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QUANTITATIVE RISK ANALYSIS IN MEGAPROJECTS SCHEDULES:

A CRITICAL COMPARISON BETWEEN THE THEORETICAL FINDINGS AND THE EMPIRICAL EVIDENCE FROM A BRAZILIAN OIL AND GAS COMPANY

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Abstract: Megaprojects are temporary endeavors that involve high investments and long-term results, a high degree of uncertainty and risks. The purpose of this article is to establish a critical comparative analysis of the quantitative risk analysis process in megaproject schedules. The methodology includes a study of the scientific literature and the empirical evidence obtained from interviews with specialists of an oil and gas segment company. A systematic survey of the scientific literature was carried out in ISI Web of Science, Scopus and Scielo databases. The primary data collection was carried out through interviews with a sample of 10 professionals with high level of seniority. As results, the evidences indicate that there is restricted scientific literature on the subject in peer-reviewed journals, which suggests an academic contribution of the present study. In addition, Monte Carlo simulation is the most frequent technique used in risk management of megaproject scheduling that provides precision to the probability of project completion date. Besides, it was observed an existence of subjectivities, such as the bias of experts, not judgment of the time estimates of activities, and gaps, such as an inconsistency of the logic of the schedules, no process of quantitative risk analysis. Finally, it was detected the need for training in risk management of hierarchical senior managers, as a way to contribute to the achievement of better results with the use of non-decision-making practice.

1. Introduction

As Papke-Shields et al. (2010) state, project management practices have been perceived as relevant by organizations as a way to improve the results of their projects. However, even though there is a lot of information available on project management, there is still no profusion of literature on the subject of megaprojects (MERROW, 2011; IRIMIA-DIÉGUEZ et al., 2014). Irimia-Diéguez et al. (2014) say that megaprojects involve investments above US $ 1 billion and present long-term results. In addition, they have a high degree of uncertainty and thus imply many risk factors that can cause delays during the project life cycle.

According to Merrow (2011), data from more than 300 megaprojects executed worldwide in 2010 in different application areas have indicated that 65% of projects with a budget of more than US $ 1 billion have failed to achieve their objectives. This study evidenced these objectives are impacted especially by execution schedules different from the planned ones.

If, on the one hand, there is the recognition that schedules are essential for the execution of planned activities in projects (LUU et al., 2009; HULETT, 2011); on the other hand, it is not uncommon for deadlines to be defined by decisions which do not necessarily reflect the criteria established in the technical and economic feasibility studies. For example, a company may propose an unrealistic schedule only for the purpose of winning a bid or satisfying a customer (HULETT, 2011). According to Hulett (2011), this fact can generate plans of low quality, low accuracy and even impracticable, due to excessive logic errors, large number of constraints, long lags between activities, and mainly because they do not consider the risks involved. In addition, it should be noted that most schedules are elaborated in a deterministic manner without considering the uncertainties inherent in all projects.

As a result, delays are common and cause considerable losses for the parties involved, which recommend to quantify the probabilities of delays in project management schedules (LUU et al., 2009; HULETT, 2011). A study by Papke-Shields et al. (2010) shows that schedule management practices are among the most used in the industry, along with those related to scope and cost management. According to these authors, the practices associated with communication, quality and risks are used less frequently.

Regarding risk management, Kvalnes (2016) argues that project planning models tend to consider project uncertainty as a threat to the success of its implementation and that studies have focused on finding ways to reduce this uncertainty. In fact, this uncertainty translates into so-called project risks that, when not effectively managed, can have negative impacts on all parties involved - project team, clients, companies, communities, the environment, and governing bodies (MERROW, 2011).

Irimia-Diéguez et al. (2014) attribute to risk management a high relevance for the success of projects, but also recognize that the area still remains one of the least developed in the research. Therefore, there is a low level of maturity and development in relation to methodologies that incorporate risk management, as well as the revelation of how risk analysis is still little used in the decision-making process by project managers. Papke-Shield et al. (2010) argue that the formal application of project management practices increases the chances of project success. This is the case of the quantitative risk analysis that allows a broad understanding of the potential risks, their possibilities of occurrence and their respective impacts on the project objectives. For these authors, this analysis enables the elaboration of a contingency plan appropriate to the reality and context of the project, allowing the project to be completed as close to plan as possible.

In order to identify and systematize the state of the art on risk analysis in megaprojects, the present study has the objective of, in theoretical terms, to carry out a review of the literature in international bases of journals and, in empirical terms, to identify and interview senior professionals of a brazilian energy company. Considering the partial results of these steps, the present study also aims to establish a comparison between the theoretical and empirical findings, in order to offer contributions for the densification of the theory and the improvement of the practices of risk analysis in megaprojects. From a practical point of view, the study highlights procedures used in megaprojects that reflect the culture and management context of the brazilian company, but which may support replication in similar cases.

2. RESEARCH METHODOLOGY

This study has a qualitative aspect. Items 2.1 and 2.2 highlight the protocols for systematic investigation of the literature and the procedures for conducting and analyzing the interviews.

2.1. Procedures for research fundamentals: systematic literature review

For Guedes and Borschiver (2005), processes of systematic survey of the literature are executed through routines that aim the mapping, treatment and management of information and knowledge available in information and communication systems, in scientific and technological environments. The systematic review of the literature adopted for the present study was carried out by consulting the periodicals available in the ISI Web of Science, Scopus and Scielo databases, accessed from 14 to 17/Feb/2017, which are considered as the most comprehensive and greater relevance for engineering field.

According to Higgins and Green (2011), the formulation of the review question should be the first step towards the application of systematic review techniques. In the case of the present study the question that guides the systematic review is: what are the main methodologies observed in the international literature related to risk management and schedules in megaprojects?

For the data collection of this study, the acronym PICO that is used in systematic surveys in the health sciences area (CRD, 2009), was employed to obtain the secondary data of the research. The question of revision inspires the identification of the keywords according to the acronym PICO, which enables the definition of search terms (PETTICREW and ROBERTS, 2006; HIGGINS and GREEN, 2011). **Table 01** consolidates the search terms adopted based on the acronym PICO.

Acronym		Relevance	Search Terms
P	Population	Definition of the search population to match the objectives aimed with the systematic review.	Megaprojects, large projects, complex projects, big projects, construction, industrial, energy, oil and gas, engineering
I	Intervention	Nature of the phenomenon to be observed. In the case of this study: risk management and megaproject schedules.	Risk management, risk analysis, schedule assessment, schedule evaluation
C	Comparison	Used in health sciences áreas for application of clinical protocols.	Not applicable
O	Outcome	Expected search results or outputs.	Methodologies, techniques, practices, templates, indicators, drivers, key performance indicators

Table 01: Guidelines and search terms based on acronym PICO

2.1.1. Searches in databases ISI Web of Science, Scopus and Scielo

In order to obtain the articles adhering to the purposes of the proposed research scope, primary refinements (by language, type of document and areas of knowledge) and secondary (by individual screening of works, by reading title, abstract and full document reading) were carried out. Considering that the search terms and the search language of the databases are different, the syntax adopted for the search corresponds to the standard used by the ISI Web of Science base, introducing the boolean connectors AND and OR for the construction of the search string (TS) for advanced search, as shown in **Table 02**.

P	(*Engineering* OR *construction* OR *industrial* OR *energy* OR "*oil and gas*") AND (*megaprojects* OR *large projects* OR *big projects* OR *complex projects*)
I	*Risk management* OR *risk analysis* OR *schedule assessment* OR *schedule evaluation*
O	*Methodologies* OR *practices* OR *techniques* OR *templates* OR *indicators* OR *drivers* OR *KPI* OR *key performance indicators*
TS	TS=*(((Engineering OR construction* OR *industrial* OR *energy* OR *"oil and gas")* AND *(megaprojects* OR *large projects* OR *big projects* OR *complex projects))* AND *(Risk management* OR *risk analysis* OR *schedule assessment* OR *schedule evaluation)* AND *(Methodologies* OR *practices* OR *techniques* OR *templates* OR *indicators* OR *drivers* OR *KPI* OR *key performance indicators))*

Table 02: Construction of the search string for advanced search in ISI Web of Science base

After the first search, 773 articles were found in the ISI Web of Science database. The refinement of the survey considered all the years available in the base and adopted the criteria established in **Table 03**.

Critérios de Busca	Description
Language	Portuguese
	English
Type of Document	Article
	Review
Areas of Knowledge	Engineering Civil
	Engineering Industrial
	Construction Building Technology
	Management
	Environmental Sciences
	Operations Research Management Science
	Energy Fuels
	Engineering Multidisciplinar
	Environmental Studies
	Engineering Mechanical
	Economics
	Business
	Transportation Science Technology
	Green Sustainable Science Technology
	Engineering Manufacturing
	Social Sciences Interdisciplinary
	Engineering Petroleum

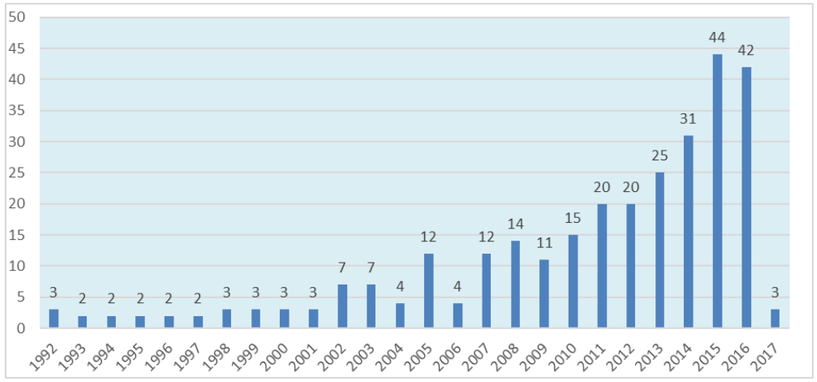
Source: ISI Web of Science base

Table 03: Criteria of search refinement

After the application of these initial filters, 296 articles were found and submitted to a second refinement involving the reading of titles and abstracts. The chronological survey of the articles is shown in **Figure 01**. There is a significant increase in the number of articles related to the topic since 2011.

Figure 01: Number of articles published per year

Source: authors (based on data from ISI Web of Science base)



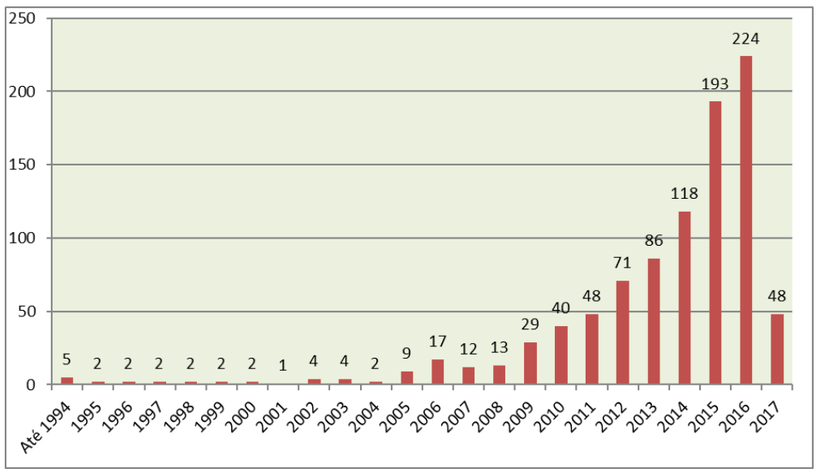


Figura 02: Number of articles published per year Source: authors (based on data from Scopus base)

In the initial search carried out in the Scopus database, developed in a similar way to that adopted for the ISI Web of Science database, 5386 articles were found. After applying the filters for idiomatic refinement, document type and area of knowledge, 936 articles were identified. For these articles a second refinement was applied involving the reading of titles and abstracts. The chronological survey of the articles is illustrated in **Figure 02**. There is a significant increase in the number of articles related to the topic since 2009, reaching the highest volume of publications in 2016.

The research in Scielo base was developed introducing the keywords in english and portuguese, in the basic and free forms, available in the database. Unlike the ISI Web of Science and Scopus databases, in Scielo base no articles were found related to the research topic, which may suggest a less robustness of this base in relation to the other two consulted.

2.1.2. Summarizing the results of the searches in databases

Considering the research carried out at the Scopus, ISI Web of Science and Scielo databases, the research reference points were defined, which compose the set of articles selected in each database. Table 04 consolidates the steps of the article selection process adopted to form this collection.

Step	Step Description	Total of Selected Articles
Initial search in databases	Conducting research in the ISI Web of Science, Scopus and Scielo databases.	6159
Initial filters application	Erro de traduçãoAdoption of the language criteria (Portuguese / English), type of document (article / review) and area of knowledge.	1232
Duplicity remotion	Elimination of articles in duplicity found in the *ISI Web of Science* and *Scopus* databases.	1229
Reading of titles and abstract of articles	Reading of titles and abstracts of the selected articles to check their relevance to the research theme.	41
Reference Points	Consolidation of the final list of selected articles	20

Table 04: Steps of article selection process

Considering the research carried out at the Scopus, ISI Web of Science and Scielo databases, the research reference points were defined, which compose the set of articles selected in each database. **Table 04** consolidates the steps of the article selection process adopted to form this collection.

Despite the large number of articles selected initially, after the application of filters for idiomatic refinement, document type and area of knowledge, 1232 articles were identified. Three articles were identified and removed from ISI Web of Science and Scopus databases due to duplicity. Shortly after the reading of titles and abstracts, it was verified that only 41 articles had effective relevance to the research, since the others dealt with aspects not related to megaprojects or were not in line with the theme of the study. These articles were read in full as a way of selecting the research reference points, which are consolidated in **Table 05**.

#	Article	Author (s)	Source	Year
1	Risk assesment in construction schedules	Mulholland, B; Christian, J.	Journal of Construction Engineering and Management	1999
2	The project assessment by simulation technique	Cates, Grant R.; Mollaghasemi, Mansooreh	Engineering Management Journal	2007
3	Dynamic risk analysis in construction projects	Nasirzadeh, Farnad; Afshar, Abbas; Khanzadi, Mostafa	Canadian Journal of Civil Engineering	2008
4	A fuzzy multi-criteria approach for critical path definition	Zamori, Francesco A.; Braglia, Marcello; Frosolini, Marco	International Journal of Project Management	2009
5	Fast and accurate risk evaluation for scheduling large-scale construction projects	Jun, Dho Heon; El-Rayes, Khaled	Journal of Computing in Civil Engineering	2011
6	A fuzzy approach to construction project risk assessment	Nieto-Morote, A.; Ruz-Vila, F.	International Journal of Project Management	2011
7	Measuring the efficiency of project control using fictitious and empirical project data	Vanhoucke, Mario	International Journal of Project Management	2012
8	Maximizing strategic value from megaprojects: The influence of information-feed on decision-making by the project manager	Eweje, John; Turner, Rodney; Müller, Ralf	International Journal of Project Management	2012
9	Network theory-based analysis of risk interactions in large engineering projects	Fang, Chao; Marle, Franck; Zio, Enrico; Bocquet, Jean-Claude	Reliability Engineering and System Safety	2012
10	Measuring the maturity of risk management in large-scale construction projects	Jia, Guangshe; Ni, Xiaochuan; Chen, Zhen; Hong, Baonan; Chen, Yutting; Yang, Fangjun; Lin, Chen	Automation in Construction	2013
11	Success evaluation factors in construction project management - some evidence from medium and large Portuguese companies	Ribeiro, Pedro; Paiva, Anabela; Varajão, João; Dominguez, Caroline	KSCE Journal of Civil Engineering	2013
12	Effects of project governance structures on the management of risks in major infrastructure projects: a comparative analysis	Guo, Feng; Chang-Richards, Yan; Wilkinson, Suzanne; Li, Ti Cun	International Journal of Project Management	2014
13	Completion delay risk management: a dynamic risk insurance approach	Kokkaew, Nakhon; Wipulanusat, Warit	KSCE Journal of Civil Engineering,	2014
14	Understanding megaproject success beyond the project close-out stage	Fahri, Johan; Biesenthal, Christopher; Pollack, Julien; Sankarn, Shankar	Construction Economics and Buildings	2015
15	Enterprise's risk assessment of complex construction projects	Konior, J.	Archives of Civil Engineering	2015
16	Risk management in construction projects	Iqbal, Shahid; Choudhry, Rafiq M.; Holschemacher, Klaus; Ali, Ahsan; Tamosaitiene, Jolanta	Technological and Economic Development of Economy	2015
17	Impact of risk management on project performance: the importance of soft skils	Carvalho, Marly M.; Rabechini Junior, Roque	International Journal of Production Research	2015
18	Workforce-related risks in projects with a contingent workforce	Becker, Karen; Smidt, Michelle	International Journal of Project Management	2015
19	Exploring the relationship between rework projects and risk indicators	Yim, Rachel L.; Castaneda, Jason M.; Doolen, Toni L.; Tumer, Irem Y.; Malak, Richard	Project Management Journal	2015
20	Dynamic management of risk contingency in complex design-build projects	De Marco, Alberto; Rafele, Carlo; Thaheem, Muhammad Jamaluddin	Journal of Construction Engineering And Management	2016

Table 05: Articles selected to form the research reference points

2.2. Primary data collection procedures: planning of empirical research with senior specialists

The company works in the oil, natural gas and energy industry, dealing with exploration and production, refining, commercialization, transportation, petrochemical, distribution of derivatives, natural gas, electricity, gas-chemical and biofuel sectors. Present in 19 countries, company produces about 2 million barrels of oil per day, and forecasts investments of US $ 74 billion over the next 5 years, with priority for megaprojects exploration and production of oil in Brazil, with emphasis on deep waters. In the other business areas, investments are basically aimed at maintaining operations and projects related to the flow of oil and natural gas production. As a way to achieve these business objectives, the company has about 78,000 employees with varied profiles, with continuous training and training in order to prepare the energy market for new demands. Risk management consultants and project managers selected for research fall into these specialized professionals.

This study adopts a non-probabilistic sample since the choice of elements does not depend on the probability, but on the characteristics of the research, according to an informal selection procedure (SAMPIERI et al., 2013). The sample type was selected by typicity, that is, individuals who are representative in the population (VERGARA, 2014). Therefore, two distinct groups of professionals, consultants and project managers were identified, with a minimum of 10 years in the company, having worked on the various types of projects carried out by the company in the upstream (production development projects) and downstream areas (refining and transportation projects).

This time of employment is considered by the company as the period necessary for a professional to reach the level of senior professional, with knowledge and maturity to perform managerial functions with a greater degree of responsibility. Therefore, ten professionals were selected, five consultants, specialists in risk management, responsible for the methodological support regarding the application of management practices in the company, and five project managers, who are responsible for making the decisions related to the projects.

Considering the geographic dispersion of the company, which has operations throughout the brazilian territory, the criterion for choosing the professionals that would compose the sample was the accessibility and the fact that they are all involved with the risk analysis in megaproject schedules. Due to these characteristics, it is understood that these professionals meet the profile required for the research objectives.

According to Marconi and Lakatos (2009), the selection of the instrument of data collection is a function of the problem to be studied and depends on the objectives of the research, the resources involved in the research, and the delimitation of the universe or sample to be studied. This study used the semi-structured interview model, which script was based on the theoretical base consolidated in Table 05. This type of interview allows the interviewer to develop each situation in any direction that he deems appropriate, exploring more broadly a question with opened questions and that can be answered in the context of an informal conversation (MARCONI and LAKATOS, 2009). For Gray (2012), these interviews are not standardized and the order of the questions may change, depending on the progress of the interview, including additional questions that were not anticipated at the beginning of the interview, making it possible to deepen the visions and respondents' opinions.

According to Marconi and Lakatos (2009), once the interview script is drawn up, this instrument should be submitted to a pre-test as a way of ascertaining its validity and ensuring that the results of the research are the most reliable. The script was reviewed and submitted to two professionals in the area, a consultant and a project manager, to conduct a pilot interview as a way to verify the levels of understanding and adherence of the questions and identify opportunities for improvement.

Table 06 consolidates the questions formulated in the interviews with the respective theoretical foundation in the researched literature.

#	Study Objective	Question	Theoretical Foundation
1	Carry out an empirical investigation on practices of elaboration of megaprojects schedules.	What practices are used for elaboration of a project schedule?	Mulholland e Christian (1999); Cates e Mollaghasemi (2007); Zamori *et al.* (2009); Jun e El-Rayes (2011); Vanhoucke (2012); Hulett (2011), Iqbal *et al.* (2015)
		Is there an evaluation of the quality of this schedule? If so, how is it done?	Mulholland e Christian (1999); Cates e Mollaghasemi (2007); Zamori *et al.* (2009); Hulett (2011); Vanhoucke (2012)
2	Conduct an empirical research on risk management practices in megaprojects.	To what extent are the risks considered in the proposed project schedule?	Cates e Mollaghasemi (2007); Nasirzadeh *et al.* (2008); Zamori *et al.* (2009); Jun e El-Rayes (2011); Nieto-Morote e Ruz-Vila (2011); Fang *et al.* (2012); Jia *et al.* (2013); Ribeiro *et al.* (2013); Guo *et al.* (2014); Fahri *et al.* (2015); Konior (2015), Iqbal *et al.* (2015), Hulett (2011); Vanhoucke (2012); Eweje *et al.* (2012); Carvalho e Rabechini Junior (2015); Becker e Smidt (2015); Yim *et al.* (2015); De Marco *et al.* (2016)
		How are quantitative risk analyzes performed on the schedules (process / tool used / frequency / resources used)? Are there perceived gaps in the process?	Cates e Mollaghasemi (2007); Nasirzadeh *et al.* (2008); Zamori *et al.* (2009); Jun e El-Rayes (2011); Kokkaew e Wipulanusat (2014); Hulett (2011), Iqbal *et al.* (2015); Vanhoucke (2012)
		Is there subjectivity in this process? If so, how is it treated?	Cates e Mollaghasemi (2007); Jun e El-Rayes (2011); Hulett (2011), Iqbal *et al.* (2015)
		Are there factors (technical, human, managerial, etc.) that can influence the application and results of a quantitative risk analysis?	Cates e Mollaghasemi (2007); Jun e El-Rayes (2011); Hulett (2011), Iqbal *et al.* (2015)
		Are there other aspects that should be considered in the schedule risk analysis?	Cates e Mollaghasemi (2007); Jun e El-Rayes (2011); Hulett (2011), Iqbal *et al.* (2015)
		What is your assessment of the application of the quantitative risk analysis in the project schedules (relevance / validity)?	Hulett (2011), Iqbal *et al.* (2015); Nieto-Morote e Ruz-Vila (2011); Eweje *et al.* (2012); Yim *et al.* (2015); De Marco *et al.* (2016)
		To what extent are risk analyzes used in the decision-making process of project managers?	Hulett (2011), Iqbal *et al.* (2015); Nieto-Morote e Ruz-Vila (2011); Eweje *et al.* (2012); Yim *et al.* (2015); De Marco *et al.* (2016)

Table 06: Theoretical foundation for formulated questions

The interviews were conducted in the period from November 18 to December 12, 2016, at the company's headquarters, with a duration of approximately 60 minutes, and were recorded with the consent of the respondents and later transcribed. Based on interviews transcripts, and through the qualitative techniques of data triangulation (GRAY, 2012) and content analysis (BARDIN, 1997), it was possible to systematize the perceptions of consultants and project managers on the questions formulated in the interviews. It is worth mentioning that the interviewees' names were kept confidential as a way of preserving their anonymity.

3. RESULTS ANALYSIS

The theoretical and empirical results from the research are presented in the following sections.

3.1 Analysis of Literature

As can be seen in **Table 05**, most articles selected (35%) were published in the International Journal of Project Management from 2009 to 2015. The year 2015 presents the highest number (30%) of publications, which may indicate a growing interest in the topic in the last decade. Among the selected studies, two main themes dominate the discussion: techniques of elaboration of schedules and management of risks in megaprojects. **Table 07** consolidates these themes by author

In the first case, Critical Path Method (CPM) is mentioned as the simplest available technique for modeling the execution of a project with application in various areas of the industry, including construction projects. However, CPM considers duration of activities as deterministic, which means that does not consider the effects of variability and uncertainty on activity estimates, such as climate, productivity, and availability of resources (MULHOLLAND & CHRISTIANIS, 1999; HULETT, 2011; ZAMORI et al., 2009, JUN and EL-RAYES, 2011). Cates and Mollaghasemi (2007) define the project schedule as a simulation model that aims to analyze several scenarios of project completion. For Hulett (2011), the schedule is the basis for a robust risk analysis and should realistically represent the activities to be carried out, their duration estimates, the total float, and the project critical path.

In almost all of the works surveyed (JUN and EL-RAYES, 2011; HULETT, 2011; NIETO-MOROTE and RUZ-VILA, 2011; VANHOUCKE, 2012; FAHRI et al.), risks are defined as threats to project objectives, usually translated into time, cost and quality goals. For Becker and Smidt (2015), however, risks show both positive (opportunities) and negative (threats) aspects. For these authors, risk responses should be planned and implemented, both to improve project objectives, taking advantage of opportunities, and to minimize negative impacts on project objectives, mitigating these threats.

Guo et al. (2014), Eweje et al. (2012), Ribeiro et al. (2013), Jia et al. (2013) and Fahri et al. (2015) emphasize the greater vulnerability of megaprojects to risks, given their special characteristics such as long lead times, large investments, multiple complex interfaces that require efficient management, technological innovation, and social and environmental issues.

Thus, risk management is considered an essential tool in the decision-making process for project managers, and can represent the difference between success and failure of the project in achieving its objectives (DE MARCO et al., 2016; NIETO-MOROTE e RUZ-VILA, 2011; IQBAL et al., 2015; EWEJE et al., 2012; YIM et al., 2015).

Although there are different approaches, risk management in projects presents a similar pattern, being composed of the following processes: risk identification; risk assessment; responses to risks; and monitoring and control of risks (NIETO-MOROTE and RUZ-VILA, 2011).

#	Temas	Autores
1	Elaboration of schedules	Mulholland e Christian (1999); Zamori *et al.* (2009); Hulett (2011); Jun e El-Rayes (2011); Vanhoucke (2012); Iqbal *et al.* (2015); Cates e Mollaghasemi (2007); Hulett (2011).
2	Risk management in megaprojects	Malcolm *et al.* (1959); Cates e Mollaghasemi (2007); Nasirzadeh *et al.* (2008); Zamori *et al.* (2009); Jun e El-Rayes (2011); Hulett (2011); Nieto-Morote e Ruz-Vila (2011); Eweje *et al.* (2012); Fang *et al.* (2012); Vanhoucke (2012); Jia *et al.* (2013); Ribeiro *et al.* (2013); Guo *et al.* (2014); Fahri *et al.* (2015); Kokkaew e Wipulanusat (2014); Iqbal *et al.* (2015); Konior (2015); Carvalho e Rabechini Junior (2015); Becker e Smidt (2015); Yim *et al.* (2015).

Table 07: Themes by author

In the process of risk assessment is considered schedule risk analysis, which steps are highlighted in Vanhoucke's study (2012). Hulett (2011) details how these steps should be conducted, from the schedule construction - consistent with its constructive logic - to issuing reports with information that enables the project manager to make a decision.

Schedule risk analysis is a simulation technique to reveal critical components of a project that are most likely to impact project objectives (VANHOUCKE, 2012). This technique adopts a statistical approach that considers the effects of uncertainty on estimated durations. When this happens, the duration of the project defined by its critical path most likely differs from the duration determined by the CPM technique (HULETT, 2011).

The statistical approach is commonly used by the Monte Carlo simulation technique to generate several scenarios for project execution, ensuring a more accurate estimate for the most probable date of completion of the project, being the most used in megaproject scheduling (VANHOUCKE, 2012; HULETT,2011; ZAMORI et al., 2009; JUN and EL-RAYES, 2011; KOKKAEW and WIPULANUSAT, 2014).

Among the identified studies, only Jun and El-Rayes (2011) present a method called FARE (Fast and Accurate Risk Evaluation) that proposes to reduce the computing processing time of the Monte Carlo simulation (around 94%) while maintaining an error rate in the probability estimates on the order of 3%.

3.2 Analysis of Interview Results

The company operates in the oil, natural gas and energy industry, mainly performing megaprojects in the oil exploration and production segment with emphasis on deep water. As a way to deal with this challenge, the company relies on the solid training of its professionals. Risk management consultants and project managers selected for research fall into these specialized professionals.

3.2.1. Interviews with Consultants

The consultants selected for the interviews are specialists in risk management in projects and work in the corporate area of the company, providing methodological support to the areas responsible for project implementation, and respective teams, in the application and development of management practices demanded by the organization, which include the quantitative analysis of risks in schedules. The participation of these professionals in the results of the research is relevant to support the empirical evidence of the research, given the knowledge accumulated and for their critical view on the process of risk analysis in project schedules.

Regarding the scheduling techniques, the five consultants interviewed pointed to the CPM as the technique used by the company to generate the deterministic schedule of the projects. This technique offers a preliminary plan that follows the traditional way of elaborating the schedule and that does not consider the inherent risks to the projects. With the use of this technique, the elaboration of the schedule follows the basic steps as definition and sequencing of activities, according to its logic of execution and durations estimates.

However, it is not a common practice to allocate resources to schedule activities, and their durations are estimated through specialized opinion, usually by professionals with previous experience in that type of activity, or using historical data related to previously executed projects.

According to the consultants interviewed, the company uses Microsoft Project® and Primavera® P6 tools to create and manage project schedules. The consistency of these schedules is evaluated through an existing functionality in the Primavera Risk Analysis® tool. This feature of Primavera Risk Analysis® allows the preparation of a report called Schedule Check Report, which details the amount of date restrictions, excessive number of lags and leads, activities without predecessors or successors that may compromise the result of a schedule risk analysis.

It was also observed the alignment of the experts' perceptions regarding the methodology used to carry out the risk analysis in the project schedules. According to respondents, this methodology is consistent with the

one recommended in literature (HULETT, 2011; NIETO-MOROTE and RUZ-VILA, 2011; VANHOUCKE, 2012).
According to interviewees, the company defines that schedule risk analysis should be preceded by the identification and prioritization of the risks of the project. Then, during a workshop convened specifically for this purpose, and with professionals of various disciplines of the project, risks and probability distribution curves are associated with the activities of greater criticality of the schedule.
These activities of greater criticality are those most likely to appear in the project critical path are selected through the so-called Stress Test - functionality available in risk analysis tools, usually executed on schedules with a large number of activities (usually above 10,000).
For each of these activities, experts estimate three different duration scenarios: optimistic, more likely, and pessimistic. The collected data are then entered into the Primavera Risk Analysis® or @Risk®, being submitted to a large number of iterations (usually 5,000), executed by the Monte Carlo simulation algorithm. This mechanism allows to generate several possible scenarios for the project completion date, providing data such as the probability distribution curve and the sensitivity analysis (Tornado graph).
For the consultants interviewed, the logical inconsistencies verified in the schedules correspond to the largest gap in the process of quantitative risk analysis. From a consultant perspective:

> "[...] For me the main problem in relation to risk analysis is the issue of the consistency of the schedule. We have a hard time having a consistent schedule that shows the strategy, that shows a logical sequencing, that you can build that way. In terms of analysis, I think it's the biggest gap [...]".

This poor quality of the schedule ends up taking a lot of time from the professionals involved in the risk analysis, who need to adjust the logical network of the schedule before submitting it to a risk analysis. Without this prior work, risk analysis becomes fragile and compromised.
The lack of specialists in risk analysis was also cited as an important gap in the process, as it may negatively impact the preservation and dissemination of knowledge, and is responsible for the low maturity in the use of risk analysis as a management practice.
Regarding the subjectivities in the risk analysis process, the consultants indicated that they are more related to human and managerial aspects, and have as sources: the bias introduced in the estimates of duration of activities; qualitative risk assessment; individual experiences of the professionals involved; organizational culture; and pressure by results. As a way to reduce this bias, the following practices were mentioned: the use of statistical databases prepared from historical data, allowing for the traceability of data and information; analysis of quantitative data; and histograms of resources confronted with the proposed schedule presented.
On the other hand, according to respondents, the lack of an organizational culture of planning and the pressure for results, coupled with the deficiencies in the schedules and the subjectivities mentioned, also contribute to the lack of more effective results, contributing to the existence of a set of gaps that can be determinant to inhibit the evolution of organizational maturity in risk management.
Table 08 consolidates the main aspects highlighted by consultants related to the research points.

Research Points	Consultants Notes
Technique for schedule elaboration	Critical Path Method (CPM)
Tools used to create schedule	MS Project and Primavera P6
Tools used to carry out quantitative risk analysis in schedules	@Risk® and Primavera Risk Analysis®
Recommended periodicity for carrying out the risk analysis	From 4 to 6 months, that can be changed depending on the company's scenario or disruptive risks that occur in the project environment.
Gaps pointed out in the risk analysis process	Low quality or inconsistency in schedules and lack of specialists in risk analysis.
Subjectivities identified in the process of risk analysis	Introduction of bias in the use of expert opinion to estimate durations of activities, in addition to pressure for results that imposes an optimistic view in the schedule.

Table 08: Consultants opinion related to the research points

3.2.2. Interviews with Project Managers

The project managers selected for the interviews work in the implementation of the company's projects, coordinating multidisciplinary teams that apply technical knowledge to create the company's production assets in line with its business plan.
The participation of these professionals in the results of the research is relevant to support the empirical evidences of the research given the experience accumulated in managing projects from diverse areas and their involvement in the decision-making process - including the use of practices of management processes required by the corporation, as quantitative risk analysis in schedules.
The project managers interviewed pointed out the CPM as the technique used to elaborate the deterministic schedule of the projects, that is, the traditional way of elaborating the schedule and that does not consider the risks related to the projects. This elaboration follows the steps of definition and sequencing of activities, according to its execution logic and duration estimation, and is performed in the Microsoft Project or Primavera P6 tools.
According to the project managers, it is not a current practice to allocate resources into the schedules activities, and their durations are estimated through specialized opinion, usually professionals with some previous experience in that type of activity or using historical data related to previously executed projects.
Three managers interviewed highlighted the need to analyze and promote the alignment of the schedule with the Work Breakdown Structure (WBS) as a way to better detail its scope. From this view, it follows that the project schedule should be viewed as an extension of the WBS, being configured in a greater detail of the scope of the project and clearly defining what should actually be produced as project deliverables.
In order to carry out the schedule risk analysis, the interviewees pointed out the use of @Risk® or Primavera Risk Analysis® tools made available by the company. It was also observed the alignment of the opinions of the managers and the consultants regarding the methodology used to carry out the risk analysis in the project schedules.
Regarding the periodicity of the quantitative risk analysis, a diversity of points of view was observed among the managers interviewed. Regarding the gaps in the quantitative risk analysis in schedules, the lack of reliability of the process input data was verified.
It is observed in the managers' statements, the concern with the consistency of the schedules that are submitted to the risk analysis. Not only with its execution logic, established in the dependency relations between activities, but also with the veracity of the physical progress data that are inserted in the running activities, during the periodic updating of the schedule. According to one of the interviewees:

> "[...] The great difficulty in doing a credible risk analysis, and that the management can use as a tool for decision making or course correction, is the reliability of the input data in this process. If you can not capture input data of a schedule in a consistent way, consistent with what is actually happening in the field, the paper accepts anything. And credibility and reliability are associated with this detachment between what is written and what is done".

In fact, the lack of accuracy in the measurement of physical progress, or even its non-measurement, can cause inconsistencies in the results of the risk analysis of the schedule. It is the case of non-measurement of activities that are in the past and that for some reason have not been updated. In this situation, the project may be behind schedule and the planner does not notice.
Regarding their evaluation of the application of the risk analysis in the project schedules, the five project managers interviewed pointed out their relevance as a management tool. Given the condition of decision makers, the perceptions of project managers amplify the viewpoints of the consultants.
The lack of a greater professional development in risk management by high-level managers and project teams inhibits the evolution of risk analysis as an effective management tool since it prevents a degree of understanding of the risks that the projects are exposed, reducing the chances of adopting measures capable of reducing its effects.
Table 09 consolidates the main aspects highlighted by project managers related to the research points.

Research Points	Project Managers Notes
Technique for schedule elaboration	Critical Path Method (CPM)
Tools used to create schedule	MS Project and Primavera P6
Tools used to carry out quantitative risk analysis in schedules	@Risk and Primavera Risk Analysis
Recommended periodicity for carrying out the risk analysis	From 2 to 6 months, or only in the decision gates for phase approval.
Gaps pointed out in the risk analysis process	Low reliability or lack of accuracy of process input data, logical inconsistency of schedules, qualitative and quantitative peer-to-peer analysis, and pressure for results that imposes an optimistic view to project completion date.
Evaluation of risk analysis use in the decision-making process.	From relevant to very relevant, with perspective of increasing use in decision making.

Table 09: Project managers opinion related to the research points

4. CONFRONTATION OF THE EMPIRICAL FINDINGS WITH THE LITERATURE

The main empirical findings of this study are related to the aspects of subjectivity and organizational culture present in the process of risk analysis. It is worth noting that no mention was found of these findings in the selected studies to compose the reference points of the research, which may indicate a shortage of scientific literature published in journals on the subject.

Subjectivity is present, for example, when collecting data from specialists to estimate the optimistic, most probable and pessimistic durations of the schedule activities, either through interviews or workshops convened for this purpose. As mentioned by the consultants, there is the possibility of inserting skewed data in the schedule based on the experience of the expert with a given activity in a previous project. According to one of the interviewees:

> "[...] subjectivity is a feature of the process that, in my understanding, is diminished, but is not avoided or eliminated, when you put people with a lot of experience in the workshop, who already lived that moment there in other works, or when you have some kind of historical base that you can consult and draw some lesson".

However, the preponderance of one person's opinion over another may still occur due to more or less company time, experience, position, and the facilitator's own ability to conduct the workshop. The same can be said for the organizational culture aspect.

It is also important to emphasize the role of the barriers that involve the fear of announcing negative news regarding the fulfillment of the expected completion date of the project. This date is usually deterministic, and even when risk analysis points to a very low probability of being reached, top management often insists on its maintenance. According to one of the project managers interviewed:

> "[...] in my perception, is that this can not disturb. I mean, you have to do the process of risk analysis, you have to map the risks, you have to act on the risks, but you can not get in the way of the schedule. You can not bring bad news to senior management, you can not change the deterministic date due to risks".

This organizational view that risks pose threats and have a negative effect on the project objectives, represented by time, cost, quality and safety, is in line with that stated by Cates and Mollaghasemi (2007), Fang et al. (2012), Konior (2015), and Iqbal et ali (2015). This perception is in opposition to the one advocated by Becker and Smidt (2015), for whom risks can lead to positive or negative consequences, that is, risks can also be seen as opportunities for projects.

In addition, if the organization is not mature enough to accept that risks exist and, therefore, need to be treated with transparency, project managers feel pressured to conceal information in order to avoid been seen as bad managers. Finally, it is important to note that risks continue to exist, regardless of whether a response plan has been developed, and may materialize with unforeseen and undesirable impacts to the company's business.

It is understood that, in shedding light on the influence that aspects of subjectivity and organizational culture can exert on the results of the quantitative analysis of risks in schedules, this study plays a contributing role to the improvement of the practice.

Another empirical finding, much emphasized by the interviewees and in line with Hulett (2011), concerns the work of evaluating the quality of schedules, when the main components of a schedule are studied and the problems caused by their inadequate use in the construction of the schedule. It is thus evidenced that a consistent schedule is the basis for robust risk analysis.

The stages of the quantitative risk analysis process proposed by Vanhoucke (2012) also make up another empirical finding that aligns with the practice defended by the interviewees, although the author does not address the aspects of subjectivity already discussed.

Another factor evoked by Nieto-Morote and Ruz-Vila (2011) is the importance of qualitative risk analysis, where risk identification and prioritization are done according to their degree of severity, as a step prior to quantitative analysis. It means that risks are identified and classified and subsequently associated with the schedule activities.

However, this note was reported by only one of the project managers interviewed, who highlighted the detachment between these analyzes as a gap in the process. In his report, the professional stated that some risks of high impact in the date of completion of the project were identified in the qualitative analysis and were not considered in the quantitative analysis.

> "[...] I think we have a very large gap when we do not bring qualitative to quantitative analysis. So, I'll give an example of a project I managed: the biggest risk was the contractor bankruptcy. And when we performed a schedule risk analysis, you had nothing related to that risk".

This fact may indicate that different tools were used to make qualitative and quantitative risk analysis. In addition to this perceived decoupling, we have as a consequence the loss of traceability of the assumptions adopted in the qualitative analysis, as well as the data about the risks, their causes, their impacts and response plans adopted.

In order to avoid this deleterious effect, it is suggested that the qualitative and quantitative analysis steps be carried out as closely as possible or in a period of time not exceeding six months, as indicated by the consultants interviewed.

It is worth noting that in the articles that compose the reference points of this study, no notes were found regarding the need for a greater proximity between the qualitative and quantitative analyzes of risks in projects, which suggests a contribution of the present study to the improvement of the literature and organizational practices.

Finally, regarding the decision-making process, the unanimity of the interviewed project managers stands out in pointing out the importance of quantitative risk analysis for decision making. This empirical finding is in line with that advocated by Eweje et al. (2012), Iqbal et al. (2015), Yim et al. (2015) and De Marco et al. (2016).

For the aforementioned authors, decision-making based on reliable and timely information plays a central role in the creation of megaprojects value in the construction industry, as it makes it possible to identify and treat risks either preventively or through corrective actions. These steps taken by project managers to mitigate risks can represent the difference between success and failure of the project.

5. CONCLUSIONS AND SUGGESTED FUTURE STUDIES

The methodological approach adopted in this study, having as a first step the systematic review of the specialized literature on risk analysis in megaproject schedules, and a second stage with semi-structured interviews addressing the specificities involved in the application of the process, contributed to highlight the main theoretical and empirical findings of the research, which are consolidated in **Table 10**.

Theoretical Findings	Empirical Findings
Evidence of a significant increase in the number of articles related to the research topic especially from the year 2011.	Subjectivities in the process of risk analysis, such as the influence of specialized opinion on duration estimates and pressure for results from the organizational culture, as well as its impacts on the results of risk analysis.
Confirmation of the CPM technique as the most used practice for the elaboration of project schedules.	Gaps in the process of risk analysis, such as the low reliability of the process input data, especially the logical inconsistency of project schedules.
Quantitative risk analysis in schedules adopts a statistical approach using the Monte Carlo simulation technique to generate several scenarios for the execution of the project, ensuring a more accurate estimate for the most probable date of completion of the project, being the most used in megaprojects programming.	The need for training in risk management of higher level managers as a way to ensure greater commitment to the process of risk analysis and therefore the achievement of better results with the full use of the practice in the decision making process.

Table 10: Main theoretical and empirical findings of the research

The comparison between specialized literature and interviews with professionals who use risk analysis as a management tool contributed to highlight the existing gaps and the space for improvement of the risk analysis process, which is understood as a contribution of the present study.
In dealing with a topic of growing interest in the literature, such as the risk analysis in megaproject schedules, with the adoption of an approach that seeks to highlight the points of view of two distinct groups of professionals who use the practice, the study has contributed to the advancement of knowledge on the subject. On the other hand, there is a limitation of the experimental field and that new research can be carried out to verify the findings presented in other organizational realities and in other countries.
Regarding the practices used in schedules elaboration, there was no significant distance between the techniques used for smaller projects and megaprojects, which indicates that the size of the project does not influence the definition of the technique for schedule project creation.

The study concluded that these practices are based on two basic pillars:

- · Use of the CPM technique to elaborate the deterministic project schedule, given its ease of use and dissemination in the community of project planning professionals.
- · Evaluation of the logical consistency of the project construction strategy established in this schedule by existing functionalities in the software of risk analysis and databases with historical information.

According to the specialized literature, the CPM technique is the simplest and the most used by planning professionals in the elaboration of project schedules, although there are still cases of excessive use of scheduling restrictions and lags, as well as logic errors, among other factors, that need adequacy before submitting the schedule to a risk analysis. Although the CPM technique is cited as being most widely used, the Monte Carlo simulation tool is also mentioned. The latter is a complementary form to PERT to calculate the accuracy of an estimate of schedules. It performs thousands of simulations that allow the project manager to calculate the probability that a project will end on a given date.

Professionals interviewed reinforced the need to improve the quality and consistency of the schedule, not only with the use of existing resources in risk management software, but also with the use of statistical databases, analysis of histograms and resources that minimize the bias of the specialized opinion of professionals involved in the schedule elaboration.
Project logical consistency can be complemented by checking the schedule alignment with the WBS, as a way of better detailing and understanding the project scope, and by the integrated analysis of interfaces and interdependence between contracts and other projects.
Regarding the role of quantitative risk analysis in schedules as a subsidy to the decision-making process, the study concluded that it involves the training of managers at strategic level in risk management and their greater involvement in the process of risk analysis, since it was evidenced in the perception of project managers interviewed.
This aspect is related to the pressure for results coming from top management and the organizational culture of the company that collaborate to incorporate subjectivities in the process of risk analysis, one of the main findings of the research.
In order for risk analysis to support the decision making process, project managers indicated the need for the input data from the risk analysis to present sufficient reliability, related to the consistency of the schedule and to the data used in its periodic updating.
As a way of exploring in greater depth the results obtained in the present study, it is suggested the deepening of the research in relation to the subjectivities present in the process of risk analysis, its characterization and its forms of treatment. It is understood that this closer examination of the subjectivities can contribute to make the practice of risk analysis an even more solid management tool, with better results for the management of projects in organizations.
It is also proposed to study in more detail what periodicity would be appropriate to carry out risk analyzes in megaproject schedules, considering the effort employed and the cost-benefit ratio inherent in the process. The absence of this topic of discussion, among the articles selected to compose the reference points of the present study, can signal a shortage of specialized literature on the subject.
Finally, it is recommended the development of similar studies, especially empirical studies, considering the following possibilities: the amplification of the sample; conducting interviews with professionals specialized in risk management in companies of the same segment or other industrial sectors that operate with megaprojects. As a continuity of the present study, a theoretical investigation is proposed that evidences the perception of the importance of risk analysis in schedules for project performance.

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