PAPERS

Risk Identification in Megaprojects as a Crucial Phase of Risk Management: A Literature Review

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ABSTRACT

The purpose of this study is to perform a literature review of risk management in megaprojects and systematize the risks studied in the literature. A systematic search of the main databases has been performed. The contributions include: (1) a bibliometric analysis of articles; (2) the systematization and classification into nine categories of the risks found in a content analysis of the articles; and (3) the identification of possible areas of interest for research and practice. Risks are comprehensively categorized to assist practitioners during the identification phase, while potential areas for future lines of research are presented for academics.

KEYWORDS: megaproject; complex project; risk management; risk identification

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INTRODUCTION

A megaproject is a large-scale project characterized by complexity, uncertainty, ambiguity, dynamic interfaces, significant political or external influences, and time periods extending to ten years or longer (Floricel & Miller, 2001). Megaprojects are considered to be the most complex of all the various types of projects, since their overall behavior is difficult to understand, predict, and keep under control, even when reasonably complete information about the megaproject system has been provided (Vidal, Marle, & Bocquet, 2011).

The characteristics of megaprojects make them an interesting research topic, because according to Esty (2004), they provide a decision-making environment in certain areas of project management that cannot be found in any other type of project. The differences between megaproject management and project management include (Zhai, Xin, & Cheng, 2009): (1) a higher volume of investment, which means more sponsors and/or shareholders, which in turn contributes toward the complexity of the project; (2) greater community involvement, due to the high impact that these projects usually have on the environment where they are implemented (although the impact differs depending on the type of construction), which may result in public sector participation; (3) a more complex decision-making process, due to the size of the budget and amount of resources involved, since each decision made in a megaproject can drastically change its direction; and (4) a higher number of stakeholders involved, meaning that there is also a larger number of interests and expectations that have to be fulfilled, thereby increasing the complexity of the project. In addition, Flyvbjerg, Bruzelius, and Rothengatter (2003) state that the principal difference is that when megaprojects fail, they can cause the collapse of the agents that have been funded and sometimes even the governments that are behind them, thus escalating the risk factors.

Risk management is currently considered to be a mandatory part of project management in general (including megaprojects), and also an integral part of successful project management (Burcar, Radujković, & Vukomanović, 2013). Risk management can be defined as the systematic process of identifying, analyzing, and responding to risks (Dey, 2010). It includes maximizing the likelihood and outcomes of positive events and minimizing the likelihood and outcomes of events that are detrimental to the project's objectives (Project Management Institute, 2013a, 2013b). The best projects display an ability to manage risks more effectively, which in turn contributes toward positive outcomes and results in safer projects, lower costs, and projects being completed on time (Greiman, 2013).

The risk management of small- and medium-scale projects has been the subject of research on numerous occasions (e.g., Marcelino-Sádaba, Pérez-Ezcurdia, Echeverría Lazcano, & Villanueva, 2014). However, the number of articles on this subject falls considerably when only studies on megaprojects are considered, since, as this article demonstrates, this continues to be an area of research that is still developing and expanding. Furthermore, risks are more complex and have a greater impact on megaprojects, which makes risk management even more important. Be that as it may, there is no evidence that the literature has addressed risk management in megaprojects, specifically, or differently than risk management in small- and medium-scale projects.

Studying risk management in megaprojects is justified by the growing interest being shown in megaprojects as a research area due to their unique characteristics (Esty, 2004; Fiori & Kovaka, 2005); the important role that risk management plays in the management of megaprojects (Dimitriou, Ward, & Wright, 2013; Greiman, 2013; Lehtiranta, 2014); the need to address all types of risks so as to take a more holistic view (Lehtiranta, 2014); the increasing growth in number and value of megaprojects (Flyvbjerg, 2014); and the great heterogeneity detected in recent studies on megaprojects, which do not seem to adopt a framework that is any different from smaller-scale projects. As the size and complexity of a project increase, however, the associated risk management effort increases exponentially (Kwak, 2003).

Risk management is considered to be a major success factor for all types of projects and an attractive research and development topic (Lehtiranta, 2014), especially with respect to megaprojects because it can help project managers anticipate any delays that might lead to projects not being delivered on time (Grant, Cashman, & Christensen, 2006). The success of a megaproject is considered to depend on the proper management of risks, uncertainties, and the complexity of the decision-making process (Dimitriou et al., 2013), among other factors. Risk management is an expanding field, which the literature has shown can be used not only to control against loss, but also as a way to achieve greater rewards (Dey, 2012). It is also significant as, among other things, analyzing and assessing potential risks in the early stages of a megaproject help to determine whether the megaproject should be executed at all. The identification phase is considered to be the most important stage of risk management, because once a risk has been identified, it can be managed (Chapman & Ward, 2003; Cooper & Chapman, 1987; Courtot, 2001; Haifang, Shimiao, & Danfeng, 2010; Perry & Hayes, 1986; Wideman, 1992). Furthermore, the sooner risks are identified, the more the cost and effort of mitigating them can be reduced (Fukayama, Fernandes, & Ebecken, 2008).

This fundamental role of risk management in megaprojects leads us to establish the following objectives: (1) a systematic literature review of risk management in megaprojects and (2) the systematization of the risks studied in the literature, since risk identification is a crucial phase of the risk management process. To achieve these goals, a systematic literature review of major databases (WoK, Scopus, and ABI/Inform) was conducted between the years 2000 and 2013, including quantitative and qualitative analyses of the selected articles using ATLAS.ti software and a checklist.

These objectives contribute to the previous literature by providing: (1) a bibliometric analysis of articles focusing on risk management in megaprojects; (2) the systematization and classification into nine categories of the risks found in a content analysis of the articles with a detailed description of each risk; and (3) the identification of possible areas of interest for risk management research and practice in megaprojects (current weaknesses and future opportunities). Moreover, articles of this nature help prospective researchers situate and contextualize their contributions to the fields of study about which the articles are written.

The remainder of this article is organized as follows. The second section analyzes prior literature on this topic. The third section describes the methodology employed; the fourth section sets out the analysis and discussion of the results; and finally, conclusions, further research, and the implications of this study for practitioners and academics are presented.

Prior Studies

Megaprojects and Risk Management

The term *megaproject* was coined in the 1970s to characterize the size and cost of large-scale energy development projects being undertaken around the world (Altshuler & Luberoff, 2003) and used to describe very large capital projects costing millions of U.S. dollars (Dimitriou et al., 2013).

No single definition as to what constitutes a megaproject can be found in the literature. According to van Marrewijk et al., 2008), a megaproject is a mega-infrastructure project that costs many billions of dollars (Flyvbjerg et al., 2003; Koppenjan, 2005; Turner, 1999); is usually delivered by private enterprises on behalf of a government; and is a venture involving uncertainty, complexity, and a wide range of partners that is highly sensitive in political terms (Clegg, Pitsis, Rura-Polley, & Marosszeky, 2002).

The characteristics that may classify a project as a megaproject include: an investment over US$1 billion, high uncertainty, possible intangible benefits, and attractive long-term outcomes (Eweje, Turner, & Müller, 2012; Miller & Lessard, 2000). The effects of a megaproject are considerable and can have a highly visible positive or negative impact. Along with the uncertainty inherent in megaprojects, these effects generate a wide range of risks that need to be taken into account over the life cycle of a megaproject. Research studies (Cooper, Edgett, & Kleinschmidt, 2001; Torok, Nordman, & Lin, 2011) have suggested that much of the root cause of project-related risks of largely complex projects can be traced to the organizational dynamics and multidisciplinary nature of today's business environment, especially in the case of technology-based developments (Thamhain, 2014). The involvement of processes, technologies, and different stakeholders compounds the level of uncertainty and distributes risk over a wide area of the enterprise and its partners (Thamhain & Wilemon, 1999; Thamhain, 2004, 2013). To manage megaprojects, it is therefore necessary to go beyond a simple analysis of the cost and dates and try to understand the true cause of any uncertainty (Thamhain, 2013).

Risk can be defined as any uncertain event that might fail to serve the interests of stakeholders as stated in the project design (Young, 2010). In other words, a risk is "an uncertain event of condition that, if it occurs, has a positive or negative effect on a project's objectives" (Project Management Institute, 2008). Every risk always has a cause and a potential positive or negative consequence. Risk is an essential factor that must be taken into account, because it can affect both the cost–benefit analysis throughout an entire project, and the demand, production costs, execution time, and financial variables (de Palma, Picard, & Andrieu, 2012). Even though every project requires such a study to be carried out, they are especially relevant in megaprojects due to their much greater complexity. The literature review performed by Harvett (2013) indicates that many projects are still failing; that project complexity grows over time; and that there are concerns as to whether established industry risk management standards are effective in managing uncertainty and risk, especially in complex project environments (Atkinson, Crawford, & Ward, 2006; Zhang, 2011).

In addition, risk management is not carried out in the same way for all projects, as risks do not impact all projects to the same extent (Thamhain, 2013). Risk impact depends not only on the risk event, but also on the way that management deals with the event and its timing. This, in turn, has a bearing on the importance of the problems caused by the event and the knock-on effects in the project organization.

A megaproject entails many risk factors that can cause delays or failures during the project life cycle, which means that, in order to reduce the likelihood of these risk factors causing the megaproject to fail, specific management actions have to be taken that involve the implementation of models or mitigation measures (Flyvbjerg et al., 2003). Whatever the size of the project, the risk management process seeks to identify and assess risks so that they can be understood clearly and managed effectively (Mojtahedi, Mousavi, & Aminian, 2008). This involves identifying strategies to reduce risks, including the ways in which they are shared among the parties involved and the risks that should be transferred (Flyvbjerg et al., 2003).

Although risk management is sometimes described as a three-phase process (risk identification, risk analysis, and risk response) (Buchan, 1994; Haifang et al., 2010), recent research (Dey, 2012; Project Management Institute, 2013a) breaks risk management down into six steps: planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control (Figure 1).

Effective risk management relies on risks being identified, particularly at the front end, before the project concept has been finalized. Nevertheless, it must be emphasized that risks are present in a megaproject from the outset, even in the very early planning stage. In the following stages, these risks are assessed and decisions are made as to what actions are needed for their potential impact to be eliminated or mitigated.

The literature has shown that major risks in complex projects include: (1) political risk that results in uncertain financing and a significant decline in potential revenues; (2) potential for

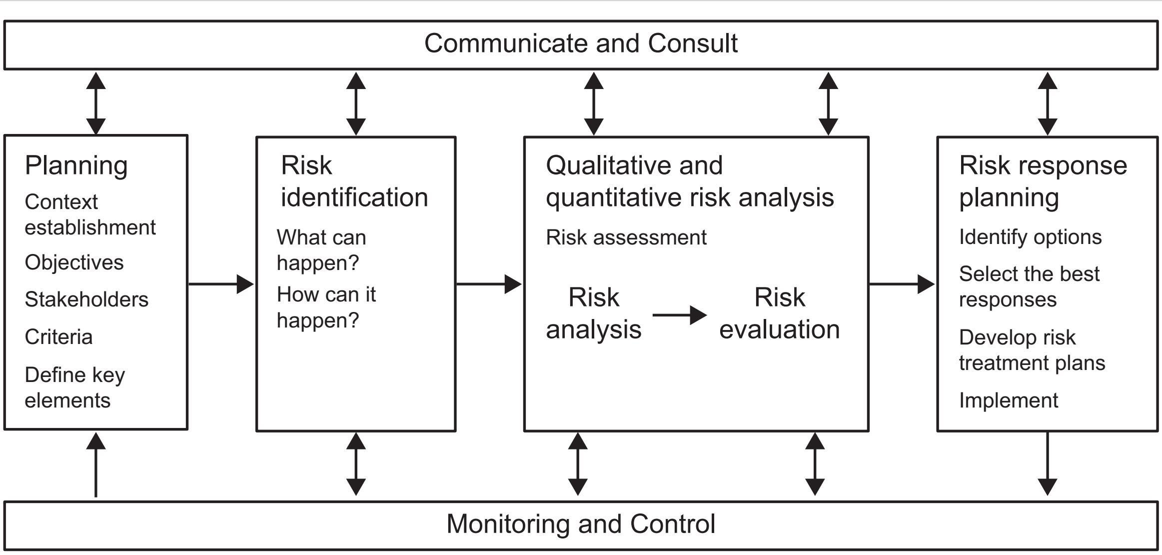

Figure 1: Risk management process (Source: Based on Cooper, Grey, Raymond, & Walker, 2004).

catastrophic loss; (3) complex engineering and design risk; and (4) substantial unknowns that have an impact on budgets and schedules (Greiman, 2013). Of these risks, those most frequently analyzed in the literature on megaprojects are those that have a consequence on time delays and increased costs, because they imply lower performance of the megaproject (Altshuler & Luberoff, 2003; Flyvbjerg et al., 2003). Indeed, time, cost, and scope according to specifications, constitute a traditional performance measurement called 'triple constraint' or the 'iron triangle' in project management (Toor & Ogunlana, 2010). This lower performance can be explained by a number of factors that often occur in megaprojects: their complexity, the lack of realism in the estimates, resource scarcity, inefficient management, and, simply, public stakeholder resistance due to cultural or political interest (Flyvbjerg et al., 2003; Han et al., 2009; Nelson, 2007; van Marrewijk et al., 2008). On the other hand, it is also important to note that there are certain risks that are often found in megaprojects and to which the literature has not devoted special attention. Some common risks that contribute to higher costs in megaprojects are linked to competitive bids, with unrealistic and undervalued bids made in an attempt to be more competitive, which subsequently leads to the risk of renegotiation.

Although there is a large amount of literature on risk management in projects (Marcelino-Sádaba et al., 2014), there is much less with respect to megaprojects. The literature has demonstrated the need to study large-scale projects (Esty, 2004) because they provide a clear setting in which to analyze how managers make important structuring and financing decisions to respond to capital market imperfections. Furthermore, there appears to be ongoing academic and political interest in megaprojects, particularly those involving both public and private agencies. Several models and methods of public–private partnerships in megaprojects have been developed in the current financial crisis due to both budgetary constraints on the public sector and the need to optimize financial resources (Irimia Diéguez & Oliver-Alfonso, 2012). The failure of these projects is highly visible due to their size and scope, thus there is both the need for, and interest in, projects being managed and delivered effectively (Fiori & Kovaka, 2005). The importance of risk management in megaprojects is based on the high impact and high uncertainty involved, both of which make risk management a key factor in megaproject success.

Nevertheless, the difficulty that studying megaprojects presents means that there is a lack of academic research in the area. This limited amount of research has been attributed to factors such as the need to collect a large volume of information and the difficulties that private agents encounter in accessing that information (Esty, 2004). This lack of studies marks our first objective: to conduct a systematic literature review of risk management in megaprojects in response to calls from a number of authors (Botetzagias, Malesios, Kolokotroni, & Moysiadis, 2013; Creedy, Skitmore, & Wong, 2010; Lehtiranta, 2014).

Previous Literature Reviews of Risk Management in Megaprojects

Studies on risk management in megaprojects are scarce. Only four literature reviews have been found that can to any degree contextualize the situation of research into risk management in megaprojects (Lehtiranta, 2014; Rezakhani, 2012; Taroun, 2014; Zhang, 2011); however, the objectives of these reviews differ from those of this article.

Zhang (2011) analyzed the articles that include the word 'risk' in their title, abstract, and/or keywords published in the *International Journal of Project Management* and in the *Project Management Journal®* between 1999 and 2009. This search therefore focuses on projects in general (not on megaprojects). For each of the 171 selected references, the author examines the ways in which risk is considered and frames articles in one of two schools: risk as an objective fact and risk as a subjective construction. A content analysis of the articles determines the basic concepts of risk adopted by each of these and their basic assumptions, viewpoints, and tendencies, as well as their methods of analysis and the management policies that are consistent with these conceptions of risk. This author concludes that, in general, risk is perceived from an objective point of view (over 90% of the articles); therefore, Zhang's study neither performs bibliometric analysis nor draws specific conclusions on megaprojects.

Rezakhani (2012) conducts an extensive literature survey of risk modeling and analysis methods, with particular attention to fuzzy risk assessment in construction projects. He concludes that it is a common recommendation in the literature to consider 'the imprecision, vagueness, and fuzziness of the risk factors in a construction project to appropriately deal with a contractor's project risks by using Fuzzy Set Theory (FST).' Unfortunately, there is no specification as to the methodology, database, or journals analyzed.

Lehtiranta (2014) studies risk perception and risk management approaches in temporary multi-organizations (TMOs) to identify any gaps that need to be addressed in future research; she analyzed 105 articles published in the *International Journal of Project Management*, the *Project Management Journal®*, the *Journal of Construction Engineering and Management*, and *IEEE Transactions on Software Engineering* for the period between 2000 and 2012. Her study of the body of knowledge of risk perception and risk management approaches in temporary multi-organizations identifies four main differences compared with previous studies in risk management. First, the author discovered that the literature considers the threat of the risk but not the opportunity that can also be implied. Second, previous research focused on anticipated risks; hence, it is suggested that future research should better address the full scale of risk types and analyze their nature and relative balance or significance in different project types. Third, Lehtiranta concluded that temporary multi-organizations can be helpful for collaborative risk management by involving the participant organizations in the risk management process. Finally, the shared approaches to project risks that are common to several participants are advisable in temporary multi-organization projects, rather than the risk being assigned to a single participant. This bibliometric study is largely a reduction to a temporal evolution of the articles, and risks are grouped according to their nature (anticipated/specific, unanticipated, or unrealistic). Therefore, there is a minor overlap with this article, since Lehtiranta (2014) focuses on temporary multi-organizations and only four journals, whereas our article considers megaprojects, a greater number of journals, and a more in-depth bibliometric analysis.

Finally, Taroun (2014) reviews the literature on risk models and risk assessment in construction projects in articles published in academic journals on the construction industry, project management, risk analysis, and management science, and performs searches, with no time restrictions, in six databases (Science Direct, Web of Science, ABI-Inform (Proquest), Business Source Premier (EBSCO), Emerald, and Sage Management & Organization Studies), and in Google Scholar. The keywords used are 'project risk,' 'construction risk,' 'risk analysis,' 'risk assessment,' 'risk modeling,' and 'risk management.' From the total of 400 references resulting from the search, 68 meet the objectives of the article, thus including references from the 1960s, which enable the concept of risk to be studied from this perspective. The study provides a detailed analysis of the definitions and elements that underlie the concepts of risk models and risk assessment in construction projects. The author also determines the main tools and theories that support the two concepts. One of the main conclusions of the study is that there is a lack of a general framework for assessing the risk presented by the various types of impact that construction risk can have on many project objectives.

The four articles analyzed (Zhang, 2011; Rezakhani, 2012; Lehtiranta, 2014; Taroun, 2014) slightly overlap with our research. One major difference is that our article focuses on megaprojects, whereas the aforementioned articles focus on projects in general or on a particular type of project. Furthermore, the present article provides a more detailed bibliometric analysis, since we study a wider range of variables (see the third section). In addition, the current research has a different scope, since there are no limits to the type of risk, the type of project, the sector analysed, and takes all the main databases into account. Finally, the research objectives are different in each study.

Previous Classifications of Risks in Megaprojects

Risk classification is a key part of the risk identification phase and is also of great use in the subsequent steps. Nevertheless, there is no consensus on risk categorization in megaprojects in the literature. Several classifications based on the range of variables can be observed. Bruzelius, Flyvbjerg, and Rothengatter (2002) propose a classification that is too general for the identification phase because they simply distinguish between: (1) cost risk: construction, maintenance, and operation; (2) demand risk: traffic forecast, and revenues; (3) financial market risk: future interest rates; and (4) political risk: regulation, parallel public investment, and pricing in adjacent parts of the network.

Little (2011) develops a wider classification and considers that the risks that should be taken into account in megaprojects are:

- Political risks, such as an unanticipated change in government, cancellation of a concession, unanticipated tax rises, arbitrary toll or fee imposition or increases, and new and unilateral regulatory policies.
- Construction risks, such as incorrect or inappropriate design, delays in land acquisition or escalation of land costs, project delays, unanticipated site conditions, and poor contractor performance.
- Operation and maintenance risks, such as the physical condition of a concession facility, operator incompetence, and poor construction quality.
- Legal and contractual risks, such as the concession warranty and incomplete or inadequate contracts.
- Income risks, such as inaccurate estimates of traffic volume or revenue, the construction of a competing facility that would reduce the level of use and forecast profitability.
- Financial risks, such as inflation, local currency devaluation and difficulty for conversion to hard currency, interest rate fluctuations, changes in monetary policies, and highly leveraged positions.
- *Force majeure*, such as wars, natural disasters, extreme weather conditions, and terrorism.

From a different perspective, Bing, Akintoye, Edwards, and Hardcastle (2005) propose a distinction between macro, meso, and micro levels of risk. The macro level of risk comprises exogenous risks, whereas the meso level of risk includes endogenous risks, and last, the micro level represents the risks found in the stakeholder relationships formed during the procurement process due to the inherent differences between the public and private sectors in contract management. The following specific risk factors can be found at each level:

- Macro-level risks: (1) political and government policy, (2) macroeconomic, (3) legal, (4) social, and (5) natural.
- Meso-level risks: (1) project selection, (2) sources of financing, (3) residual value, (4) design, (5) construction, and (6) operation.
- Micro-level risks: (1) internal and (2) third-party relationships.

Rolstadås and Johansen (2008) and Westney and Dodson (2006) propose alternative risk groups. These authors distinguish between strategic risk (prospective impact on earnings or capital from adverse business decisions, improper implementation of decisions, or lack of responsiveness to industry changes) and contextual risk (connected with circumstances external to the project, which may influence the scope of the work and the performance of the organization).

Krane, Olsson, and Rolstadås (2012) and Krane, Rolstadås, and Olsson (2010) classify the risks according to the project's objectives: operational risks (related to the project's operational objectives, restricted to the direct results of the project), short-term strategic risks, and long-term strategic risks. Finally, Turner (2005) distinguishes between business risk (related to the uncertainty of estimates) and insurable risks (due to the occurrence of an unplanned event).

This wide range of classifications means that no standard classification is applied. Furthermore, after studying these classifications, we found that no broad and homogeneous classification exists. The need for a new classification of risks arises for two reasons. First, existing classifications remain insufficient to identify all types of risks found in our bibliometric analysis; and second, the classification should be a source-oriented grouping of potential risks that organizes and defines the total risk exposure of the megaproject (Mojtahedi, Mousavi, & Aminian, 2008). In consequence, our second objective is to systematize and classify the potential risks to be managed in a megaproject.

Methodology

A systematic literature review of risk management in megaprojects has been performed to achieve the objectives. In the literature we find two types of literature reviews: the traditional or narrative review and the systematic literature review (Cronin, Ryan, & Coughlan, 2008). As Hemingway and Brereton (2009) explain, a systematic literature review differs in that there is a peer-review and the findings can be replicated. A systematic review can be defined as a process of 'synthesizing research in a systematic, transparent, and reproducible manner with the twin aims of enhancing the knowledge base and informing policymaking and practice' (Tranfield, Denyer, & Smart, 2003). Due to its structured approach, the systematic review has been widely accepted in a variety of scientific fields, such as the social sciences (Tranfield et al., 2003), education (Oakley, 2003), and supply chain management (Alfalla-Luque, Medina-Lopez, & Dey, 2013; Fabbe-Costes, Jahre, & Roussat, 2009).

Our review follows a strict process that can be divided into five steps (Alfalla-Luque, Medina-Lopez, & Dey, 2013; Medina-Lopez, Marin-Garcia, & Alfalla-Luque, 2010): (1) identification of the field of study and the period to be analyzed; (2) selection of information sources; (3) search; (4) management and debugging of search results; and (5) analysis of the results.

In the current research, the field of study is risk management in megaprojects and the period analyzed covers articles published between 2000 and 2013, since modern risk management has evolved substantially over the last decade (Fukayama et al., 2008). This change in risk management has been caused by a variety of factors, such as the shift from dangerous physical work toward knowledge-intensive work; the growing importance of projects, such as the framework for planning and executing work in organizations; the central role of technology and its inherent uncertainty; ever-increasing competitive pressures, and the increasing regulation with which businesses must comply (Fukayama et al., 2008). The evolution over the last decade is linked to a substantial increase in the number of megaprojects undertaken (Kardes, Ozturk, Cavusgil, & Cavusgil, 2013), and an increasing number of megaprojects have appeared since 2000 (Jia, Yang, Wang, Hong, & You, 2011).

The information sources selected are three relevant academic databases: WoK, Scopus, and ABI Inform. A wide-ranging search limited to scientific journals and proceedings was carried out examining the abstract, title, and keywords for the keyword 'risk' in combination with 'megaproject' or 'mega project' or 'big project' or 'complex project' or 'large project.'

The search yielded 365 articles (WoK: 69; Scopus: 114; ABI: 182). The references were then stored in *RefWorks* with 30 duplicate references. The remaining 335 articles were assessed for their suitability for our research objectives. Following the same process applied by other literature reviews (Frishammar, Kurkkio, Abrahamsson, & Lichtenthaler, 2012; Mok, Shen, & Yang, 2015), a strict selection of references followed. In the first phase, some articles were screened out after reviewing their titles and abstracts. In the second phase, some references were excluded after a review of the article's text. After this two-phase process, 83 articles were eventually selected because their principal focus was risk management in megaprojects. The low proportion of articles selected is justified by the keywords used covering a wide range of concepts and the search being performed only of the abstract, title, and keywords.

A bibliometric analysis was conducted of the 83 references. Each article was tabulated using ATLAS.ti data analysis software. Open codes were assigned to identify risks, definitions, and other aspects of the literature. A checklist was also created in Excel and reviewed by several experts. This tool was used to classify the articles according to several variables. Each article was checked by two of the study's authors. When there was any doubt, there was discussion about the article to determine the correct category in the checklist to which it should be assigned. The analyzed variables can be grouped as follows:

- Basic information about the article: journal, year of publication, number of authors, and number of author institutions.
- Type of research: research methodology, type of analysis, longitudinal or

cross-sectional study, data analysis methods, and information sources.
- Characteristics of the megaproject: project analysis, geographical area, sector, and project life cycle phase.
- Types of risks identified in the article.
- Methodology employed to deal with risk.

Once this first stage of the analysis had been completed, a content analysis of the selected articles was performed to systematize risks. Content analysis is a method that can be used with qualitative or quantitative data, both inductively and deductively (Elo & Kyngas, 2007). This methodology selects, filters, and summarizes large volumes of data, thus facilitating data analysis (Gao, 1996). As it is a systematic technique, it can be replicated by other researchers (Weber, 1990). Systematization was carried out because our analysis found no agreed-on list of risks in the literature. The results of the analysis are explained in the following section.

Journal Title	Number of Articles	Percentage of the 83 References
International Journal of Project Management	10	12.05%
Project Management Journal®	4	4.82%
American Association of Cost Engineers International Transactions	3	3.61%
Public Works Management & Policy	3	3.61%
Journal of Civil Engineering and Management	2	2.41%
Journal of the Operational Research Society	2	2.41%
Transport Policy	2	2.41%
Other journals with a single reference	57	68.87%

Table 1: Journals with multiple published articles.

Analysis and Discussion of Findings

Bibliometric Analysis

A total of 83 references were analyzed; of these, 79.52% (66) were journal articles and the remaining 20.58% (17), conference papers. The references were grouped in 47 journals and 17 conference proceedings, with a low concentration in specific journals; we found only seven journals with two or more articles (Table 1). The *International Journal of Project Management* had the highest number of articles (10), followed by the *Project Management Journal®* (four articles).

For the most part, the number of authors per article was one (33.73%) or three (33.73%), with two authors in 21.69% of the articles. Regarding the authors' institutions—55.42% of the references (46) had authors from a single institution; 27.71% (22) from two institutions; 15.66% (13) from three institutions; and a single reference (1.20%) from four. Therefore, approximately 45% of the references were joint articles affiliated with various institutions.

Figure 2 shows the evolution of publications per year from a longitudinal perspective. In general terms, the production rate of articles in this field has increased over recent years. Almost half of the existing articles were published

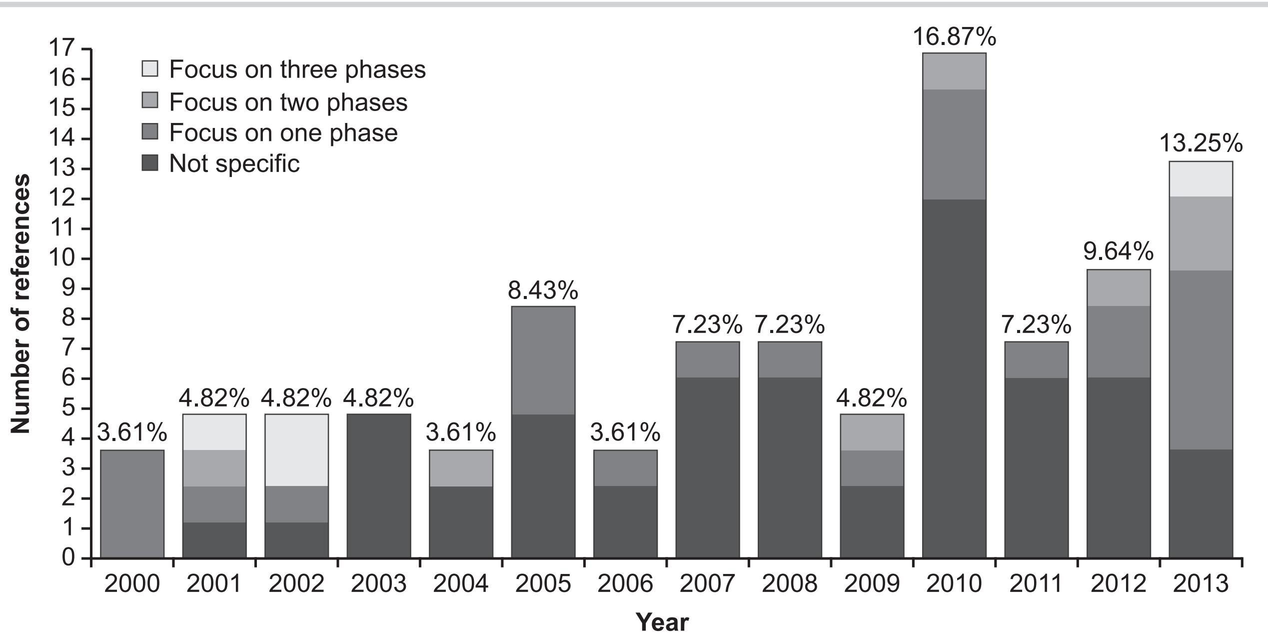

Figure 2: Number of references analyzed per year and life cycle phase.

between January 2009 and December 2013. Interest in this topic has clearly continued to rise in recent years; the years 2010 and 2013 especially stood out as to the level of research carried out, which was not due to the publication of any special issues devoted to the topic.

We also analyzed the phases of the megaprojects upon which the studies focus. As it is widely known, the life cycle phases of a project or megaproject can be summarized as: the planning/development phase, the construction/execution phase, and the operational phase. Only 34 articles specify the phase analyzed, whereas most of the references fail to specify the phase (49 references). Almost 30% of the 83 references focus on the planning/development phase, 16.87% on the construction/execution/delivery phase, and 14.10% on the operational phase. Figure 2 shows the articles per year that focus on one (27.71%), two (8.43%), and three (4.82%) phases, respectively. There is no noticeable trend during the period regarding this issue.

Type	Number of References	Percentage
Case study	34	40.96%
Single case	23	27.72%
Multi-case	11	13.25%
Theoretical/conceptual (T/C)	30	36.14%
Models and simulations (M/S)	24	28.92%
Survey analysis	7	8.43%
Field research/field experiments	3	3.61%

Table 2: Research methodology.

Table 2 shows the research methodology employed. It must be taken into account that an article can be categorized in more than one research methodology. For example, there are some articles classified as models and simulations and also as case studies, because they use or propose a model and develop a case study to test said model. The most commonly employed research methodology observed is the case study. Case studies represent 40.96% of the articles, of which 67.65% are a single case study. Theoretical/conceptual articles make up 36.14% of the total, and 28.92% include a model or simulation. No literature reviews were found.

An analysis of the temporal evolution of the methodology (Figure 3) reveals that case studies have increased and models and simulations have decreased in recent years. However, theoretical/conceptual studies have been developed throughout the whole period, which reflects the need for theory in this field. This need is a common feature in areas of research that are still in their early stages of development.

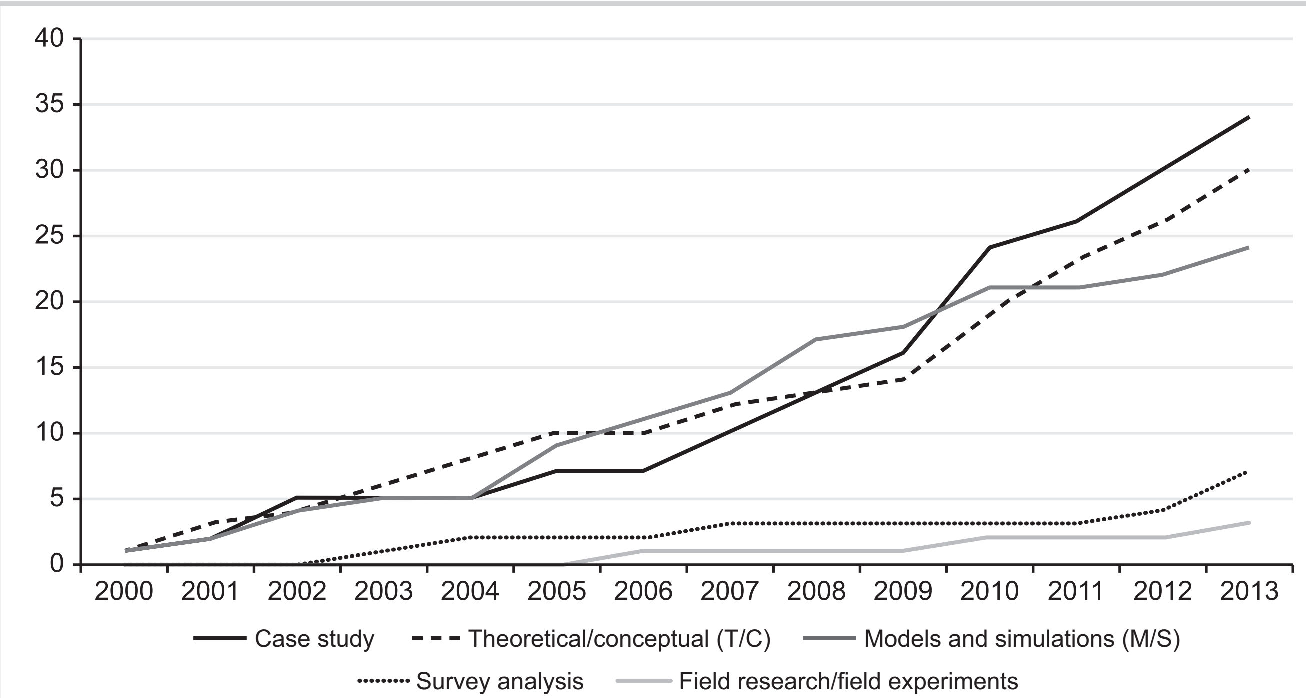

Figure 3: Temporal evolution of research methodologies.

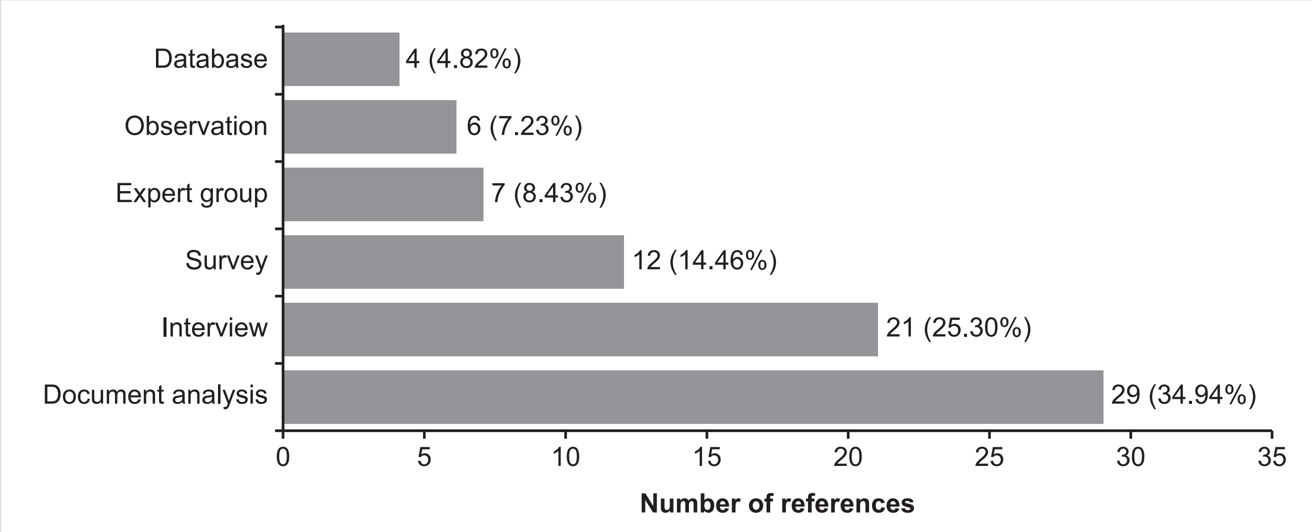

Figure 4: Information sources.

Survey analysis has seldom been used, despite being the third most employed research methodology in 2013.

The articles primarily developed cross-sectional (or transversal) studies (92.77%) rather than longitudinal studies (7.23%). With respect to the qualitative and quantitative focus of the articles, 54 references employed a qualitative focus and 17 a quantitative analysis; however, 12 references applied both types of analysis. The temporal evolution of qualitative and quantitative analyses shows no noticeable trend.

Information collection methods are also considered (Figure 4). A mere 43 references (51.8%) indicate how the information is obtained, although it is possible that any of the articles could have used a variety of sources. The most commonly used information sources are documents (34.94%), interviews (25.30%), and surveys (14.46%). Session groups are also used in certain studies, especially those with expert risk identification and assessment.

The temporal evolution of the information sources used (Figure 5) demonstrates that document analysis was the predominant source up to 2008;

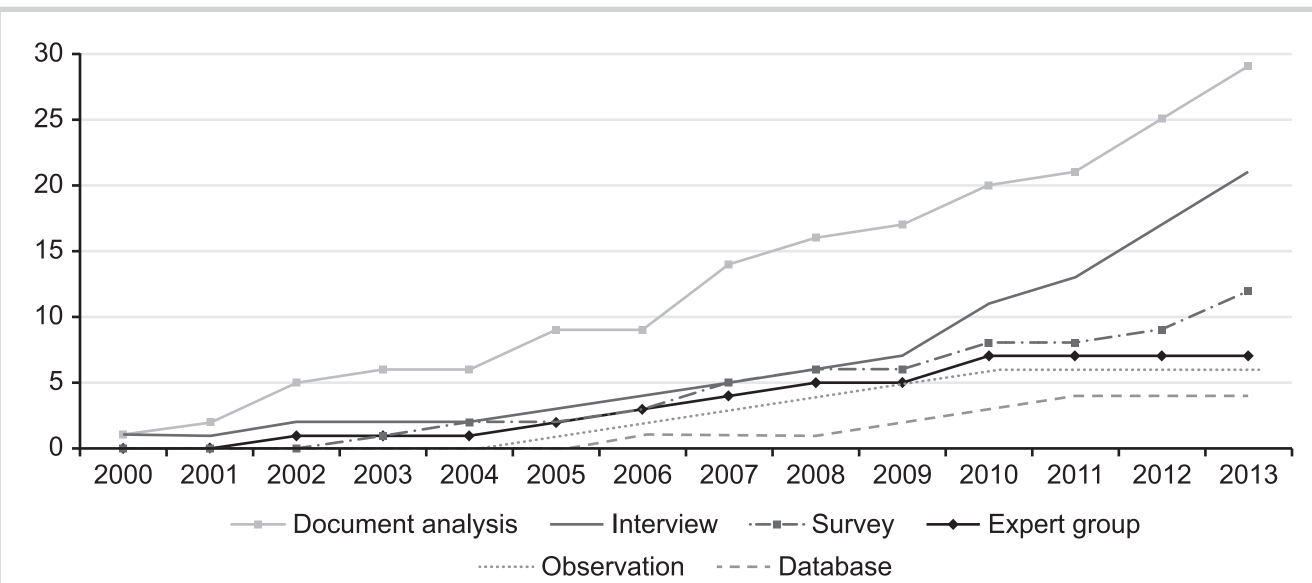

Figure 5: Temporal evolution of methods of information sourcing.

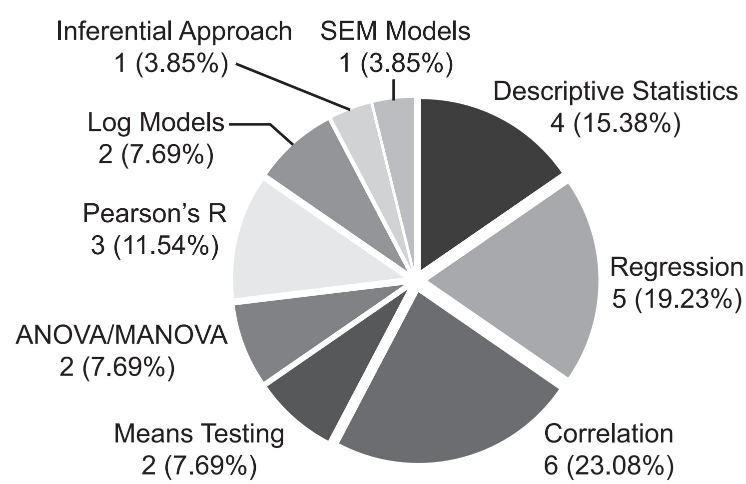

Figure 6: Data analysis methods.

however, interviews have become the most used information source since 2009. This coincides with the increase in case studies (see Figure 3), in which interviews are a commonly used tool.

In relation to the data analysis method, only 15 articles (18%) developed a statistical analysis, although more than one methodology may have been used in the same article. The percentage of use of each methodology is shown in Figure 6. The most commonly employed data analysis method was correlation and regression tests.

With respect to the sector of the megaprojects, a total of 49 articles (59%) focused on a specific sector (Table 3). The most researched sectors were rail (underground, high-speed rail, toll roads, and so forth) and road (avenue, tunnels, and so forth) with nine references each, followed by three sectors: large buildings (construction in general), energy (nuclear plants, electrical plants, hydropower, and so forth), and refinery (oil and gas), each with six references. It should be borne in mind that there were some multi-case studies with articles focusing on more than one sector.

The geographical areas of the megaprojects were also analyzed (Table 4). Only 31 references (37.3%) indicated the geographical area of the megaprojects or the geographical area of the study in relation to megaprojects, such as when a survey was employed. One article might have analyzed more than one megaproject in more than one country; as a result, partial totals may differ from the overall total. The megaprojects most commonly studied were executed in Europe (16 articles), followed by North America (9 articles). No study located in Africa was found. In terms of country, the majority of the studies focused on the United Kingdom (5 articles) and the United States (5 articles), followed by Australia and the Netherlands (4 articles each) and Canada (3 articles).

A total of 68 different cases were identified, although 30 of these cases were in a single article (Dimitriou et al., 2013). The majority of the cases appeared only once, and only two of the cases were the subjects of study three times: *Environ Mega-Project (Gideon's gang)* and *London Heathrow's Terminal 5*.

Finally, we looked for the approaches employed by the decision makers to deal with risk, identifying those applied in each article. Currently, there is a wide range of tools and techniques for managing risks in construction projects (Goh, Abdul-Rahman, & Abdul Samad, 2013). In the same way, there is no single successful approach to risk management, as Brady and Davies (2014) conclude regarding their case-study comparison of two successful projects. Our literature review confirms this and highlights the lack of a single set of risk management models in megaprojects; instead, there is a range of proposals supported by different tools or variables. A total of 27 references (32.5%) met the objectives of this section.

Table 5 summarizes the 27 references identified and sorts them according to the phase of the risk management process to which they refer (see Figure 1). All the references propose their own model or tool for handling risk. They usually focus on one phase, although nine references propose models to handle risk throughout the entire risk management process.

Sector	Number of References	Percentage of the 83
Rail	9	15.25%
Road	9	15.25%
Buildings	6	10.17%
Energy	6	10.17%
Refinery	6	10.17%
Airport	4	6.78%
Aeronautical	2	3.39%
Space exploration	2	3.39%
Other	15	25.42%

Table 3: Number of references per sector.

Geographical Area	Number of References	Countries
Europe	16	Denmark (2), Finland (1), France (2), Germany (2), Greece (1), Netherlands (4), Norway (1), Sweden (2), Turkey (1), United Kingdom (6)
North America	9	Canada (3), United States (6)
Asia	7	China (2), Hong Kong (1), India (2), Thailand (1), Turkey (1)
Australasia	4	Australia (4)
Central and South America	1	Brazil (1)

Table 4: Number of references per geographical area.

Proposal of Risk Categorization

As previously outlined, risk categorization is a key step in the risk management process. Nevertheless, there is no evidence of a consensus on risk classification in the literature due to the complex nature of risk. The study of existing classifications in the literature (see previous section on Classifications of Risks in Megaprojects) highlighted this lack of systematization. Consequently, at the outset of the bibliometric analysis of the 83 references, it was noticed that there was no classification that included the broad variety of risks detected. As explained at the end of the second section, therefore, we develop a proposal of risk categorization based on an in-depth study of the prior literature. Our objective was to create a classification of risks: (1) to unify and extend as far as possible the categories found in the literature; and (2) to frame the wide variety of risks that may arise that could not be placed in existing categorizations. The broader the risk classification, the more likely and easier is the identification of the risks that must be managed. Effective risk management requires a careful risk identification whereby no factor should be left that may affect the megaproject in a substantial way. Therefore, a broad classification of risks is merely a guide to the identification and classification of risks. This is the first step in a risk management process, which continues by assigning probabilities of occurrence and impact on the megaproject in order to subsequently decide what action should be taken to manage each of the risks.

We propose a total of nine homogeneous categories that encompass all types of risks included in previous classifications and all the risks identified in the 83 references analyzed, specifically:

1. Design risks are those mainly related to the planning/design phase of the megaproject, such as delivery method, contract formation, bid cancellation (pre-investment risk, risk of non-recovery of pre-investment costs), land use and acquisition risk (site availability risk), feasibility analysis, and scope of project control. Examples of such risks may be found in Bradshaw (2008) Bruzelius et al., (2002), and Owens, Ahn, Shane, Strong, and Gransberg (2012).
2. Legal and/or political risks deriving from changes in the governing policy of the country in which the megaproject is being undertaken, for example, authorization criteria, political actors, changing government regulations, and cancellation of a concession. The risks discussed in Giezen (2012) and Owens et al. (2012) are included in this section.
3. Contractual risks include those that derive from the renegotiation of the contract, such as the midstream change of project scope and problems caused by imprecision and vagueness in the contract. Dettman, Harty, and Lewin (2010) detected these types of risks.
4. Construction risks are usually the most significant in the whole life cycle of the megaproject. These usually occur during the construction phase but can also occur in any phase of the megaproject. The occurrence of

Phase	Reference
Risk identification and risk assessment	Dulac & Leveson (2005); Mojtahedi et al. (2008)
Risk assessment	Bender & Ayyub (2001); Chen et al. (2007); de Palma et al. (2012); Dillon, John, & Von Winterfeldt (2002); Fisher, Greanias, Rose, & Dumas (2002); Jia, Wei, & Wei-geng (2007); Kim (2010); Lauras, Marques, & Gourc (2010); McCabe (2003); Reilly (2005); Wang, Liu, & Chou (2006); Willems, Janssen, Verstegen, & Bedford (2005)
Risk mitigation/risk treatment	Chen & Chang (2001); Dillon, Pate-Cornell, & Guikema (2005); Kirk & Garrett (2005); Klastorin & Mitchell (2013); Marle, Vidal, & Bocquet (2013)
Full process	Cates & Mollaghasemi (2007); Dey (2010); Kardes et al. (2013); Lyneis, Cooper, & Els (2001); Turner (2005); Vidal & Marle (2008); Williams (2003); Yan & Xu (2010)

Table 5: References with risk management models classified by phase.

these risks may incur consequences in terms of cost overruns (or cost escalation) and/or project schedule delays. Construction errors, unexpected technical difficulties, failure to comply with the agreed on quality standards, coordination problems, and inappropriate design or accident during construction, are examples of risks classified in this category. Giezen (2012), Santoso, Ogunlana, and Minato (2003), and Vit (2011) study these types of risks.

5. Operation and maintenance risks are those related to the operational phase that can affect the operation cost, operation capacity, or quality, including economic viability issues, unnecessarily high operations costs, poor construction quality, and operator incompetence. Brady and Davies (2010), de Sousa Júnior and Reid (2010), Gil, Miozzo, and Massini (2012), and Santoso et al. (2003) analyzed these risks.
6. Labor risks are linked to workers and include training, language difficulties, accident cost, and cultural differences. These risks can arise at any stage of the megaproject, especially during the construction operational phases. A wide variety of labor accidents that fall within this type of risk are discussed in Wang et al. (2006).
7. Customer/user/society risks are those that affect revenues. Customers are those who buy the product or service, users are those who use the product or service, and society is that which benefits from the social profitability of the project. These risks include:

    a. Demand risks, relating to the level of sales in megaprojects where users pay charges during the operational phase. These are affected by factors such as variations in the rate of inflation, price trends, and price range. Severance (2009) analyzed these risks.
    b. Market risks, such as variations in the customer's requirements and the existence of a market for the megaproject, as outlined by Dillon et al. (2005).
    c. Social profitability risk, which queries whether the project provides the expected benefits to society as deemed by Jennings (2013).
    d. Social impact—related to the risk of impact on society—on local groups and on the people involved and their acceptance of the megaproject. The risk of causing an impact on local groups arises when the inhabitants of an area are a source of risk due to not being managed correctly. In this classification, we include the NIMBY ('Not-In-My-Back-Yard) groups as reaction–opposition. For example, Giezen (2012) studies these risks.
    e. Environmental risks, which are usually called environmental impact assessments and are considered by authors, including Bedi (2013) and Owens et al. (2012).
    f. Reputational risks, including media and marketing control, as identified by Owens et al. (2012).

8. Financial and/or economic risks encompass a variety of events related to the financing and performance of the megaproject. These are composed of:

    a. Economic risks relating to investment in the megaproject or its economic structure, such as lower-than-expected profitability, asset residual value risk (i.e., technical obsolescence), residual transfer value, and inappropriate metrics used in the project. These are analyzed by Williams (2003).
    b. Financial risks due to the high level of leverage, which exerts an impact on the megaproject's solvency, as a result of high leverage or downgrading of the credit; liquidity problems, such as credit constraints, shortages in the availability of funds; and risks caused by changes in the exchange rate and/or interest rate, resulting from the long-term contracts that are made for this type of project. Owens et al. (2012) and Severance (2009) detailed these risks in their articles.

9. *Force majeure* risk, such as war, natural disasters, extreme weather conditions, terrorism or the case of a natural collapse, as mentioned by Davies, Gann, and Douglas (2009).

Table 6 assigns each of the outlined risks to the phase of the megaproject where it is most likely to appear; however, all risks must be considered and analyzed during the planning phase.

Next, we analyze the references using the proposed classification (Table 7). The main risk studied in the literature is construction risk (43.37%), largely in terms of its impact on cost and project schedule overruns. Risks related to customers and society are the second most studied (14.46%), including ROI and the impact of the megaproject on society. There are a limited number of studies on risks relating to *force majeure* and workers. Over 44% of studies (37 references) analyze risk from a general perspective. A lack of research in certain sectors can be observed in certain types of risk and in some sectors. Research into aeronautics focuses on construction risk, whereas rail and road are the sectors in which a greater variety of risks are studied.

Conclusions, Managerial Implications, and Further Research

This article focuses on the first phase of the risk management process, risk identification. In line with Burcar et al. (2013), our review highlights the lack of consensus on this topic, and different concepts and approaches to risk are observed, which results in a variety of terminology, definitions, and explanations. Our study serves as a comprehensive basis for understanding the current research on risk management

<table>
<tr><th>Planning/Development Phase</th><th>Operational Phase</th><th>Construction/Execution Phase</th></tr>
<tr><td rowspan="2">• Design risks</td><td>• Operation and maintenance risks
• Demand risks
• Market risks
• Social profitability risks</td><td>• Construction risks</td></tr>
<tr><td colspan="2">• Labor risks
• Environmental risks
• Financial risks
• Economic risks</td></tr>
<tr><td colspan="3">• Legal and/or political risks
• Contractual risks
• Risk of impact on local groups
• Reputational risks
• Force majeure risks</td></tr>
</table>

Table 6: Types of risks per phase of the megaprojects most likely to occur.

in megaprojects, the main types of risk to be considered, and the key practical and research implications. Our study confirms the current importance of risk management in megaprojects, since the number of articles in this field has increased in recent years, in keeping with the gaining importance of this topic (Dimitriou et al., 2013; Greiman, 2013; Lehtiranta, 2014). However, research in the field is scarce. There is a lack of empirical studies that provide an in-depth analysis of the various aspects of the process during the different life cycle phases. Numerous theoretical/conceptual articles (36.1%) have been identified throughout the whole period, revealing a need to create a body of knowledge in this field of research. The most common type of empirical study is the case study, with a single case being presented in general terms. More research, in general, and more detailed case studies and survey studies, in particular, are required in order to develop or corroborate theories on this topic, which would facilitate the risk management process, thus contributing toward the success of a megaproject. Still, there are only a limited number of studies that perform statistical analyses and test hypotheses; consequently, a meta-analysis to provide aggregated results that would improve research and practice in this field is unviable. This also highlights the need for further studies along this line.

Type of Risk Sector	General	Design	Legal Political	Contractual	Construction	Operation	Labor	User	Financial	*Force Majeure*
Aeronautical	1	0	0	0	1	0	0	0	0	0
Airport	0	0	1	0	2	3	0	1	0	1
Buildings	2	1	1	0	4	1	0	1	0	0
Energy	2	1	0	0	4	1	0	2	1	0
Rail	2	1	2	2	6	0	0	2	2	0
Refinery	5	0	0	0	0	0	0	1	0	0
Road	3	1	1	2	3	1	0	1	0	0
Space exploration	2	0	0	0	0	0	0	0	0	0
Other	7	1	1	0	6	1	0	4	1	0
(non-specific)	15	1	1	0	13	0	1	2	2	0
Percentage *	44.58%	7.23%	7.23%	4.82%	43.37%	8.43%	1.20%	14.46%	7.23%	1.20%

* Percentage of each type of risk over the total of 83 references. The sum of these percentages exceeds 100%, because some of the articles studied different types of risks found in multiple sectors.

Table 7: Number of references by sector and type of risk.

Furthermore, there is a lack of longitudinal studies analyzing the evolution of risk management models and their results over time, as along with a shortage of studies analyzing the different stages of a megaproject's life cycle and the way in which decisions are made in the initial phases affect the later stages. Further research is required in sectors neglected in the literature to ascertain whether different risks are detected, and whether the risks in these sectors are managed using different techniques; many industries have not yet been covered by research. Moreover, our literature review has highlighted the lack of a consolidated way of dealing with risk, finding no evidence of the existence of a single set of risk management models in megaprojects; rather, there is a variety of proposals supported by numerous tools and/or variables.

A risk classification is required for systematic risk management (Burcar et al., 2013). Nevertheless, no agreement as to risk categorization in megaprojects can be observed in previous articles. Several classifications can be found in the literature, with different approaches (Bing et al., 2005; Little, 2011; Rolstadås & Johansen, 2008; Rothengatter, 2008). The need for a more comprehensive categorization is motivated by the fact that no systematic classification has been found that includes the broad range of risks identified in the literature review. Our categorization encompasses all the types of risks studied in the literature, whereas other classifications are limited by the exclusion of certain risks. A total of nine main risks have been identified and defined. This research confirms that the most frequently identified risks in project and megaproject management are construction risks, which may cause high cost and schedule overruns. These risks have already been identified in the literature as the main problems in megaprojects (Altshuler & Luberoff, 2003; Flyvbjerg et al., 2003); therefore, this articles shows that megaprojects continue to fail due to the same mistakes being made as in the past, thus a new way of addressing these risks is needed. A lack of studies that focus not solely on construction risks but also on other types of risks has also been detected. Furthermore, additional research and managerial effort are needed with respect to the remaining types of risk, since all these risks have an influence on the execution of a megaproject.

The results presented in this article are relevant for both practitioners and researchers. Practitioners are able to examine a synthesis of different aspects of the risk management process, with special emphasis on the risk identification phase. A comprehensive categorization of risks in megaprojects is provided to assist practitioners during this phase, which also serves as a support for the subsequent steps in the risk management process, such as risk analysis, risk evaluation, planning risk response, and monitoring and control. Finally, the importance of cost and time control for megaproject management has been clarified, but this should not be to the detriment of the attention paid to other types of risks. Appropriate risk identification could help to establish mitigation strategies that reduce the possible negative effect of these risks.

For researchers, our study presents a systematic literature review of risk management in megaprojects and identifies gaps in the literature, enabling them to further contribute toward a better understanding of risk management's effects on performance measures. There is still a lack of empirical studies and well-documented case studies on several megaproject sectors and life cycle phases. Empirical data, obtainable through surveys and in-depth interviews with managers and stakeholders, is still in short supply. Longitudinal studies are also required. Furthermore, it has yet to be demonstrated whether the findings obtained for a specific project and sector can be generalized or how this can be done. Additional case studies and surveys are needed to corroborate findings and test hypotheses in order to improve the risk management process.

This article identifies the most important risks addressed in the literature and provides evidence that more research is necessary in the area. Further research into how these risks are managed in megaprojects is called for in an effort to identify risk mitigation and coverage measures. In other words, research should continue with the subsequent steps in the risk management process (qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control). Future research could include the application of the proposed risk classification and the remainder of the risk management process to a megaproject case study.

A number of limitations have arisen during the development of this article due to the methodology used. The main limitation identified was the inability to use an initial broader search criterion combining 'risk' and 'project,' which would have enabled the subsequent selection of references meeting the condition to be considered as megaprojects. Such a search was not possible, since the combination of such generic keywords yielded an output of approximately 100,000 references. Furthermore, with respect to the search criteria, the terminology relating to megaprojects used in the literature can be noted as a second limitation. Although the use of the term 'megaproject' is well-established in the literature, it is not employed by all authors, and other similar terms (such as 'complex project') have been used.

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