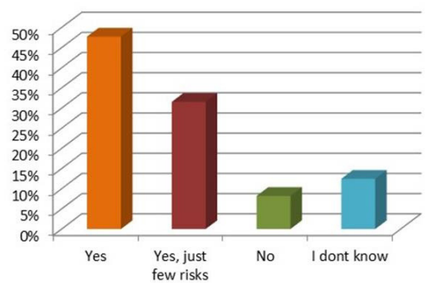
Most of the participants indicated that the PMBoK® guide is a good reference for a risk management method because, among other factors, it is widely known and available for study and consultation [36]. Even although it is a general guide, the research indicates that most engineering professionals recognize the PMBoK® as the best practice for risk management. Despite the professionals' knowledge

concerning guidelines for implementing risk management, most of them have never experienced risk management practices in engineering projects, even in an indirect way (contact with stakeholders or colleagues from their area that worked with risk management); that is, they are familiar with certain concepts and the literature, but in practice, the professionals do not apply risk management in their processes. Despite the knowledge of its importance, the effective implementation of risk management in organizations and projects is not common [37].
When asking the respondents about any situation in which disregarded or underestimated risks were responsible for unsatisfactory results in the project, the answers indicate that 48.4% of the professionals had experienced this problem, followed by 32.8% of the respondents who did not know if they had experienced this problem, and 18.8% of the professionals who never had this experience. It is observed that most of the professionals recognize that the risks generated by project management failures are very significant and, when underestimated or not considered, are the main factors negatively affecting the project results (Table 4).

	Yes	No	I do not know
Count	180	70	122
Percentage	48.4	18.8	32.8
Cum (%)	48.4	67.2	100.0

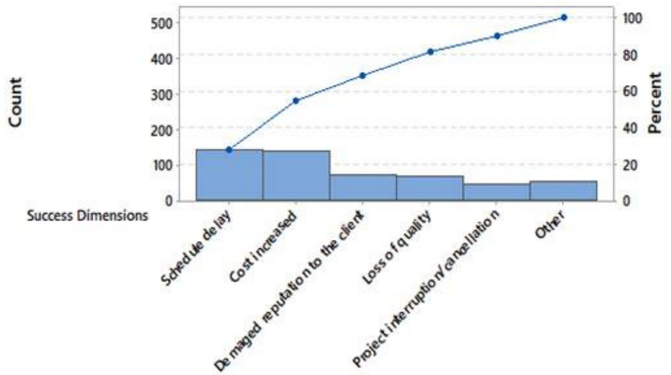
Table 4: Distribution of answers to the following question: based on your experience, was there any situation in which disregarded or underestimated risks were responsible for unsatisfactory results in the project?

Concerning situations in which risks were not previously identified, 47.7% of the answers demonstrated that the professionals had experienced such a situation, 31.6% indicated that they had experienced situations in which just a few risks had not been previously identified, 8.2% of the professionals stated that they had never been in this situation, and 12.5% did not know if they had previously experienced this (**Graph 5**).



Graph 5: Distribution of answers to the following question: Over your career, have you ever been in a situation in which many risks were not previously identified?

Considering situations in which disregarded or underestimated risks were responsible for unsatisfactory results in the project, the professionals indicated the main consequences of this phenomenon (**Table 5**).
Graph 6 illustrates that schedule delay and cost increase are the main consequences, with 28% and 27%, respectively. Damaged client reputation represents 14%, followed by reduced quality (13%), project interruption/cancellation (9%), social or environmental impact (6%) and scope change (4%).
The main consequences of situations in which disregarded or underestimated risks were responsible for unsatisfactory results in the project, as indicated by the professionals, suggest that the iron triangle (schedule, cost and quality) is still the most representative critical factor of project success.
Frequently, projects are viewed as isolated processes, without taking into consideration their environment. Therefore, important influencing factors producing uncertainty can be dismissed [35].



Graph 6: Distribution of answers to the following question: What were the main consequences of a situation in which disregarded or underestimated risks were responsible for unsatisfactory results in the project?

Project Success Dimension	%
Schedule delay	28%
Cost increased	27%
Damaged reputation to the client	14%
Loss of quality	13%
Project interruption/cancellation	9%
Social or environmental impact	6%
Scope change or reduction	3%

Table 5: Main consequences of situations in which disregarded or underestimated risks were responsible for unsatisfactory results in the project

5 Conclusions

This paper contributes to the literature in 3 ways by answering the three research questions posed. First, the study sought to identify the main risk management approach noted by the professionals involved in engineering projects, revealing the predominance of the PMBoK approach. Second, the study aimed to explore the level of professional knowledge and the application of risk management, showing a lack of risk management experience by professionals who still do not use it in practice in engineering. Third, the study demonstrates that most professionals perceive that poor risk management can lead to delayed schedules, increased costs, damaged client reputation, decreased quality and other negative impacts, leading to an unfavorable project performance. Additionally, professionals demonstrate that they have more difficulty facing nonidentified risks and uncertainties in projects, suggesting the need for further studies related to this theme to contribute to the effective practice of risk uncertainty management by engineering companies.
This research has limitations because the nonprobabilistic sampling process can generate some bias. In addition, the sample is composed predominantly of Brazilian professionals; therefore, the sample is unbalanced in relation to other countries.

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