



\*27<sup>th</sup> IPMA World Congress

## Risk Management in Megaprojects

Ana I. Irimia-Diéguez<sup>a\*</sup>; Alvaro Sanchez-Cazorla<sup>a</sup>; Rafaela Alfalla-Luque<sup>a</sup>

<sup>a</sup>*Faculty of Economics and Business Administration, University of Seville, Av. Ramón y Cajal, s/n, 41018 Seville*

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### Abstract

Despite its high relevance to the success of megaprojects, risk management remains one of the least developed research issues. Risk management is a process composed of several phases. This paper is focused on the first of these phases: risk identification. Our purpose is to establish the state of the art in risk management in megaprojects, systematize the risks studied in the literature, as well as to identify potential areas of further research. To this end, a systematic review is carried out. Academic journals and conference papers published from 2000 onwards in main databases (WoK, Scopus and ABI) have been examined. A qualitative analysis has been performed by using ATLAS.ti together with a checklist. To the best of the authors' knowledge, no previous systematic revision of papers on risk management in megaprojects has ever been carried out, although certain authors have emphasized its importance.

The contribution of this research includes: a bibliometric analysis of the papers that focus on risk management in megaprojects; a systematization and classification of the risks; two matrices comprised of the proposed risk categorization, first in relation to the sector studied, and second related with the different stakeholders; and an identification of gaps in the research in risk management in megaprojects.

The systematization of the risks helps managers towards their identification within the megaproject, and to follow the subsequent steps in the risk management process. Moreover, the matrix developed on the transfer of risks can enable managers to analyse who would be the best partner to support each risk. Furthermore, from an academic point of view, potential areas for future lines of research are presented.

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Selection and peer-review under responsibility of the IPMA.

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\* Corresponding author. Tel.: +34-954-559875; fax: +34-954-557570.  
E-mail address: [anairimia@us.es](mailto:anairimia@us.es)

*Keywords:* megaproject; complex projects; risk management.

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## 1. Introduction

Risk Management can be defined as the systematic process of identifying, analysing and responding to project risk. It has six steps: planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk monitoring and control (Dey, 2012; PMI (Project Management Institute), 2008). Furthermore, it is an expanding field which literature has shown can be used not only for control against loss, but also as a way to attain greater rewards (Dey, 2012; Wu & Olson, 2008).

Risk constitutes an essential factor for consideration since it can affect both the cost-benefit analysis during the whole process of a project, and the demand, production costs, execution time, and financial variables (de Palma, Picard, & Andrieu, 2012). Even though this study is necessary in every project, it is especially relevant when we talk about megaprojects, where these issues are a reality.

Several definitions of megaprojects can be found in the literature. The characteristics that may classify a project as megaproject are an investment over \$1 billion, high uncertainty, possible intangible benefits and attractive long-term outcomes (Eweje, Turner & Müller, 2012; Miller & Lessard, 2000). A megaproject includes many risk factors that can cause delays or failures during the project life cycle (Flyvbjerg, Bruzelius & Rothengatter, 2003). Thus, it is important to establish a method and system to manage these risk factors effectively in advance. Moreover, it is necessary to reduce the probability of such risk factors causing failures in the project by implementing models or mitigation measures.

There is a large amount of literature on risk management in projects; this becomes greatly reduced if the focus is on megaprojects. The literature has demonstrated the need to study large projects (Esty, 2004), since they provide a clean setting in which to analyse how managers make important structuring and financing decisions in response to capital market imperfections. Furthermore, due to the difficulty in studying large projects, there is a lack of academic research in this area.

As mentioned earlier, risk management is a process composed of several phases. This paper is focused on the first of these phases: risk identification. In this context, owing to the importance of risk management and the inexistence of a previous literature review of the topic in megaprojects, our purpose is to establish the state of the art in risk management in megaprojects, systematize the risks studied in the literature, and also to identify potential areas of further research. To this end, a systematic review is carried out. As a consequence of our review, our contribution becomes: (1) a bibliometric analysis of the papers that focus on risk management in megaprojects; (2) a systematization and classification of the risks; (3) two matrices comprised of the proposed risk categorization, first in relation to the sector studied, and second related with the different stakeholders; (4) and an identification of gaps in the research in risk management in megaprojects.

The remainder of this paper is organised as follows. Section 2 describes the methodology employed. Section 3 analyses the bibliometric characteristics of the papers selected in the systematic literature review. Section 4 is focused on the risk in megaprojects in the previous literature and on the development of a classification of risks. In addition, two matrices comprised of the proposed risk categorization, first in relation to the sector studied, and second related with the different stakeholders are shown. Finally, conclusions, further research and the implications of this study for practitioners and academics are presented.

## 2. Methodology

A systematic literature review (Medina-Lopez, Marin-Garcia, & Alfalla- Luque, 2010) of risk management in megaprojects has been undertaken. Using the keyword "risk" in combination with "megaproject" or "mega project" or "big project" or "complex project" or "large project", a wide-ranging search was carried out on the three most relevant data bases: ISI Web of Knowledge, Scopus, and ABI Inform by searching for in the abstract, title or keywords.

Our research is centred on papers from the year 2000 to the present day (the search was performed in March 2013) since modern risk management has evolved substantially in the last decade (Fukayama, Fernandes, & Ebecken, 2008). Furthermore, the year 2000 is marked by Passwell (2009) as the beginning of a technological revolution in communications technology, which has changed the approach to both planning models and actual system operations. At the same time, since 2000, studies on megaprojects have become more and more prevalent (Jia, Yang, Wang, Hong, & You, 2011). After the broad search, 314 papers were obtained (ABI: 150; Scopus: 95; ISI: 69), of which 30 were duplicates. Those remaining 284 references were then stored in RefWorks and were screened and retrieved for ease of selection. Since a certain number of the papers were not related with megaprojects, and others were the wrong type of paper (we only focus on research papers and conference papers), 206 references were excluded. Finally, the papers found to be focused on risk management in megaprojects numbered 78.

Each paper was tabulated using ATLAS.ti data analysis software. Open codes to identify risks, definitions and other literature aspects were assigned. A checklist, based both on previous experience in the literature review and on a first reading of our 78 references, was also created and reviewed by several experts. This tool was used in order to classify the papers, through the analysis of aspects, such as year of publication, research methodology, data analysis methods, geographical area of the megaproject, sector and type of risk studied. These aspects will be analysed in the following sections. Each paper was checked by two of the present authors. In the case of doubts, the paper was discussed in order to assign it to the correct category in the checklist.

## 3. Analysis of the bibliometric characteristics of the papers focused on risk management in megaprojects

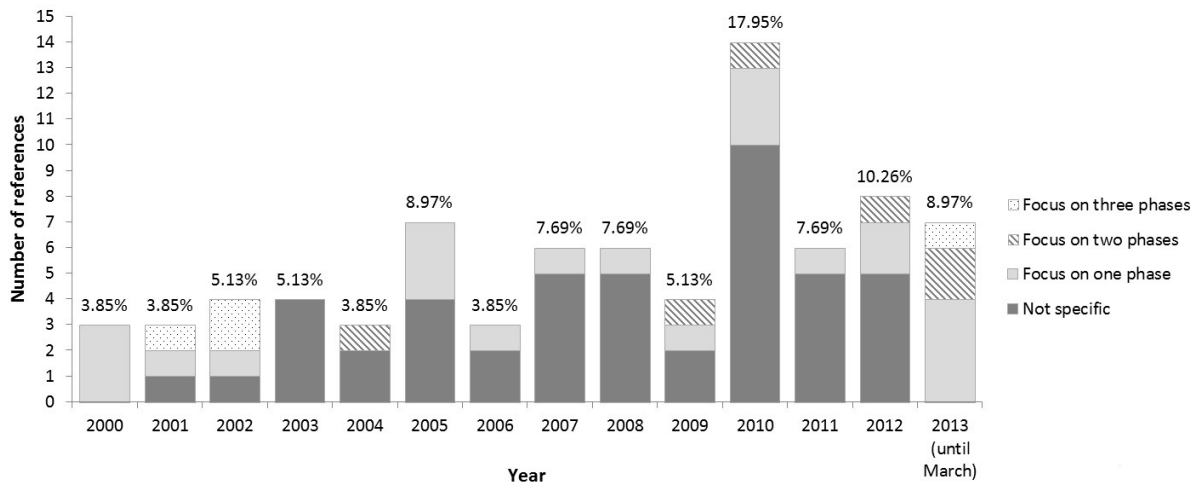


Fig. 1. References per year and phase of study

Starting our analysis from a longitudinal perspective, we can see the evolution of the publications year by year (Fig. 1). It is observed that, in general, the rate of production of papers in this field has been increasing over recent years. Between January 2009 and March 2013, 50 per cent of the articles were published. It should be borne in mind that, although the search finished in March 2013, almost the same number of papers was detected from this current year as was in all of 2012. Interest in this topic has clearly continued to increase in recent years. We have examined the number of references per journal in 2010, due to the abundance of references published that year. Just two magazines, the *International Journal of Project Management*, and the *Journal of Civil Engineering and Management*, published two papers that year, the remaining journals published a maximum of only one single paper each. There is no sign of a special issue that year. We can also remark how the *International Journal of Project Management* is the journal with the most papers published in this field: a total of 10 papers in our period of analysis. The number of authors per paper is mainly one (34.62%), two (20.51%), or three (34.62%).

We have also analysed the phases of the project upon which the study is focused (planning/development phase, construction/execution phase, and operational phase). Almost 30% of our 78 references are focused on the planning/development phase, 15.38% on the construction/execution/realization phase, and 14.10% on the operational phase. Additionally, in Fig. 1, we have also taken into account the number of papers per year which are focused on one, two or all three phases. Only 32 articles specify the phase analysed whilst most of the references fail to specify the phase.

The papers developed principally transversal (or cross-sectional) studies (92.31%), as against longitudinal studies (7.69%). The research methodology employed is analysed in Table 1. Here, a certain paper could be categorized in more than one research methodology. For example, there are articles classified as Models and Simulations because they use or propose a model, however, at the same time, they develop a case study to test the model. It is observed that the most commonly employed research methodology is that of the case study. Case studies constitute 41.03% of the papers, of which 71.88% are a single case study. Theoretical/conceptual papers make up 35.90% of the total, and 30.77% include a model or simulation. No literature review has been detected.

Table 1. Research methodology

Type	Number of references	Percentage
Theoretical/conceptual (T/C)	28	35.90%
Models and simulations (M/S)	24	30.77%
Case study	32	41.03%
Single case	23	29.49%
Multicase	9	11.54%
Survey Analysis	5	6.41%
Field research / Field experiments	2	2.56%

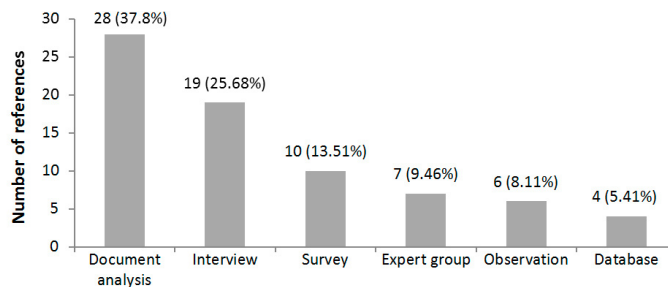


Fig. 2. Methods of information sourcing

Related to the qualitative and quantitative focus of the papers, 62 articles employed a qualitative focus, and 27 a quantitative analysis. However, it should be borne in mind that, due to the mix of various research methodologies in the studies, some papers are included in both classifications.

The methods of information collection are also considered (Fig. 2). Just 40 references indicate how the information is obtained, and at the same time, one paper can use more than one method. The methods most commonly used are those of observation (37.8%), interviews (25.7%), and surveys (13.5%). It is important to mention that session groups are also used in certain studies, especially those employed to identify and value risks by experts.

Related with the data analysis method, only 13 papers have developed some statistical analysis, although more than one methodology can be used in the same paper. The percentage of use of each methodology can be seen in Fig. 3. The most commonly employed data analysis method is that of correlation and regression tests. Furthermore, it should be pointed out that only four papers perform a hypothesis test.

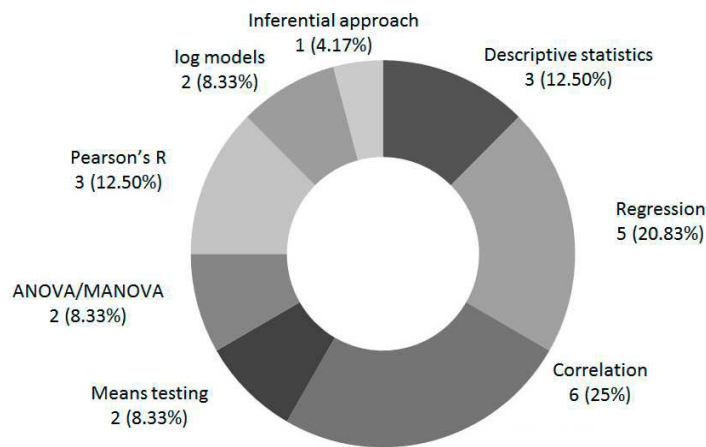


Fig. 3. Data analysis method

The sector of analysis is also considered in our checklist and will be analysed in depth in Section 4. A total of 49 papers focus on a specific sector. The most researched sectors are Rail and Road with eight references both of them, followed by three sectors, Buildings, Energy and Refinery (each with six references). Notice that since there are multicases, some papers can focus on more than one sector.

The geographical area of megaprojects has also been analysed. Only 29 papers over 78 indicate the geographical area of the megaproject (research can analyse cases developed in more than one area). The megaprojects most commonly studied are located in Europe (14 papers), followed by North America (8 papers). No study whose focus is on Africa has been found. In terms of country, the majority of the studies are focused on the United Kingdom (5 papers) and United States (5 papers), followed by Australia (4 papers) and the Netherlands and Canada (with 3 papers each).

The specific projects analysed in the papers are shown in Table 2. All the projects are defined as mega, large and/or complex projects, although the threshold of the investment is not always available in the paper. A total of 38 different cases are identified. The majority of cases appear just once, and only two of these cases are the object of study three times: Environ Mega-Project (Gideon's gang) and London Heathrow's Terminal 5.

Table 2. Specific project per sector and geographical area

Sector	Name and description	Geographical area	Country
Airport	London Heathrow's Terminal 5	Europe	United Kingdom
	New North Terminal Replacement	North America	USA
Buildings	City Planning	North America	USA
	Courthouse Standards (Ministry of Justice)	North America	USA
	K-12 School for Cherokee	North America	USA
	New Veterans' Administration	North America	USA
	Office / Bank Tower	North America	USA
	R & D Center, Renovation & New, Fortune 50	North America	USA
	Residential Tower and Townhouses	North America	USA
University Campus	North America	USA	
Energy	BeloMonte Hydroelectric Complex	Central and South America	Brasil
Mine	Niyamgiri mine	Asia	India
Rail	Beijing-Tianjin High-Speed Railway	Asia	China
	E-470, Segment 4	North America	USA
	Fehmarn Belt	Europe	Denmark and Germany
	I-15 Reconstruction	North America	USA
	I-64 Reconstruction	North America	USA
	København Metro	Europe	Denmark
	Marmaray	Asia	Turkey
	Metro project Beneluxlijn: Metro extension	Europe	Netherlands
	TH-212 DB	North America	USA
	Vancouver Island Highway Project (VIHP)	North America	Canada
	Warwick Intermodal	North America	USA
Refinery	Lanjigarh refinery	Asia	India
Road	Central Artery/Tunnel Project "Big Dig"	North America	USA
	Environ Mega-Project	Oceania	Australia
	North Side Tunnel Project	Europe	Netherlands
	Stockholm charging system	Europe	Sweden
Other	Assembly, Fortune 50	North America	USA
	DesignSolution	Europe	Finland
	Gaspesia	North America	Canada
	Haalderen	Europe	Netherlands
	Hulhuizen	Europe	Netherlands
	Hospital	Asia	Thailand
	London 2012 Olympic Games	Europe	United Kingdom
	Peace Shield Weapon System	North America	USA
	Production of a family stage musical in Paris	Europe	France
	SafetySystem	Europe	Finland

#### 4. A systematization of the risks in megaprojects and areas requiring research

As previously outlined, the aim of a risk management process (in every project size: small, medium or megaproject) is to identify and assess risks in order to enable the risks to be understood clearly and managed effectively (Mojtahedi, Mousavi, & Aminian, 2008). This process is composed of six steps: planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control. One of the objectives of this paper is to focus on the phase of risk identification through the development of a systematization and classification of the potential risks to be managed in a megaproject. After identifying the risk, a quantitative and qualitative risk analysis would be necessary. Finally, the risk needs to be planned, monitored, and controlled.

Risk management involves a variety of partners (public sector, construction company, management company,

and so on). Hence, each risk needs to be analysed and then distributed, if possible, to various partnerships, which is the key to effective risk management. If risk can be transparently identified, equitably allocated, and costed appropriately, successful projects will result (Little, 2011). Fig. 4 illustrates the risk management process. Bearing this process in mind, this paper is focused on the beginning of the analysis of risk, which attempts to identify and quantify the potential outcomes from a certain set of events. The subsequent steps continue on from this essential phase. It must be emphasized that risks are present in a megaproject from the beginning, even in the very early planning stage.

The classification of risks constitutes a basic element in this process since not only does it help in the process of risk identification, but also in the subsequent steps, including how these risks should be managed. During our study, risk categorization was found to differ widely in the megaproject literature. Several classifications based on the range of variables can be observed. Bruzelius, Flyvbjerg, & Rothengatter (2002) distinguish between only four risks (cost risk, demand risk, financial market risk, and political risk). Little (2011) considers a wider risk classification (political risk, construction risk, operation and maintenance risk, legal and contractual risk, income risk, financial risk, and force majeure). Certain authors analyse the risks from macro and micro levels (Bing, Akintoye, Edwards, & Hardcastle, 2005), while others relate the risk categories to the levels of project objectives (operational risks, short-term strategic risks, and long-term strategic risks) (Krane, Rolstadås, & Olsson, 2010).

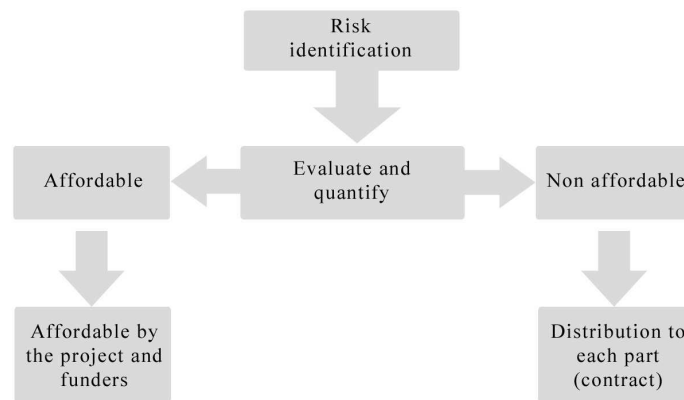


Fig. 4. Risk management process  
Source: Irimia-Diéguez & Oliver-Alfonso (2010)

Following the idea of creating homogeneous categories of risk, we propose a categorization which takes into account the many risks to be considered in megaproject management. This is based on the extensive review of types of risk in infrastructure made by Azpitarte Melero (2001 & 2000) and Irimia-Diéguez & Oliver-Alfonso (2010), as well as the megaproject literature review developed. The proposed categorization encompasses all types of risks studied in previous literature, whilst other classifications are limited due to the exclusion of certain risks. A total of nine main risks have been identified:

- Design risks are those related with the planning phase of the megaproject, such as delivery method, contract formation, and scope control.
- Legal and/or political risks are derived from changes in the governing policy of the country where the megaproject is developed i.e. authorization criteria, political actors, changing government regulations, cancellation of a concession.
- Contractual risks include those derived from the renegotiation of the contract, such as midstream change of project scope, and issues caused by imprecision and vagueness in the contract.

- Construction risks are usually the most significant in the whole life of the megaproject, not only of the construction phase. Cost overruns (or cost escalation), project schedule, coordination problems, and inappropriate design or accident during the construction are examples classified within this section.
- Operation and maintenance risks are those related with the operational phase that can affect the operation cost, operation capacity or quality, such as economic viability issues, unnecessarily high operations costs, poor construction quality, and operator incompetence.
- Labour risks are related with the workers linked to training, language, accident cost, and culture.
- Clients/users/society risks are those which affect revenues. These risks include: (a) demand risks such as inflation, price trends, price range; (b) market risks, such as variations in the client's requirement, existence of the market; (c) social profitability risk which puts into question if the project provides the expected benefits to society; (d) impact on local groups' risk arises when the inhabitants of an area are a source of risk due to not being managed correctly; (e) environmental risks, which are usually called environmental impact assessments (EIAs); and (f) reputational risks, including media and marketing control.
- Financial and/or economic risks encompass a variety of events related with the financing and performance of the megaproject. These are composed of: (a) economic risks related with the investment or economic structure of the megaproject, such as lower-than-expected profitability, and inappropriate metrics about the project; (b) financial risks due to the high level of leverage which exerts an impact on the megaproject solvency; (c) liquidity risks, such as financial restrictions, availability of funds, and downgrading of credit ratings; and (d) foreign-exchange and interest-rate risk derived basically from long-term interest rates and foreign exchange rate.
- Force majeure, such as war, natural disasters, extreme weather conditions, terrorism.

Table 3. Risk categorization proposed per sector

Type of risk	Aeronaut.	Airport	Building	Energy	Rail	Refinery	Road	Space exploration	Other	Non-specific	% of papers
General	1	0	2	2	2	5	3	2	7	15	46.15%
Design	0	0	1	1	1	0	1	0	1	1	7.69%
Legal / political	0	1	1	0	2	0	1	0	1	1	7.69%
Contractual	0	0	0	0	2	0	2	0	0	0	5.13%
Construction	1	2	4	4	5	0	2	0	6	11	42.31%
Operation	0	3	1	1	0	0	1	0	1	0	8.97%
Labour	0	0	0	0	0	0	0	0	0	1	1.28%
Clients/society	0	1	1	2	2	1	1	0	3	2	14.10%
Financial / economic	0	0	0	1	2	0	0	0	1	2	7.69%
Force majeure	0	1	0	0	0	0	0	0	0	0	1.28%

By taking into account the risk categorization performed, the risks studied in previous papers are analysed. In Table 3, the number of papers is summarized per type of risk and sector analysed. The last column indicates the percentage of papers per type of risk. Since any paper can study a type of risk featured in several sectors, the sum of these percentages, which are calculated over the 78 papers analysed, exceeds 100%. The main risk studied (42.31%) is the construction risk, mainly in the form of cost and project schedule overruns. The risk related with clients and society (14.10%), due to the return on investment as well as the impact of the megaproject on society, is also a major factor. Risks from force majeure, and those related with workers are seldom studied. A large proportion of the studies analyse risks under a general focus; namely, there are 36 references (that represent 46.15% of total papers) which fail to detail any specific risk whilst 42 papers identify specific risks as shown Table 3. In addition, if the type of risk studies in megaprojects are analysed in depth per sector, the lack of research in various sectors can be observed (Table 33). Rail and road are the sectors where more types of risk are analysed whilst aeronautical papers focus on the construction risk.

In the same way as for any project, megaprojects represent a significant challenge to the stakeholders (Fiori &



Kovaka, 2005). These stakeholders could be defined from different perspectives (Littau, Jujagiri, & Adlbrecht, 2010). From our approach, stakeholders are individuals, groups or institutions with an interest in the project, who can affect the outcome (Boddy & Paton, 2004), whereby it is understood that stakeholders develop an active role in functions such as the assumption and management of a certain type of risk. Hence, those risks that can be assumed by the megaproject may be managed by their own, and those which are not affordable should be transferred by contract to several stakeholders in order to best control the risk management (see Fig. 4). This crucial issue needs to be analysed carefully once the various risks have been identified in the megaproject. Identifying and allocating risks to those stakeholders best able to manage them is crucial in megaproject management (Beidleman, Fletcher & Veshosky, 1990). Risks are often allocated using a matrix (Bing, Akintoye, Edwards, & Hardcastle, 2005) as the one shown in Table 4, where the risk that could be assumed by each stakeholder is identified.

Table 4. Transfer of risks to stakeholders

Stakeholders	Public sector	Management company	Construction company	Shareholders	Financial institution	Consultants
Type of risk						
Design	✓	✓		✓		✓
Legal/political	✓	✓		✓		✓
Contractual	✓	✓		✓		
Construction			✓			
Operation		✓	✓			
Labour		✓	✓			
Clients/users/society	✓	✓				
Financial/economic		✓		✓	✓	✓
Force Majeure	✓	✓	✓			

## 5. Conclusions, managerial implications, and further research

This paper has implications for both academics and practitioners. Our focus is on the first step in the risk management process, that is, the risk identification. An exhaustive literature review and qualitative analysis on risk management in megaprojects have been carried out. From the bibliometric analysis point of view, it can be pointed out that the number of papers in this field has been increasing in recent years; consistent with the importance that this topic has assumed. Numerous theoretical/conceptual papers (almost 30% of the total under study) have been identified. The most common type of empirical studies is that of case studies, whereby, in general, just one single case is presented. More research, in general, and more detailed case studies and survey studies, in particular, are required in order to improve megaproject management and risk process management.

No agreement in risk categorization in megaprojects can be observed in previous papers. Several classifications can be found in the literature, with major differences between them. Our categorization encompasses all types of risks studied in previous literature, whilst other classifications are limited due to the exclusion of certain risks. A total of nine main risks have been identified and defined. This systematization of the risks helps managers towards their identification within the megaproject and to embark on the subsequent steps in the risk management process: qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control.

The first matrix (Table 3), comprising the proposed classification risks studied by sector, highlights the need for further research in several specific topics (type or risk per sector) and shows that the main risk studied is that of the construction phase. Our study corroborates that the most common risks mentioned in project and megaproject management are cost and schedule overruns.

However, more research and managerial effort is needed with respect to the remaining types of risk, since all these risks hold an influence in the development of the megaproject. Several papers, which are real case-studies, underline those risks that can appear during the development of the project. These issues can remain unnoticed

throughout the project until the execution of the very final stage. The transfer of risks to the various stakeholders is an important point in the risk management process. A matrix (as shown in Table 4) is an useful tool that can help managers to analyse who would be the best partner to support each risk. Further research may analyse possible differences between sectors related to the risk transfer between stakeholders.

This paper identifies the most important risks tackled in the literature and provides evidence that more research is necessary in this area. Further research into how these risks are managed in megaprojects is called for, in an effort to recognize risk mitigations 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 may include the application of the proposed classification of the risks and the rest of the risk management process to a megaproject case-study.

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