

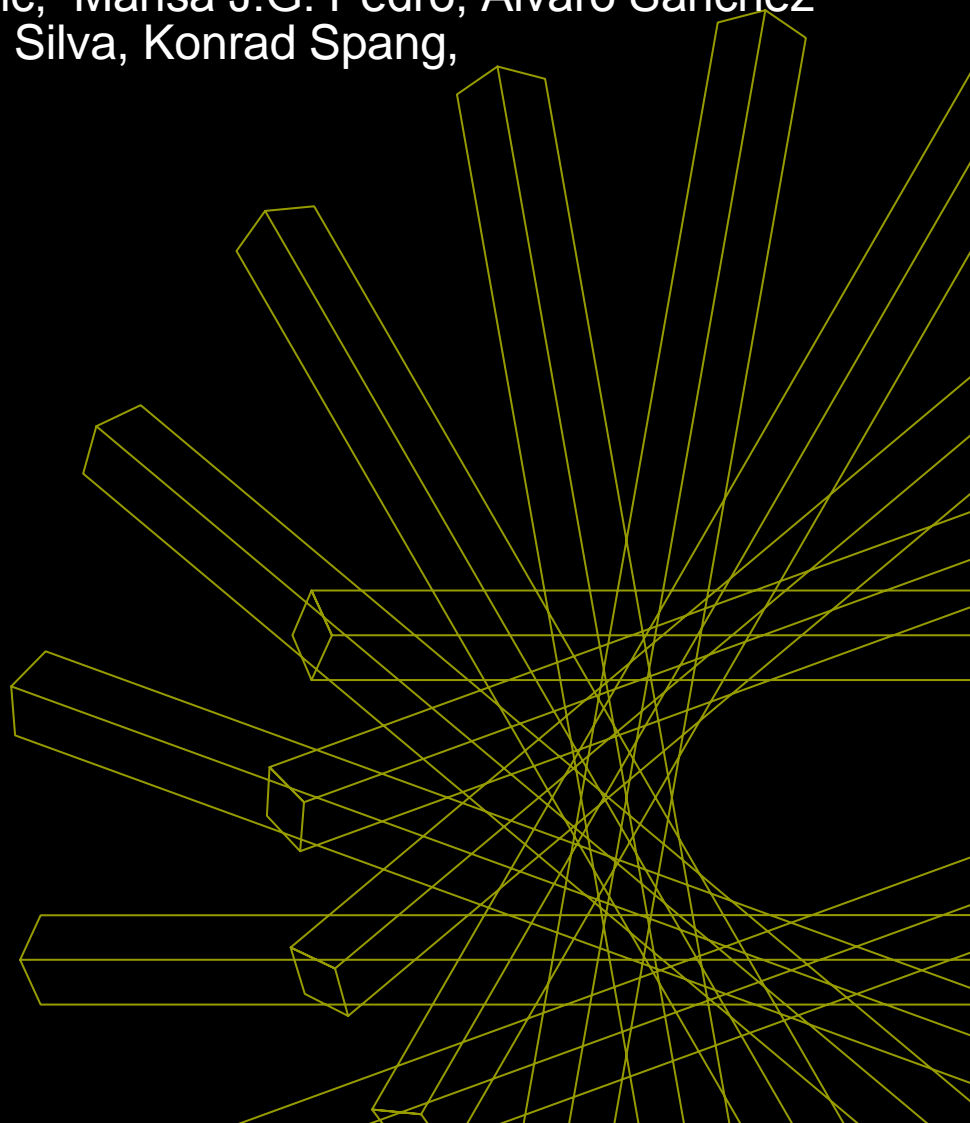
Risk in the Front End of Megaprojects

The RFE Working Group Report

Editor: Ivana Burcar Dunović

Authors:

Rafaela Alfalla-Luque, Ivana Burcar Dunović, Aldo Gebbia, Ana I. Irimia-Diéguez, Miljan Mikić, Marisa J.G. Pedro, Álvaro Sánchez-Cazorla, Joao de Abreu E Silva, Konrad Spang,



COST – European Cooperation in Science and Technology is an intergovernmental framework aimed at facilitating the collaboration and networking of scientists and researchers at European level. It was established in 1971 by 19 member countries and currently includes 35 member countries across Europe, and Israel as a cooperating state.

COST funds pan-European, bottom-up networks of scientists and researchers across all science and technology fields. These networks, called ‘COST Actions’, promote international coordination of nationally-funded research.

By fostering the networking of researchers at an international level, COST enables break-through scientific developments leading to new concepts and products, thereby contributing to strengthening Europe’s research and innovation capacities.

COST’s mission focuses in particular on:

- + Building capacity by connecting high quality scientific communities throughout Europe and worldwide;
- + Providing networking opportunities for early career investigators;
- + Increasing the impact of research on policy makers, regulatory bodies and national decision makers as well as the private sector.

Through its inclusiveness, COST supports the integration of research communities, leverages national research investments and addresses issues of global relevance.

Every year thousands of European scientists benefit from being involved in COST Actions, allowing the pooling of national research funding to achieve common goals.

As a precursor of advanced multidisciplinary research, COST anticipates and complements the activities of EU Framework Programmes, constituting a “bridge” towards the scientific communities of emerging countries. In particular, COST Actions are also open to participation by non-European scientists coming from neighbour countries (for example Albania, Algeria, Armenia, Azerbaijan, Belarus, Egypt, Georgia, Jordan, Lebanon, Libya, Moldova, Montenegro, Morocco, the Palestinian Authority, Russia, Syria, Tunisia and Ukraine) and from a number of international partner countries. COST’s budget for networking activities has traditionally been provided by successive EU RTD Framework Programmes. COST is currently executed by the European Science Foundation (ESF) through the COST Office on a mandate by the European Commission, and the framework is governed by a Committee of Senior Officials (CSO) representing all its 35 member countries.

More information about COST is available at www.cost.eu

© University of Leeds

Published by the University of Leeds, April 2015

ISBN 978-0-9576805-4-8

While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission.

Content

Content	3
Background And Aims Of The Working Group	4
What The Working Group Did (Research Methodology)	6
Results Of The Working Group	12
Literature Review	12
Case Study Analysis Results	37
Reflections on EU Funded Major Projects	48
Conclusions and Recommendations	56
Papers And Other Outputs Produced By The Working Group	57
References	59

Background and Aim of the Working Group

The Evolution of the Working Group

The 'Risk in the Front End' (RFE) Working Group idea resulted from a joint interest that arose both from the work of the Transportation and Cross Sectorial Working Groups in the MEGAPROJECT COST Action. Both working groups looked at issues related to risks associated not only with budget and schedule overflows but also related to the socio-economic impacts of projects. Specifically, most transportation and urban renewal megaprojects are marketed and sponsored based on their positive socioeconomic impacts. Thus, there are also risks associated with the projects not achieving the forecasted impacts. Both the Transport Working Group and the Cross-Sectoral Working Group expressed concerns about how and when these sort of risks should be dealt with.

The concept of risk and concerns about when should the different risks should be considered and managed, is fundamental to the focus of the RFE Working Group. In addition, the way that risk was managed in practice in megaprojects and the possible gaps that exist between practice and academic research were formed part of the aims of the RFE Working Group. Finally, the issues related to risk evaluation in the front end and in project evaluation in general, (such as Cost Benefit Analysis (CBA), were strong motivations to constitute this RFE Working Group

The RFE Working Group was initiated in a Management Committee Meeting in Dubrovnik on 30th September 2013 with the following aims:

- i) To review existing literature concerning risks in megaprojects
- ii) To identify the main issues in the common experience of cases in the MEGAPROJECT portfolio relating to risks at the front end.
- iii) To clarify the difference between risk identification at the front end of the megaprojects and the risk at the front end of the projects as a whole
- iv) To demonstrate the possible ways of dealing with risk in the evaluation of megaprojects in the front end

The launch of the RFE Working Group was followed working meetings in Brno (14th February 2014.), Burgas (06th-07th July 2014.), Liverpool (11th-12th July 2014.), Kassel (17th November 2015.) and Zagreb (6th-7th February 2015).

The RFE Working Group was led by Ivana Burcar Dunovic. The membership of the RFE Working Group was as follows:

- + Milen Baltov – Bulgaria
- + Rafaela Alfalla-Luque – Spain
- + Miljan Mikic – Serbia
- + Joao Abreu E Silva – Portugal
- + Marisa Pedro – Portugal
- + Alex Stamov – Bulgaria
- + Konrad Spang – Germany
- + Vit Hromadka – Czech Republic
- + Zhen Chen – UK

Further support was also received from:

- + Jana Korytarova – Czech Republic
 - + Ana Irimia Dieguez – Spain
 - + Alvaro Cazorla – Spain
 - + Alison Hood – UK
 - + Aldo Gebbia – Italy
 - + Nigel Smith – UK
 - + Marco Kuemmerle – Germany
 - + Camelia Michaela Kovacs – European Commission
-

What the Working Group Did (research methodology)

Introduction

Risk management processes must be carried out continuously during the entire life cycle of a project, especially when making decisions. The level of uncertainty is known to be the highest at the beginning of a project, with a tendency to decrease towards the end of a project as knowledge about the project increases together with committed values, which is why management is most effective in the early phases of the project life cycle (Table 1).

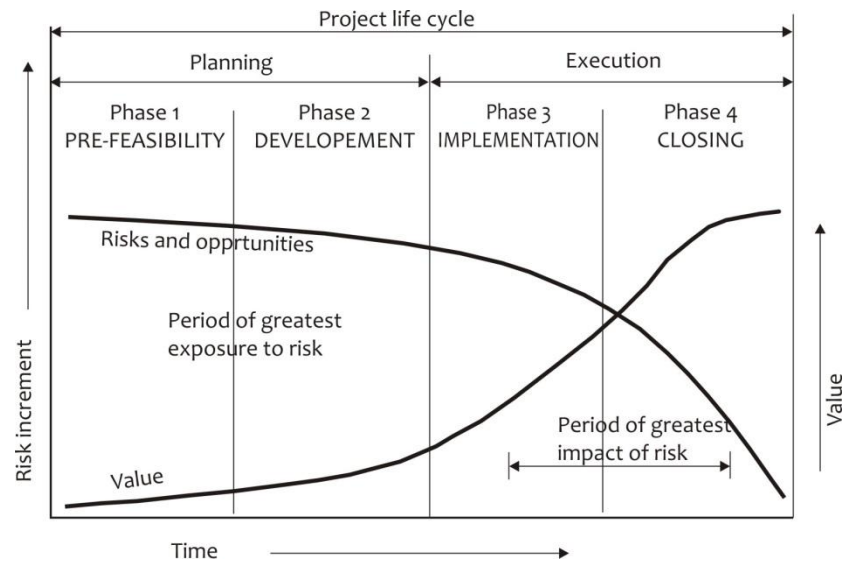


Table 1 Project risks and life cycle (Wideman, 1992)

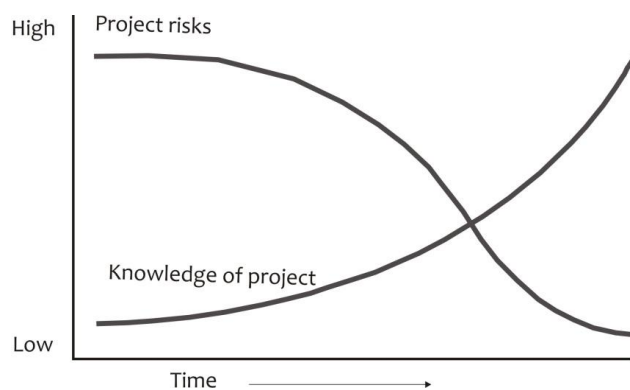


Table 2 The relationship between project risk and the level of knowledge about a project (Solomon, 2006)

Based on knowledge on change of risks and knowledge about the project over time, it is possible to establish their inter-relationship.(Table 2) Those statements apply only if the project is done and managed in the right way.

Megaprojects (also known as 'large-size infrastructure projects') have been defined as significant activities characterized by a multi-organization framework, producing relevant social impacts (Aaltonen, 2011; OMEGA, 2012). They are characterized by extreme complexity (in technical and human terms), high risk and uncertainty (concerning demand and cost estimations) and poor performance (Boateng et al., 2012; Priemus, 2010). The most common definition within experts and researchers is the concept of a large-scale investment project, typically costing more than EUR 0.5 billion (COST Action TU1003; Fiori and Kovaka, 2005) with colossal use of resources (money, human, equipment...) (Kardes et al., 2013), which frequently leads to cost overruns (Boateng et al., 2012; Flyvbjerg et al., 2003; Han et al., 2009). As a result, megaprojects should be defined in their construction management context: activities, resources, budgets and deadlines.

Fiori and Kovaka (2005) present other four key-characteristics of megaprojects: extreme complexity, increased risk, lofty ideals, and high visibility.

When these characteristics are skillfully managed, results in a successful megaproject, but the wrong combination can lead to a disaster. These features provide a guideline for planning and construction of megaprojects. They are not mutually exclusive, or they aren't hierarchically ranked. Rather, change in one characteristic drives changes on others. As result, they must be examined individually and in relation to each other.

Both, Flyvberg (2005) and Miller and Hobbs (2005) emphasize that one of the main aspect is long, complex and expensive front-end which impact project management performance more than the management of the engineering, procurement, and construction phase. The development of the project during the front-end phase was shown to be a time-dependent, non-linear, and iterative process, during which the project was formulated, tested, challenged, and reformulated through a series of episodes, during which unforeseen risks and issues emerge in successive episodes and must be managed. (Miller and Lessard, 2000) On the other hand, statistical evidence from Flyvbyerg research (2005) shows that unplanned events were not taken into account and thus the budget and other reserve funds were insufficient.

Since megaprojects involve substantial financial investments and commitment, and starting a wide set of socioeconomic effects, the decisions that are taken at early project development stage are of great importance. These decisions emerge under an environment of uncertainty. It is necessary have a flexible management since uncertainty is associated with vagueness, ambiguity and contradictions. This is linked to the lack of clarity due to missing data, incomplete and inaccurate detail related to the structure, the working and framing assumptions, known and unknown sources of bias, limited control of relevant project players and ignorance on how much effort is worth to clarify the situation. These projects are planned and

constructed with a professional culture of closed systems thinking which has a tendency to minimize risks and uncertainties. Understanding those developments is critical to evaluate what is a successful megaproject.

IMEC research project ((Miller and Lessard, 2000); (Miller and Hobbs, 2005)) showed that shaping large engineering projects will be greatly influenced by compromises, external influence (pressure), long duration, great political pressure, complex regulatory framework. The anchoring of projects to institutional frameworks was one of the most critical aspects of these projects and for that were much better able to withstand and survive the impacts of emergent uncertainty.

The projects were exposed to many different types of risk, several of which are not typically taken into account by traditional project management methods. Among the most important sources of risk are: Governments reneging on commitments, slowly materializing or insufficient markets, and social and political challenges to legitimacy. The level of uncertainty was extremely high, partly because of the large number of potential sources of risk, the projects' visibility, and their innovativeness. The length of time required for project development and anchoring increased the projects' exposure to emergent risk. Each project encountered an average of four unforeseen and potentially catastrophic events during their long life cycles.

The time for a transport megaproject to mature is usually long; it can take several decades from the first idea or draft plans to the beginning of operation. As a result, it's common that changes might occur, in the economic, political, legal and regulatory and technological contexts (Bruzelius et al., 2002), during this extended period. These changes are also related with the transportation system (e.g. new operators or transport modes that might start to operate, new transport related technologies, changes in pricing structures). Changes of project configuration and scope and, consequently, changes on cost, lifecycle and traffic forecasts might also occur. Their complexity has raised the attention of several stakeholders and usually triggers disagreements emerging under an environment of uncertainty (Curtis et al., 2012).

Numerous transport megaprojects have not been successfully delivered on-time and on-budget resulting in a negative image of the transportation sector. Several experts have noted that the costs are usually significantly underestimated and traffic estimates are systematically and significantly overestimated in such projects (Van Marrewijk et al., 2008; Williams et al., 1995). Actually, in such projects is common to observe cost overruns of a magnitude around 50-100% in fixed prices and, sometimes, higher than 100% (Bruzelius et al., 2002). Also, traffic forecasts are usually off by 20-70%. Indeed, in transport megaprojects, rail based projects tend to be more overestimated than road projects and the project viability is often very optimistic. Ninety percent of the transport infrastructure projects, from 20 countries, studied by Flyvbjerg and colleagues (Flyvbjerg, 2007; Flyvbjerg et al., 2003; Flyvbjerg et al., 2005) produced very disappointing outcomes indicating a large element of uncertainty and risk, with rail projects being systematically more overestimated than road projects. Furthermore, Flyvbjerg et al. (2003) demonstrated that rail projects have the largest cost increase (actual costs are on average 45% higher than estimated costs), followed by bridges and tunnels (34%), and finally roads (20%). The same authors also showed that are common the

existence of construction cost in transport projects and exist atwart different project types, different continents and different historical periods. The authors concluded that decision-makers should be worried about long implementation phases and sluggish planning and implementation of large transport infrastructure projects. In addition, in rail projects, this over-estimate cost seems to be more obvious in developing countries than in North America and in Europe. However, cost underestimation seems been explained by strategic misrepresentation (i.e. lying). Bruzelius, Flyvbjerg and colleagues (Bruzelius et al., 2002) attribute the biases to the project proponents, which aim to presenting it in more optimistic way in order to guarantee its approval. Politicians may also promote the projects' approval by being overly optimistic even if more precise forecasts can be estimated (Bruzelius et al., 2002).

At the end, Flyvbjerg and colleagues (Flyvbjerg, 2007; Flyvbjerg et al., 2003; Flyvbjerg et al., 2005) refer that the disappointing results of megaprojects come from mainly:

- Megaprojects always involve the intersection of risk, democracy and power. Political and regulatory authorities normally define parameters and goals to suit their own ends, but frequently forget the transparency concept in regulatory structures that affect the viability of a project.
- Megaprojects cannot be planned and executed in a predictable world where cause-effect are evident. Political interference and changing in governments make imperfect knowledge environments on executing megaproject developments.
- Megaprojects undertaken in emerging economies, for example, face poor prospects for more transparent stakeholder involvement, efficient and effective public sector risk analysis, and government bodies in emerging economies often lack the institutional capacity and depth to perform proficient risk assessments.

Research approach and methodology

Case study methodology

The first stage of the research is current literature analysis to establish research gaps. The literature review was done in three phases. First phase was bibliometric analysis of risk management in megaprojects, followed by bibliometric analysis aiming at identifying emerging topics and research gaps in risk management in projects and megaprojects. Third phase of literature review aimed at clarify the meaning of term "risk in front end" analyzing risk and uncertainty.

The second stage of research is case analysis. This research aims to analyze the data gathered in the questionnaire proposed by the RFE Working Group (WG) in order to understand within the case studies selected, what the common experience is of risk in megaprojects; how the risk has been managed in different megaproject case studies and develop some theoretical framework. In order to achieve this, the

megaprojects case studies were translated into a template in order to compare and analyze from a qualitative and a quantitative perspectives.

In general, the major tasks were to:

- Translate the megaproject case studies into a template.
- Develop a qualitative and a quantitative analysis.
- Identify similarities and differences
- Detect emerging research topics

The questionnaire about risk management in megaprojects developed by the RFE WG has been filling by the megaprojects risk managers. The case studies analysed are the following:

- Megaproject 1. Offshore Platform EPCI in the Mediterranean Sea
- Megaproject 2. Sava Zagreb, The River, Croatia
- Megaproject 3. Danube Bridge 2 –Combined rail/road bridge between Bulgaria and Romania at Vidin-Calafat
- Megaproject 4. FERTAGUS Train Concession – Railway Axis North/South Lisbon, Portugal
- Megaproject 5. Industrial Zones, Bulgaria
- Megaproject 6. Highway A1, Croatia
- Megaproject 7. City Tunnel Leipzig, Germany
- Megaproject 8. VDE 8 - HSR Berlin – Nurnberg, Germany
- Megaproject 9. Sofia Tech Park, Bulgaria

The main characteristics of the case studies analysed are the following:

Megaproject	Type Sector (1st level)	Type Sector (2nd level)	Phase
Megaproject 1	Utility Infrastructure	Oil and Gas	On-going (Operation)
Megaproject 2	Transport and Utility Infrastructure	Waterway, Water Management and Energy	On-going (Front-end)
Megaproject 3	Transport Infrastructure	Road and Rail	On-going (Operation)
Megaproject 4	Transport Infrastructure	Rail	On-going (Operation)
Megaproject 5	Cross-Sectorial	Commercial and Industrial Zones	On-going (Design, Construction, Operation)
Megaproject 6	Transport Infrastructure	Road	On-going (Operation)
Megaproject 7	Transport Infrastructure	Rail	On-going (Operation)
Megaproject 8	Transport Infrastructure	Rail	On-going (Construction and Operation)

Megaproject	Type Sector (1st level)	Type Sector (2nd level)	Phase
Megaproject 9	Cross-Sectorial	R&D Infrastructure	On-going (Design, Construction)

The surveys data have been translated into a template file in Excel in order to develop a qualitative and quantitative analysis, which also has been prepared to include more new cases and automatically update the tables and figures. There is the awareness of the sample be very small to be valid in statistical terms. However, this is a big initial step to design and create a world database and get relevant validated data.

Results of the Working Group

Literature Review

Emerging topics and research gaps in risk management in projects and megaprojects

An overview of the previous research on risk management in megaproject

Risk management (RM) is currently considered as a mandatory part of project management, and also as an integral part of successful project management (Burcar *et al.*, 2013; Dimitriou *et al.*, 2013). It is a major success factor in all types of projects and an appealing research and development topic (Lehtiranta, 2014), especially in megaprojects, as it can help project managers to anticipate delays that cause projects not to be delivered on time (Grant *et al.*, 2006).

Risks are not fully predictable, but with effective risk management practices, potential damage can be mitigated (PMI, 2015). The best projects show an ability to manage risks more effectively, which in turn contributes towards positive outcomes, resulting in safer projects, lower costs, and timely completion of projects (Greiman, 2013). RM 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). A recent study developed by PMI shows that one of the main causes of the project failures is “Opportunities and risks were not defined” (30% of the cases) (PMI, 2015). Its significance is also due to the fact that the analysis and assessment of the potential risks in the early stages of the megaproject can determine, among other things, whether the megaproject should be developed.

Risk Management of small- and medium-scale projects has been the subject of research on numerous occasions (e.g. Marcelino-Sádaba *et al.*, 2014). Nevertheless, this number of papers is greatly reduced when considering only those studies that focus on megaprojects, since, this remains an area of research still in development and expansion. The justification for studying RM in megaprojects is motivated by the growing interest in megaprojects in recent years as a research area due to their unique characteristics (Esty, 2004; Fiori & Kovaka, 2005); the important role that RM plays in the management of megaprojects (Greiman, 2013; Lehtiranta, 2014; Dimitriou *et al.*, 2013) and the need to address all types of risks to take a more holistic view (Lehtiranta, 2014).

Literature reviews in RM in megaprojects are scarce. We have found only five studies although with different focuses (Zhang, 2011; Rezakhani, P., 2012; Irimia-Diéguez *et al.*, 2014; Lehtiranta, 2014; Taroun, 2014).

Paper	Objective	Methodology
Zhang, 2011	To locate the position of past studies of project risk between the two schools of risk analysis (risk as an objective fact and risk as a subjective construction) and to help the understanding of their basic assumptions, viewpoints, and tendencies.	To review the papers published in the International Journal of Project Management and in the Project Management Journal in the period 1999-2009 that include the word "risk" in their title, abstract and/or keywords.

Rezakhani, 2012	To develop an extensive literature survey in risk modeling and analysis methods with main focus on fuzzy risk assessment.	To analyse papers published in the topic. There is no specification about methodology or database and journals analysed.
Irimia-Diéguez <i>et al.</i> , 2014	To establish the state of the art in risk management in megaprojects, to systematize the risks studied in the literature, and also to identify potential areas of further research.	A systematic literature review of major databases (WoK, Scopus and ABI/Inform) from 2000 to March 2013 using the keyword "risk" in combination with "megaproject" or "mega project" or "big project" or "complex project" or "large project".
Lehtiranta, 2014	To address how well the body of knowledge on multi-organizational RM corresponds to a state-of-art understanding on project RM and to identify which gaps need to be addressed in future research.	To analyse the papers published in four top journals representing general project management (International Journal of Project Management and Project Management Journal), construction project management (Journal of Construction Engineering and Management), and software Project management (IEEE Transactions on Software Engineering) within the thirteen-year period from 2000 to 2012.
Taroun, 2014	To review the literature of construction project risk modelling and assessment	To analyse papers published in academic journals specialised in construction management, project management, risk analysis, and management science. The databases utilized were: Science Direct, Web of Science, ABI-Inform (Proquest), Business Source Premier (EBSCO), Emerald, and Sage Management & Organization Studies. The keywords used were "project risk", "construction risk", "risk analysis", "risk assessment", "risk modeling" and "RM".
Zhang, 2011	To locate the position of past studies of project risk between the two schools of risk analysis (risk as an objective fact and risk as a subjective construction) and to help the understanding of their basic assumptions, viewpoints, and tendencies.	To review the papers published in the International Journal of Project Management and in the Project Management Journal in the period 1999-2009 that include the word "risk" in their title, abstract and/or keywords.
Rezakhani, 2012	To develop an extensive literature survey in risk modeling and analysis methods with main focus on fuzzy risk assessment.	To analyse papers published in the topic. There is no specification about methodology or database and journals analysed.
Irimia-Diéguez <i>et al.</i> , 2014	To establish the state of the art in risk management in megaprojects, to systematize the risks studied in the literature, and also to identify potential areas of further research.	A systematic literature review of major databases (WoK, Scopus and ABI/Inform) from 2000 to March 2013 using the keyword "risk" in combination with "megaproject" or "mega project" or "big project" or "complex project" or "large project".

Paper	Objective	Methodology
Lehtiranta, 2014	To address how well the body of knowledge on multi-organizational RM corresponds to a state-of-art understanding on project RM and to identify which gaps need to be addressed in future research.	To analyse the papers published in four top journals representing general project management (International Journal of Project Management and Project Management Journal), construction project management (Journal of Construction Engineering and Management), and software Project management (IEEE Transactions on Software Engineering) within the thirteen-year period from 2000 to 2012.
Taroun, 2014	To review the literature of construction project risk modelling and assessment	To analyse papers published in academic journals specialised in construction management, project management, risk analysis, and management science. The databases utilized were: Science Direct, Web of Science, ABI-Inform (Proquest), Business Source Premier (EBSCO), Emerald, and Sage Management & Organization Studies. The keywords used were "project risk", "construction risk", "risk analysis", "risk assessment", "risk modeling" and "RM".

shows the main objectives and methodology of these papers.

The literature reviews showed in Table 1 are focused in specific topics except that developed by Irimia-Diéguez *et al.* (2014). This paper analyse 78 references on RM in megaprojects. The main conclusions achieved in this research are summarized:

- 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.
- Almost 30% of the references are focused on the planning/development phase, 15.38% on the construction/execution phase, and 14.10% on the operational phase.
- The papers developed principally transversal (or cross-sectional) studies (92.31%), as against longitudinal studies (7.69%).
- The most commonly employed research methodology is 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.
- Related to the qualitative and quantitative focus of the papers, 62 articles (79.5%) employed a qualitative focus, and 27 (34.6%) a quantitative analysis.
- Just 40 references (51.3%) 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: observation (37.8%), interviews (25.7%), and surveys (13.5%).
- Related to the data analysis method, only 13 papers (16.7%) have developed some statistical analysis. The most commonly employed data analysis method is correlation and regression tests. Furthermore, it should be pointed out that only four papers (5.1%) perform a hypothesis test.
- The most researched sectors are Rail (10.3%) and Road (10.3%), followed by three sectors, Buildings, Energy and Refinery (each with six references,

7.7%). Notice that since there are multicases, some papers can focus on more than one sector.

- Only 29 papers (37.2%) indicate the geographical area of the megaproject. 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).

Table 3 Literature reviews in RM in megaprojects

Paper	Objective	Methodology
Zhang, 2011	To locate the position of past studies of project risk between the two schools of risk analysis (risk as an objective fact and risk as a subjective construction) and to help the understanding of their basic assumptions, viewpoints, and tendencies.	To review the papers published in the International Journal of Project Management and in the Project Management Journal in the period 1999-2009 that include the word "risk" in their title, abstract and/or keywords.
Rezakhani, 2012	To develop an extensive literature survey in risk modeling and analysis methods with main focus on fuzzy risk assessment.	To analyse papers published in the topic. There is no specification about methodology or database and journals analysed.
Irimia-Diéguez <i>et al.</i> , 2014	To establish the state of the art in risk management in megaprojects, to systematize the risks studied in the literature, and also to identify potential areas of further research.	A systematic literature review of major databases (WoK, Scopus and ABI/Inform) from 2000 to March 2013 using the keyword "risk" in combination with "megaproject" or "mega project" or "big project" or "complex project" or "large project".
Lehtiranta, 2014	To address how well the body of knowledge on multi-organizational RM corresponds to a state-of-art understanding on project RM and to identify which gaps need to be addressed in future research.	To analyse the papers published in four top journals representing general project management (International Journal of Project Management and Project Management Journal), construction project management (Journal of Construction Engineering and Management), and software Project management (IEEE Transactions on Software Engineering) within the thirteen-year period from 2000 to 2012.
Taroun, 2014	To review the literature of construction project risk modelling and assessment	To analyse papers published in academic journals specialised in construction management, project management, risk analysis, and management science. The databases utilized were: Science Direct, Web of Science, ABI-Inform (Proquest), Business Source Premier (EBSCO), Emerald, and Sage Management & Organization Studies. The keywords used were "project risk", "construction risk", "risk analysis", "risk assessment", "risk modeling" and "RM".
Zhang, 2011	To locate the position of past studies of project risk between the two schools of risk analysis (risk as an objective fact and risk as a subjective construction) and to help the understanding of their basic assumptions, viewpoints, and tendencies.	To review the papers published in the International Journal of Project Management and in the Project Management Journal in the period 1999-2009 that include the word "risk" in their title, abstract and/or keywords.
Rezakhani, 2012	To develop an extensive literature survey in risk modeling and analysis methods with main focus on fuzzy risk assessment.	To analyse papers published in the topic. There is no specification about methodology or database and journals analysed.
Irimia-Diéguez <i>et al.</i> , 2014	To establish the state of the art in risk management in megaprojects, to systematize the risks studied in the literature, and also to identify potential areas of further research.	A systematic literature review of major databases (WoK, Scopus and ABI/Inform) from 2000 to March 2013 using the keyword "risk" in combination with "megaproject" or "mega project" or "big project" or "complex project" or "large project".

Paper	Objective	Methodology
Lehtiranta, 2014	To address how well the body of knowledge on multi-organizational RM corresponds to a state-of-art understanding on project RM and to identify which gaps need to be addressed in future research.	To analyse the papers published in four top journals representing general project management (International Journal of Project Management and Project Management Journal), construction project management (Journal of Construction Engineering and Management), and software Project management (IEEE Transactions on Software Engineering) within the thirteen-year period from 2000 to 2012.
Taroun, 2014	To review the literature of construction project risk modelling and assessment	To analyse papers published in academic journals specialised in construction management, project management, risk analysis, and management science. The databases utilized were: Science Direct, Web of Science, ABI-Inform (Proquest), Business Source Premier (EBSCO), Emerald, and Sage Management & Organization Studies. The keywords used were "project risk", "construction risk", "risk analysis", "risk assessment", "risk modeling" and "RM".

- 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 analyses 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. 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 (e.g. aeronautic or refinery). Rail and road are the sectors where more types of risk are analysed whilst aeronautical papers focus on the construction risk.
- Related to the methodology employed by the decision makers to deal with risk, a total of 27 references (32.5%) focus on this topic. The literature review has found no evidence of the existence of a single set of model RM in megaprojects. Instead, there are a variety of proposals supported by different tools and/or variables; that is, all the references propose their own model or tool to handle risk. The papers are usually focused on one phase of the RM process (risk identification, risk assessment or risk mitigation) although 9 references propose models to handle risk throughout the whole RM process.

In summary, 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. There is a lack of empirical studies, that provide an in-depth analysis of the various aspects of this process during the different life cycle phases, and longitudinal studies analysing the evolution over time of the RM models and their results. 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. As Hartono (2013) states, there is a limited utilization of project risk models, tools, and methods which were developed on the basis of normative decision theories. Nevertheless, the number of models, methods and tools settled by researches and practitioners is growing, although it is not followed at a similar rate by the adoption of them by project practitioners.

Another important issue is to identify those topics of interest in the field of RM in megaprojects. A word count analysis of the whole text of the papers selected by Irimia-Diéguez *et al.* (2014) shows that the word “risk” appears 6,506 times, whilst other frequent words are “complex” (and similar topics as complexity) which appears 25.9%; “sustainability” (including environmental, ecologic,...) with 20.8%, “governance” with 15.9%, and finally, “stakeholder” and similar words with 11.1%; all the percentages are expressed with respect to the number of times that risk appears (100%).

Nevertheless, if the word count analysis is performed just within the keywords, the word “complex” (and its variations) appears in 20.7% of the papers, whilst the percentage decreases to 4.9% in the case of “sustainability” and similar words, to 2.4% for “stakeholder” and similar words, and lastly only 1.22% of the papers include the word “governance” as keyword. In consequence, the mentioned topics can be found in, although they have not included as keywords of the paper. Perhaps, the origin of this situation could be that some of these topics may be considered as emerging lines of research on risk in megaprojects and there is a scarce literature focused on them. Therefore, a more detailed bibliometric and content analysis is developed in the next sections.

Evolution of the emerging topics

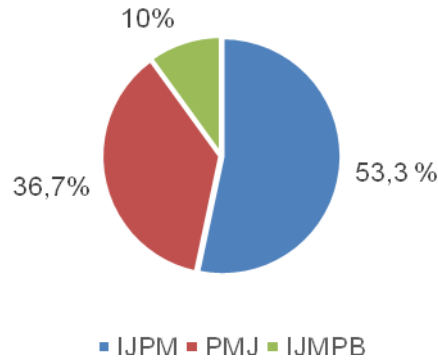
In order to analyse the evolution of the identified topics (stakeholders, governance, complexity, and sustainability), three major academic journals in Project Management have been selected: International Journal of Project Management (IJPM), Project Management Journal (PMJ), and International Journal of Managing Projects in Business (IJMPB). Our choice of the journals is guided by previous papers which performed literature reviews in project management topics (Littau *et al.*, 2010; Zhang, 2011; Lehtiranta, 2014).

A first search of the analysed topics (sustainab* or green or environ* or ecologic* or governance or complexit* or stakeholder) and the words “risk” and “megaproject” or “complex project” or “large project” in the title, keywords and abstract of the articles published until February 2015 in the three journals selected papers was performed. Due to the scarce number of papers found, a second search with the word “project”, instead of “megaproject” or “complex project” or “large project”, was then executed. We identified 101 papers. Subsequently, the abstracts and contents were assessed for their suitability to the present study. After selecting those papers which really analysed the topics considered, 30 papers were finally found.

The number of papers identified is mainly concentrated in the last four years (2010-2014), although some of the topics are treated in the journals sporadically since 1995. As shown in Figure 1, the International Journal of Project Management (IJPM) is the journal that contains more papers about these topics (53.3% of the total of 30 identified references). Instead, we have 36.7% of Project of Management

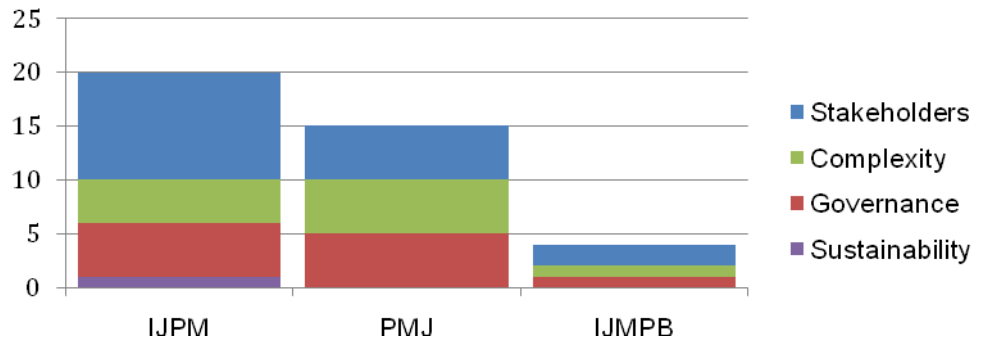
Journal (PMJ) and 10% of International Journal of Managing Projects in Business (IJMPB).

Figure 1: Number of papers per Journal



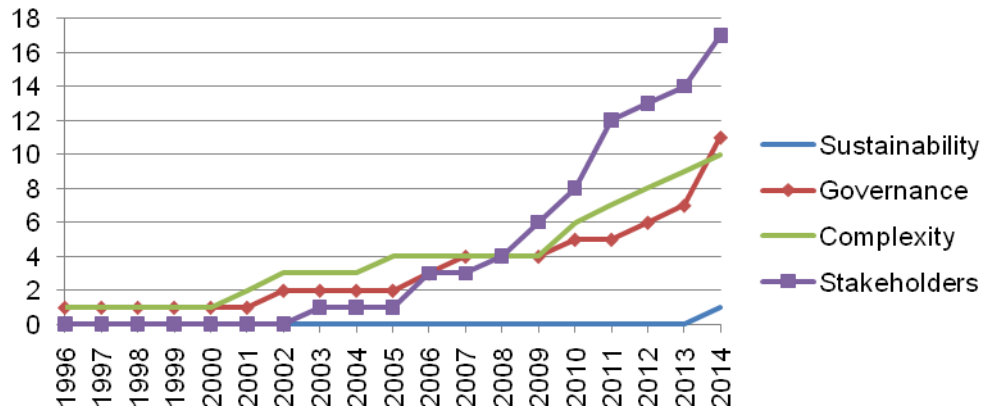
The three journals study all these topics, with the exception of sustainability. As shown in Figure 2, IJPM contains a higher proportion of papers on stakeholders.

Figure 2: Papers per topic and journal



As can be observed in Figure 3, stakeholder was the most frequently topics investigated, although, since 2009, governance and complexity has also picked as a topic of interest. Finally, sustainability is the least studied issue (only one item identified).

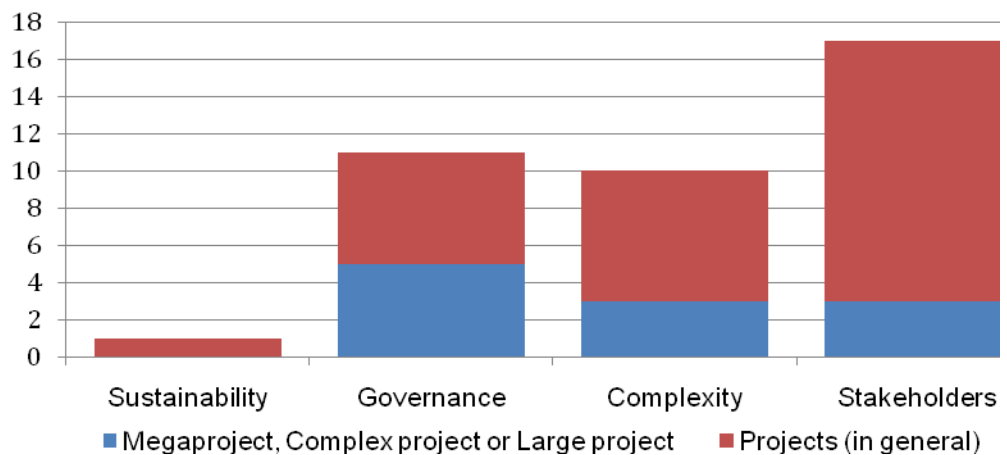
Figure 3: Papers per topic and year



The pioneer in publishing a paper on these topics, namely governance and complexity, was PMJ, it was Scott (1996). PMJ also contains the first paper identified on the topic stakeholders (Piney, 2003). The reason should be that PMJ was the first journal, starting in 1970 and was indexed in ABI, quite earlier than IJPM which began in 1983 and was indexed in 1992 in ABI, whilst IJMPB appeared and was indexed in 2008 in ProQuest.

Most of the studies focus on addressing these topics for projects in general. There are a small number of papers about complex projects, large projects or megaprojects (28.21%). As shown in Figure 4, only 11 papers specified megaproject in their analysis and most of them are focused on governance. Most of the papers analyzing the topics complexity and stakeholders refer to projects in general.

Figure 4. Papers per topic and type of project



In spite of the topics selected being closely related, in the abstract analysis, only 9 of the 30 references (30%) considered two topics simultaneously (Table 2). The remaining papers (21 references, 70%) focus on just one topic. Among the topics most frequently studied together are governance and stakeholders (4 of 30 papers), and governance and complexity (3 papers). Table 3 shows the number of papers focused on the different topics.

Table 2. Number of topics analysed by type of project

No. topics analysed	Megaproject, Complex project or Large project	Projects (in general)	Total	
			No.	%
1	3	18	21	70%
2	4	5	9	30%
Total	7	23	30	100%

Table 3. Topics of the papers

	Sustainability	Governance	Complexity	Stakeholders	Total
Sustainability	0	1			1
Governance	1	3	3	4	11
Complexity	0	3	6	1	10
Stakeholders	0	4	1	12	17
Total	1	11	10	17	39

Since the number of papers focused on these topics is very low, an additional search (similar to the previous search but deleting the word “risk”) was performed. The purpose was to check if these topics are being analysed in the literature of Project Management although the analysis is not related with risk. The results show 777 papers found (that means an increase of the 769% in relation with the 101 papers found with the word risk included). It implies that these topics have a greater consolidation in the field of project in general than in the area of risk management in particular.

An analysis of the emerging topics

1.1 Stakeholders

A good implementation of project risk management is believed to be one of the leading factors attributable to project success and hence companies' long-term success (Hartono *et al.*, 2014). In the relationship between risk management and project success, key elements are stakeholder perception of risk and success and stakeholder behaviour in the risk management process (de Bakker *et al.*, 2010). According to Millar (2007), the most important uncertainty management issues are usually related to objectives and relationships between the key stakeholders, particularly the internal stakeholders and especially within the ‘project owner’.

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 *et al.*, 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. A more comprehensive definition of stakeholders can be found in Winch (2010), who describes them as those actors which will incur a direct benefit, or loss, as a result of the project. This author provides two classifications of stakeholders in order to aid the analysis and their management, namely internal and external stakeholders. Internal stakeholders are in legal contract with the client and can be categorised to those clustered around the client on the demand side and

those on the supply side. External stakeholders are comprised of private and public actors. The private actors are from the local residents, landowners, environmentalists, and archaeologists, whereas the public actors are from regulatory agencies, and local and national government. The internal stakeholders will largely be in support of the project and external stakeholders may be in favour, against, or indifferent (Takim, 2009).

Particular challenges are presented by megaprojects since they usually are 'multi-owned' projects, where more than one organization shares ultimate control over fundamental aspects of the megaproject. In these contexts, key issues are governance arrangements and the allocation of risks and rewards so as to create and maintain incentives for cooperative behaviour as the project progresses (Millar, 2007). In many cases, risk sharing makes sense because most project risks commonly concern project participants (Tang *et al.*, 2007).

Since stakeholders should be concerned about and may be affected by the risks of the project, the consensus is that risks should be allocated to the party that is in the best position to manage them (e.g., International Organization for Standardization ISO, 2009). According to the World Bank the allocation of risks should be made according to two criteria: (a) the risk should be allocated to the stakeholder best able to manage the risk outcome and (b) the risk should be borne by the stakeholder best able to handle the risk at the lowest cost (Global Development Finance. World Bank, Washington, D.C. (2007), cited in Vassallo *et al.*, 2012). Therefore, 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. 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 *et al.*, 1990).

Risk allocation refers to a primary measure of assignment between the projects' direct participants" (Bing *et al.*, 2005). Risks are usually allocated between two parties (public and private sector) or three parties (public sector, private sector and end-users). Risk allocation should be based on a balance of parties' interests and should "distribute liability associated with risk events to proportionally distribute the possible prospect loss or gain of project" (Khazaeni *et al.*, 2012). Risk allocation has a direct and important bearing on the financial cost of the project. When the risks allocated to the private sector are very high, the financial cost of the project becomes significant and can threaten the ultimate financial feasibility of the project. Conversely, too much risk retained by the public sector might not encourage the private sector to perform properly and might end up proving to be too costly for the public budget in the future (Vassallo *et al.*, 2012). Therefore, an adequate risk allocation profile requires striking the right balance between risks retained by the public sector and risks transferred to the private sector. Ke *et al.* (2010) state that risk allocation is highly related to the unique social, economic, legal situation of the country.

An example of matrix of risks allocated to stakeholders is shown in Table 4, where the risk that could be assumed by each stakeholder is identified. This table has been elaborated from the references analyzed (e.g. Beidleman *et al.*, 1990), other examples of risk allocation (Bing *et al.*, 2005; Ke *et al.*, 2010), and our previous experience. Those other risk allocation matrices only differ between public and private sector. Our focus is broader and considers the six main stakeholders to be

found in megaprojects, excluding end-users. This matrix may not be very meaningful due to the different features of each stakeholder.

Table 4. Risk allocation to stakeholders

Type of risk	Public sector	Management company	Construction company	Shareholders	Financial institution	Consultants
1. Design	✓	✓		✓		✓
2. Legal/political	✓	✓		✓		✓
3. Contractual	✓	✓		✓		
4. Construction			✓			
5. Operation		✓	✓			
6. Labour		✓	✓			
7. Clients/users/society	✓	✓				
8. Financial/economic		✓		✓	✓	✓
9. Force Majeure	✓	✓	✓			

Hartono *et al.* (2014) identify significant gaps of risk-related concepts between project stakeholders' perspectives and the rational assumptions of the normative decision theories (e.g., risk is widely viewed by practitioners from the negative domain while the rational theory would suggest a more neutral perspective of risk). Another research gap is pointed out by Loosemore (2010) who discusses how multimedia technology can be used to effectively engage stakeholders in the management of risk in projects and in business. The author draw attention to explore the pedagogical advantages of multimedia in helping organisations develop a risk management culture as future research needs.

1.2 Governance

Governance is a growing area of interest for management and organizational researchers and theorists, although there is scarce literature about its role and impact on projects and risk management of projects; and even less is known about the systemic impact of project governance, that is, how governance and project systems have a reciprocal impact (Pitsis *et al.*, 2014). In this field, there is still work to be done in specifying how projects are distinct from other forms of organizing conceptually and philosophically (Morris, 2013). Pitsis *et al.* (2014) point out that existing theoretical perspectives offer many opportunities further to explain the tensions, challenges and opportunities inherent in project governance, making it a ripe and vibrant field of research, theory and practice.

Nevertheless, according to Sanderson (2012), governance has become an increasingly popular theme in the project management literature. This fact reflects a widening of focus away from the purely technical and operational tasks that need to be fulfilled to deliver project outcomes, to encompass a much greater interest in how interactions between the multiple actors responsible for undertaking those tasks are organized and coordinated (see, Atkinson *et al.*, 2006; Clegg *et al.*, 2002; Flyvbjerg *et al.*, 2003; Miller and Lessard, 2000; Pitsis *et al.*, 2003; Pryke and Smyth, 2006; van Marrewijk *et al.*, 2008; Winch, 2001, 2009).

Governance mechanisms refer to processes of institutional, market or network organization through legal, normative, discursive or political processes (Bevir, 2013). In its broadest definition good governance can be thought of as how individuals, groups, organizations, societies, nation states are held accountable not only for outcomes but also ethical behaviors (Clegg *et al.*, 2011). Much of the recent

governance literature focuses on the governance of organizational relationships (networks, collaboration and partnerships for example) pertaining to projects (Clegg *et al.*, 2002).

Risk governance is defined by IRGC (2005) as the identification, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how and by whom management decisions are taken and implemented. IRGC's approach states that risk governance is context-specific. A range of factors (the nature of the risk itself, how different governments assess and manage risks, and a society's level of acceptance or aversion to risk, among others) means that there can be no single risk governance process. The framework is therefore deliberately intended to be used flexibly. In this line, Cui & Olsson (2009) suggest that the more uncertainty the project has, the less likely it is to anticipate project flexibility that is to be applied in the future. Nevertheless, flexibility cannot substitute the need for governance and change control to deal with unplanned change requests (Gil & Tether, 2011).

In accordance with Pitsis *et al.* (2014), the design, execution, management and close out of contemporary complex projects occur in contexts of unparalleled uncertainty, making it difficult to govern these projects in line with intended and anticipated strategic objectives and imperatives. Projects must be managed dealing with challenges posed by “uncertainty in ecological, social and economic sustainability; ambiguity arising from advances in the technological means of communications; shifting geopolitical power relations that bring both challenges and opportunities, and at the same time the governance of these projects must be able to attract and retain people who are not only skilled and knowledgeable in all technical matters relating to projects but also able to adapt to turbulence in the operating environment”.

The literature tends to treat governance issues as being static (Miller & Hobbs, 2005), but megaprojects can rarely be treated within the context of a single organization, since their project development processes and environments are dynamic. The governance of large complex projects requires governance regimes that are themselves dynamic—that can change themselves to adapt to the emerging context. The governance regimes must adapt to the specific project and context, deal with emergent complexity, and change as the project development process unfolds. Learning to manage project governance regimes is difficult for organizations that are not involved in great numbers of large complex projects. The framework based on the progressive shaping of the project through the project development life cycle is designed to help overcome this dilemma (Miller & Hobbs, 2005). Based on a re-examination of a study of 60 large capital projects and interviews to practitioners, these authors proposed the following lessons:

- (a) The management of front end phase is critical and shows significantly more impact on project performance than the management of the engineering, procurement, and construction phase.
- (b) The anchoring of projects to institutional frameworks is one of the most critical aspects of project governance.
- (c) In large complex projects the governance relationship is very rarely a binary relationship between one project sponsor and one governing body. The interactions among the different groups of stakeholders involved in project

development, approval, and delivery can best be represented as a dynamic social network.

- (d) Megaprojects are exposed to many different types of risk, several of which are not typically taken into account by traditional project management methods. Governments renegeing on commitments, slowly materializing or insufficient markets, and social and political challenges to legitimacy are among the most important sources of risk. The level of uncertainty is extremely high, partly because of the large number of potential sources of risk, the projects' visibility, and their innovativeness. The length of time required for project development and anchoring increased the projects' exposure to emergent risk.
- (e) The development of the project during the front-end phase is time-dependent, non-linear, and iterative process, during which the project is formulated, tested, challenged, and reformulated through a series of episodes. Unforeseen risks and issues emerge in successive episodes and must be managed.
- (f) Projects and their contexts vary so greatly that no one strategy is appropriate to all cases. However, a strong correlation was found between the variety of strategies deployed, or strategic depth, and project performance. The need for strategic flexibility is in-line with the episodic nature of the project development process and the uncertainty as to the nature of the challenges and risks in future episodes. The need for strategic flexibility creates a strategic planning paradox in that being well prepared for the requirements of early episodes may result in inadequate preparation for later episodes and the associated emergent risks. Project development requires a rich and varied pool of strategic resources and the flexibility to adapt to emergent situations.
- (g) The capabilities of the project sponsor/developer had an important impact on the way the project unfolded and ultimately on performance. Strong sponsors showed: integrative business perspective, ability to evaluate complex systems from multiple perspectives, relational and coalition-building competencies, political and negotiating skills, resources necessary to support long development processes, possibility of diversifying risk through a portfolio of projects or other activities, and will to abandon bad projects.
- (h) High performing projects are subjected to intensive scrutiny. The project sponsor plays an important role in ensuring that projects are scrutinized. The involvement of other stakeholders with diverse interests and perspectives in a governance structure that encouraged scrutiny also contributed to the development and delivery of feasible projects.

Sanderson (2012) critically discusses different explanations for the performance problems exhibited by many megaprojects, and examines the proposed governance solutions. This author concludes that governance in megaprojects should make forms of organization designed *ex ante*, and should ignore spontaneous micro-processes of organizing emerging *ex post*. Identification of this gap adds support to calls by projects-as-practice researchers for a broadening of research to encompass the actuality of projects. A new line of enquiry within this broad projects-as-practice agenda is suggested. This author agrees with the general argument that research on projects 'should spend less time looking at strategic planning and more time researching everyday organizational life' (Pitsis *et al.*, 2003), and supports similar calls for a greater focus on the 'actuality of project based working and management' (Cicmil *et al.*, 2006) to stimulate a more reflexive and developmental approach to understanding project performance.

According to Pitsis *et al.* (2014), a major challenge for leadership is to ensure projects align both with strategic imperatives and changing contexts of action that might redefine these imperatives. Increasingly, there are calls for leaders to be both more strategic about projects as well as ensuring projects are more strategic (Keller-Johnson, 2008; Meskendahl, 2010) due to projects must be managed dealing with major issues of risk in times and places of financial, environmental, social and political instability.

1.3 Complexity

Megaprojects are characterized by complexity, uncertainty, ambiguity, dynamic interfaces, significant political or external influences, and time periods reaching a decade or more (Florice & Miller, 2001). These type of projects are considered the most complex within the different types of projects, but also those who have more time, more complex structures of team composition, level of risk and high level of uncertainty (Kardes *et al.*, 2013).

Vidal *et al.* (2011) propose the following definition “project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system.”

The first reason for complexity is the large scale and scope of international megaprojects. It can take several decades from project initiation to final completion. During this period, changes occur in the economy, political landscape, and within the laws and regulations (Capka, 2004). Moreover, the visibility of megaprojects and public attention increase the complexity (Kolltveit & Grønhaug, 2004)

Further contributing to complexity is the existence of a number of factors such as tasks, components, personnel, and funding, as well as numerous sources of uncertainty and their interactions (Mihm *et al.* 2003; Sommer & Loch, 2004). In addition, since the technology used in megaprojects is often new, developmental or cutting-edge, its behavior and functionality are often hard to predict. In this sense, evidence shows that new developments and changes in technology increase uncertainty (Shenhar, 2001). According to van Marrewijk *et al.* (2008), the principal factors leading to complexity include: the large scale, long time span, multiplicity of technological disciplines, the number of participants, multi-nationality, the interests of stakeholders, sponsor interest, escalating costs over time, country risk, uncertainty, and high levels of public attention or political interest.

Therefore, the significant number of stakeholders leads to further increase in complexity. Aligning a significant number of stakeholders is thorny if each stakeholder’s interests are to be maintained. Sponsors and stakeholders often have competing characteristics and goals. In addition to the difficulty of finding common ground for a large number of people, conflicts and misinterpretations can arise during the long life of project implementation. Undertakings with large amounts of resources may create controversy among stakeholders and over the management of resources (Kardes *et al.*, 2013).

Although the risk management literature is extensive, there is a dearth of studies presenting an integrated framework in risk management approaches. Giezen (2012) focuses on the reduction of complexity and its effects on the planning of mega

infrastructure projects. Kardes *et al.*, (2013) examine complexity of megaprojects under both technical and social complexity. Technical complexity is related to the size of the project, whilst social complexity includes the interactions among the people involved in the project (Baccarini, 1996; Bruijn & Leijten, 2008). Azim (2010) observed in his empirical study based on interviews that project complexity was not formally assessed at the start and during the course of project, and also that the majority of the practitioners were not aware of the existing project complexity assessment tools and those who were aware of such tools did not find them practical and useful. Liu *et al.* (2014) analyse the relationship between risks and performance and show that the negative impact of risks on performance is greater in projects that are more strategic. They propose strategies to reduce the complexity and potential conflicts inherent to strategic projects because these characteristics may amplify a risk's impact.

There are a number of project methods offered in the literature with respect to complexity. Some recent frameworks developed include measuring complexity using an Analytic Hierarchy Process (Vidal *et al.*, 2011) and the Technological, Organisational and Environmental Framework (Bosch-Rekvelde *et al.* 2011). Harvett (2013) investigates the relationship between uncertainty and risk management approaches and processes and perceived project complexity; the prevalence of uncertainty and risk management approaches and processes considered to be 'in advance' of general prescribed industry risk management; and perceptions of project success in relation to uncertainty and risk management practice. The review of the literature undertaken by this author provides limited evidence of empirical research focused primarily on the management of uncertainty and risk on complex projects. This is considered to be a research 'gap', specifically with respect to Project Manager's uncertainty and risk management practice in relation to their perceptions of project complexity.

Project management complexity is characterised by an intense debate, but two key concepts of project complexity are generally accepted - structural complexity (organisational and technological), with associated differentiation and interdependencies (Baccarini, 1996) and uncertainty (Williams, 1999). Uncertainty adds to the complexity of a project, so can be considered as a constituent dimension of a project (Williams, 1999).

Klakegg *et al.* (2010) state that there is a dilemma embedded in the processes used to analyse uncertainty and risks associated with projects. On the one hand, an important task is to reduce the complexity of a given situation to render the issues sufficiently simple for them to be understood and assessed. On the other hand, the models and assumptions upon which an analysis is based have to be sufficiently precise and detailed in order to make sense. The same dilemma is found when considering actions to address risks and uncertainties, as well as in designing management systems. They conclude that the dilemma is real and that solutions have to be found among both good and simple options. However, they do not answer how to solve the dilemma.

A criticism of the ability of current general prescribed industry risk management standards to effectively manage uncertainty and risk is performed by many authors such as Atkinson *et al.* (2006) who argue that the focus on uncertain events or circumstances does not facilitate consideration of aspects of variability that is driven by underlying ambiguity and lack of information. In addition, there is a persistent tension between risk viewed as an objective fact and a subjective construction. Even though unifying these different schools of risk analysis is not easy, integration is required to develop a more complete framework for analysing and managing

project risk (Zhang, 2011). Howell *et al.* (2010), adapt project contingency theory to encompass the selection factors seen within the project literature: uncertainty, complexity, urgency, team empowerment and criticality. These factors are then used to develop a contingency framework based on project uncertainty and its consequences.

Dealing effectively with risks in complex projects is difficult and requires management interventions that go beyond simple analytical approaches. In his study, Thamhain (2013) suggests that effective RM involves an intricately linked set of variables, related to work process, organizational environment, and people. Some of the best success scenarios point to the critical importance of recognizing and dealing with risks early in the front-end. This requires broad involvement and collaboration across all segments of the project team and its environment, and sophisticated methods for assessing feasibility and usability early and frequently during the project life cycle. In addition, communication and collaboration among all stakeholders is an important condition to early risk detection and effective risk management in complex project situations.

1.4 Sustainability and environment

In the risk management process in megaprojects, environmental risks need to be identified and managed. Irimia-Diequez *et al.* (2014) classify environmental risks in the clients/users/society risks category, which affects 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, related to the level of sales 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 questions whether 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) reputational risks, including media and marketing control; and (e) environmental risks, such as ecosystem resilience, cumulative effects, loss of biodiversity, degradation of habitats through irreversible damage and resource depletion, reduced populations of species or uptake of foreign elements (Kroeger and Simonovic, 1997).

Sustainability and environment issues are related topics. They are linked to the Impact Assessment (IA), in general, and to Environmental Impact Assessment (EIA) and Sustainability Assessment (SA), in particular. The International Association for Impact Assessment (IAIA) defines IA as 'the process of identifying the future consequences of a current or proposed action. The "impact" is the difference between what would happen with the action and what would happen without it' (IAIA, 2009). The concept of environment in IA adopted by IAIA evolved from an initial focus on the biophysical components to a wider definition, including the physical-chemical, biological, visual, cultural and socio-economic components of the total environment. EIA is defined as 'the process of identifying, predicting, evaluating and mitigating the biophysical, social and other relevant effects of proposed development proposals prior to major decisions being taken and commitments made' (IAIA, 1999).

The EIA term encompasses assessing proposed actions for their likely implications for all aspects of the environment before decisions are made to commit to those

actions, and developing appropriate responses to the issues identified in that assessment (Morgan, 2012). While common evaluative criteria such as economic efficiency are widely applied, efforts to reduce long-term ecological damage by providing for sustainable development require a deeper analysis for project selection (Lence *et al.*, 1997). Some environmental trends are likely to be more pronounced in developing countries, where there will be more pressure on environmental resources (Glasson *et al.*, 2012). Morgan (2012) has developed a review of the progress in EIA over the last 40 years. A feature of the literature over the last 20 years is the increasing maturity of EIA research. In particular, the growing influence of theoretical debates in related areas of knowledge, affecting how EIA is viewed, and potentially opening minds to alternative ways to look at the processes that make up the activity of EIA. (Morgan, 2012)

Sustainability assessment is an evolving and promising development in impact assessment. It can be defined as any process that directs decision-making towards sustainability (Bond and Morrison-Saunders 2011). Bond *et al.* (2012) appraise the current state of the art in sustainability assessment to identify its strengths, weaknesses, opportunities and threats. They explain that, currently, sustainability assessment is a concept with blurred boundaries. Environmental, social and health impact assessments could be considered forms of sustainability assessment. They state that “the point has not yet been reached at which there is universal consensus as to what sustainability assessment is or how it should be applied”. Sustainable development has a variety of meanings, and as a consequence the sustainability assessment process can be viewed in different ways. They suggest that ‘sustainability assessment is currently in this initial phase of development, where early practice is being adapted to fit new situations and new contexts as practice has not yet reached a situation where particular methods or approaches are proven to work well’. The lack of methodological definition is seen as a strength that acknowledges pluralism (Pope *et al.*, 2013).

Impact assessment practice is dominated by its use at the project level, with emphasis on major or mega projects (Wood, 2003). But, not all countries have introduced planning or development control legislation to require the routine use of EIA for proposed projects that might have significant environmental impacts (Morgan, 2012). Incomplete or disingenuous EIAs mask the potential social, environmental and economic impacts of megaprojects or large projects. For example, EIAs are the pre-project standard for outlining potential environmental and social risks related to megaprojects as mining (Bedi, 2013). Companies often carry out the assessments in a cursory manner, and at times conceal vital information. In infrastructure projects, environmental impact assessments may be deficient owing to lack of accuracy in estimates of impact predictions, time horizons considered and limited scope (Flyvbjerg *et al.*, 2003). Leviäkangas, (2007), focused on the transport projects, states that ‘environmental costs or benefits are not included, which are increasingly important factors when evaluating road as well as other projects’.

A proof of the importance that of these topics have in projects are the Equator Principles, whose standards require EIA on major projects. They provide guidelines on the use of EIA in relation to major project funding decisions by the institutions (Morgan, 2012). These standards have been a significant driver for expansion of EIA. In essence, for major and mega projects, Equator Principle finance institutions must ensure that an impact assessment appropriate to the scale and nature of the project is provided by the applicant. In June 2003, these principles were published by International Finance Corporation (IFC), part of the World Bank group and

several major banks. In 2006, 40 institutions had signed up to the Principles, and this has risen to more than 70 in 2012, representing over 70% of international project finance debt in emerging markets (Morgan, 2012).

From the research point of view, there is a lack of studies on this issue in megaprojects. We agree with the conclusions achieved by Morgan (2012): 'EIA should be integral to project development and design processes, not left to the final legal step before project implementation. This would reduce the emphasis on compliance-oriented EIA, allowing impact assessors to work more constructively with proponents and stakeholders to develop processes that meet the needs of all parties, and in so doing result in projects that are consistent with the environmental and social aspirations of local communities.' More research and more effective practical implementation are necessary in this area. Researchers may contribute further towards the research on this topic for a better understanding of its effects on the performance measures.

Risk and Uncertainty

Uncertainty is one of the main characteristics of a project, which springs directly from the fact that a project is a unique, unrepeatable undertaking of limited resources and at the end, it has the largest influence to achieving project goals. It is vital to be able to assess the uncertainty in the moments of decision-making on the future of the project. Data on the uncertainty of a project needs to provide us with information about the actual feasibility and cost-effectiveness of the project as well as the quality of preparation and implementation of the project through the phases of its life cycle. In order to evaluate the uncertainty of a project we need to know what it is, what it does and how it materializes (Burcar Dunovic, 2012).

The difference between uncertainty and risk is ambiguous, and it depends on the author's approach and purpose. In the early beginnings of risk management, the concept of risk related to any event for which the likelihood of occurrence can be statistically evaluated and can accordingly be insured. (Burcar, 2005b)

With the development of risk management in different areas different points of view emerge. Past empirical studies on management risk provide undeniable evidence to the difference between experts' perspectives about *risk* and the principles of the normative decision theory on which risk analysis tools are based.

Flanagan and Norman (1993) equate the concept *uncertainty and risk*, while decision-making theory defined the difference on the basis of the level of available (known) information and the consequent possibility of determining the probability of alternative consequences. In earlier research (Burcar, 2005b, Burcar Dunovic, 2012) an analysis was carried out of the conceptualization of risk and uncertainty which was updated with new definitions, the results of which are summarized in the Table 3.

Table 3 The definition of risk and uncertainty of various sources

Risk	Uncertainty	Source
<i>Decision-making in a state of risk is when there is <u>sufficient information</u> to determine an estimate of the likelihood of the identified consequences of a decision</i>	<i>Decision-making in a state of uncertainty is when there is <u>no or insufficient information</u> available to determine all alternative consequences or solutions or to determine their likelihood</i>	Wideman (Wideman, 1992)
<i>Risk is an <u>uncertain event or condition (circumstance)</u> that, if it happens, will have a positive or negative impact on project objectives.</i>	From the definition of risk the following can be concluded: <u>uncertainty is a characteristic of risk as an event.</u>	PMI (Project Management Institute)(PMI, 2000)
<i>Risk is "the <u>possibility</u> that unwanted outcomes or failures will disrupt a project"</i>	<i>Uncertainty is, along with loss and the time component, <u>an aspect of risk</u> that cannot be eliminated or separated from risk.</i>	Smith i Merritt (Smith and Merritt, 2002)
<i>Risk is an <u>implication (consequence)</u> of uncertainty of the level of achievable performance, presented as an unwanted variability in relation to the expected outcomes, which is estimated for each feature of execution using a comparative cumulative probability distribution when measurement is suitable.</i>	<i>Uncertainty is the lack of certainty. From the definition of risk the following can be concluded: <u>Uncertainty is a source of risk</u> in relation to the level of execution.</i>	Chapman and Ward (Chapman et al., 2003)
<i>Risk is an <u>uncertain event or set of circumstances</u> which, if they occur, will have an impact on the achievement of project objectives.</i>	From the definition of risk the following can be concluded: <u>uncertainty is a characteristic of risk as an event or circumstance.</u>	APM (Association for project management)(APM, 2006)
<i>Risk is <u>any uncertainty</u> that, if it happens, will have an effect on one or more objectives.</i>	<i>Risk arises from uncertainty</i> From the definition of risk the following can be concluded: Uncertainty can be a risk if, where it occurs, it has an impact on project objectives.	Hillson (Hillson and Simon, 2007)
<i>Risk is a measure of the <u>probability and consequences</u> of failure to achieve the defined objectives of a project.</i>	The definition does not include the concept of uncertainty.	Kerzner (Kerzner, 2009)
<i>Risk is the effect of uncertainty on objectives.</i>	<i>Uncertainty is a natural need to weigh up the project results and measure their risks and benefits, mainly when the decisions have unpredictable outcomes.</i>	ISO standard (ISO31000:2009)

Although it is evident from the previous analysis that definition of risks now include both, upside (opportunity) and downside (threat) aspect, some experts still commonly view the *risk* as a negative feature. Similar, clients' projects relate *risk* as the 'loss that must be accepted during the project', 'various possible alternatives to be selected or controlled', 'one of the consequences as a result of decision making', and 'the uncertainty that cannot be predicted' (Flyvbjerg et al., 2003:3).

It can be concluded that risk and uncertainty are related, and both need to be considered in decision-making. However, what is the best methodology that should be applied to gauge them?

Previously demonstrated definitions of risk can be viewed from two aspects - epistemological, which includes people’s epistemological assumptions and project and ontological, which considers origin of uncertainty and risks.

Epistemological aspect

Where the level of uncertainty is concerned, in a project there are three types of data: known knowns, known unknowns and unknown unknowns. Ward and Chapman (Chapman and Ward, 2002) define known unknowns and unknown unknowns as explicit or implicit assumptions or conditions which, if not assigned a value, can have uncertain, significant consequences.

Chapman and Ward assume that uncertainty is the lack of certainty, visualized in the form of variability and ambiguity that cannot be completely separated. (Chapman and Ward, 2002)



Table 4 Illustration of uncertainty according to Chapman and Ward



Table 5 Illustration of uncertainty according to Vose

Such an interpretation of uncertainty can be compared with Vose's concept that there are "two components of our inability to accurately predict what the future holds: these are variability and uncertainty," and he relies on a quote by Sir David Cox: "Variability is a phenomenon in the physical world that is measured, analysed and explained, if necessary. In contrast to uncertainty that is an aspect of knowledge." (Vose, 2005) The characteristics of variability are that it is an effect of chance (luck) and that it is a function of the system, such that it cannot be reduced through study and measurement but only by changing the physical system. Authors also call it "aleatory uncertainty" (Williams, 2002) or stochastic variability. Overall uncertainty comprises variability and uncertainty which is a reflection of the lack of the estimator's lack of knowledge in respect of the parameters and characteristics of the physical system, and is also called "epistemic uncertainty" (Williams, 2002) or "fundamental uncertainty" (Vose, 2005).

In a critical review of risk, uncertainty and governance in mega projects Sanderson (2012) emphasises the importance of considering people’s ‘fundamental epistemological assumptions about decision-maker cognition and about decision-maker views on the nature of the future (risky or uncertain)’. He identifies the following categories with regard to the assumptions about decision-maker views on the nature of the future:

Risk/Uncertainty Category	Decision-Makers View
Risk Category 1: a priori probability	The decision-makers view is that they are able to assign objective probabilities to a known range of future events on the basis of mathematically 'known chances', e.g. the probability of throwing a six when a perfect die is 1 in 6.
Risk Category 2: statistical probability	The decision-maker's view is that they are able to assign objective probabilities to a known range of future events on the basis of empirical/statistical data about such events in the past e.g. the probability of being involved in a fire.
Uncertainty Category 1: subjective probability	The decision-makers view is that they face a known range of possible future events, but lack the data necessary to assign objective probabilities to each. Instead they use expectations grounded in historical practice to estimate the subjective probability of future events.
Uncertainty Category 2: socialised	The decision-makers view is that they face a situation in which the nature and range of future events is unknown, not simply hard to understand because of a lack of relevant data. The future is inherently unknowable, because it is socially constructed and may bear little or no relation to the past or the present.

Of key importance is Sanderson's emphasis on the consideration of people's epistemological assumptions when considering the management of risk and uncertainty. The perspective is that there is a continuum between the two concepts depending on the degree of knowledge and calculation (Sanderson, 2012).

Risk involves situations where the probability of outcomes is 'known', while uncertainty is the opposite (i.e. when the probability of outcomes is not known).

All authors separate variability and uncertainty due to the need for different modelling, which is the reason that in this study these terms are maintained separately, not only because of differences in modelling but because of different methods of management as well as a different share in management during the life cycle, which will be elaborated below.

The previous analysis Burcar Dunović (2012) defined three areas of management of uncertainty, of which only one relates to traditional risk management. It starts with planning with variabilities, which is supplemented by the management of risks and uncertainties. At different phases of project the participation of specific elements of the management of uncertainty will not be equal, and depends on the degree of development of the project.

Knowing the types of uncertainty, is not only important for the selection of a method of assessment and risk modelling, it is very important for the selection of a strategy and plan for dealing with risk.

Based on this explicated look at managing uncertainty it can be concluded that there are even two areas of managing uncertainty associated with the level of knowledge about a project (Table 6).

The share of specific areas of uncertainty management change over time, and Table 7 illustrates the share of a specific area in relation to the overall management of uncertainty.

Uncertainty decreases during the project as knowledge about the project grows, and their behaviour can be illustrated with the graph below (Table 8).

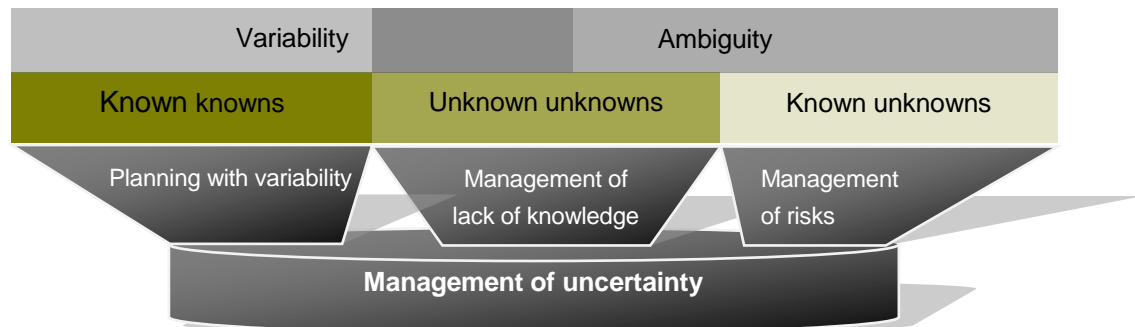


Table 6 Illustration of the field of management of uncertainty

Thus, uncertainty and risks in a project change depending on the degree of development of the project, i.e. the definition of the project, with which the level of knowledge about the project increases. In order to achieve the project objectives the project management process must ensure that the level of knowledge about the project and the definition of the project continually increase in order reduce uncertainty and risks. However, the uncertainty of a project is not only related to the level of knowledge about the project and the project definition. External changes as well as changes within the project will also affect the uncertainty of the project.

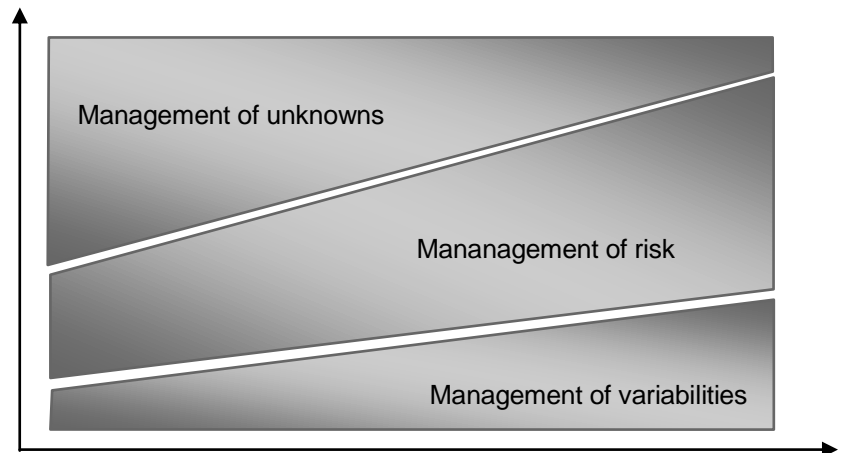


Table 7 Relative share of areas of management in the management of uncertainty over time

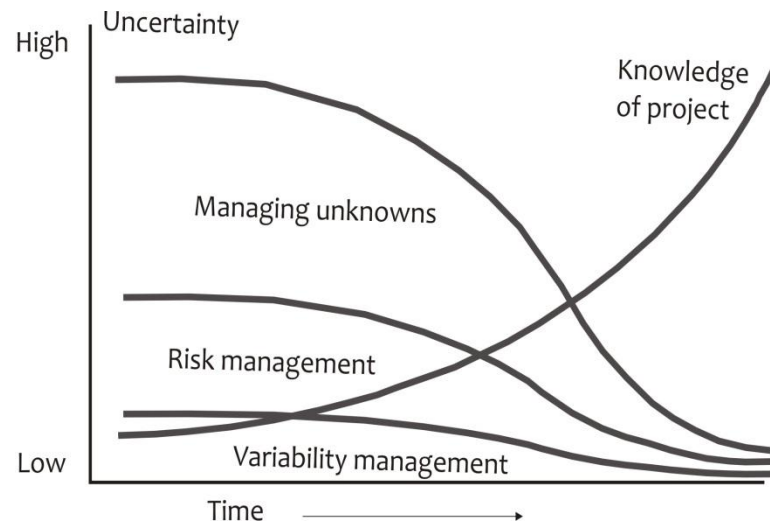


Table 8 Areas of uncertainty management over time

Ontological aspect

Analyzing the origin of risk impact there is different models of risk. Burcar Dunović (2009) analysed different models with purpose to find appropriate model for developing risk register for risk and knowledge management in construction projects. During the research on risk management in construction projects Burcar (2005a) and Burcar Dunović and Radujković (2009) understood that the main problem to project risk from issue and they cannot differ what is risk and what is source. The literature review showed that risks and models which are representing risks are understood very differently. There are no clear descriptions what risk components and characteristics are. Source and cause are treated as synonyms, as well as consequence and impact. When we talk about risks in construction projects, source and cause can be treated as synonyms which why we casted out cause from our concept. Consequence and impact, on the other hand, have absolutely different meaning and function in this risk model – consequence is component and impact is its characteristic.

Model developed for designing risk register system Burcar Dunović et. Al. (2013) treats event/risk as the central part of the model (**Error! Reference source not found.**). It represents an uncertain occurrence, action or event the occurrence of which causes a consequence.

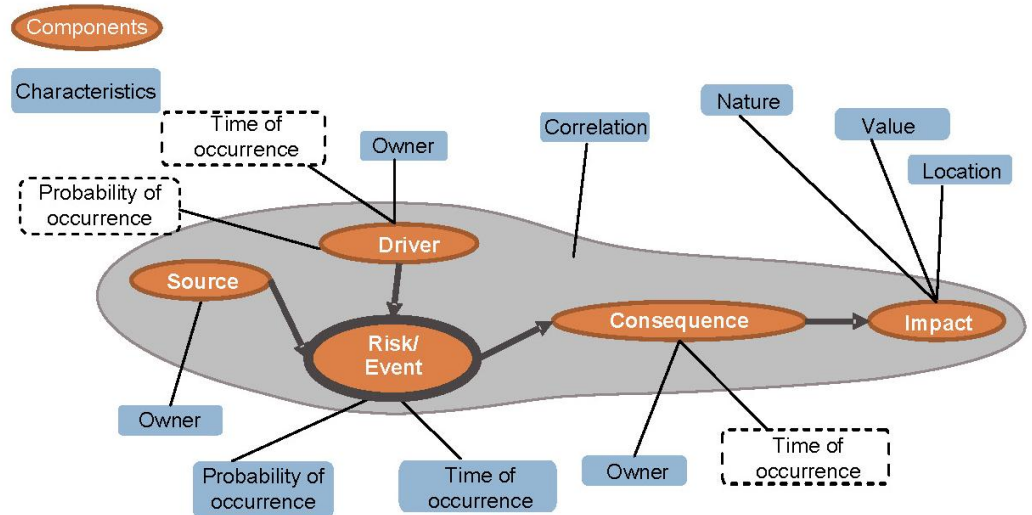


Table 9 Risk components and characteristics *Source: Burcar Dunović et al. (2013).*

The source of risk is defined as a condition of area of human activity or a natural or other phenomenon, from which the risk is generated, or from which the possibility that the risk might occur is generated. It exists either in the project or outside of the project, and does not have a variable characteristic. Its important characteristic is the owner i.e. the participant because of which a source has come to exist. The consequence is the condition, occurrence or event that has occurred precisely because of the occurrence of an event/risk, and which affects the success of the project, i.e. the project objectives, through the risk impact. Significant characteristics of the impact are the nature, size and place that define in which way the risk will impact the project and its objectives, i.e. to what extent and on what part of the project, WBS or activity.

The next component is the driver that can be either an event, occurrence or a change of condition, which leads to activation of the risk mechanism, i.e. which initiates transformation of risk into actual event. Through its actual occurrence, the risk stops being a risk and becomes actual event or problem to be dealt with. The risk can be described as a mechanism in a latent state that needs driver to be activated.

In addition to the source, the driver and the consequence must also have the owner i.e. the stakeholder to which the two events or occurrences are related. The time and probability of occurrence are the characteristics that are most often related to risk in general, but are related in this model to the event, which is regarded as the central component of risk. Both components could also be related to the occurrence of the driver being an event that activates the risk mechanism, while the time of occurrence could also be related to the consequence.

Correlation is very important part of risk model which characterize the interaction between two risks. In developing this model our intention was to link all risk characteristics with risk components, but in case with correlation we made the exception defining it on risk level instead of component level. Correlation between two risks can include any component of each risk and they together with their interactions are used to describe and define correlation type and mechanism.

Vast of research papers dealing with risks result with risk factors that affecting decision-making and which have been classified into two groups: internal and external factors. For example, internal includes 'age', 'education level', 'work experience', and 'personality type', whereas external factors embrace 'company culture', 'country culture', 'regulation', 'socio-economic condition' and 'geography' (Luu et al., 2008). Others associate internal factors with aspects related to the project as relationship among stakeholders as well as the technical and operational sides (Bing et al., 2005; Haidar and Ellis, 2010; Kendra, and Taplin, 2004). On the other hand, the external factors are not related to the project and have an indirect impact on the project success. These are associated with political, economic, natural, social and environmental changes (Bing et al., 2005; Haidar and Ellis, 2010). All differences are due to the megaproject subject (transport, business, industrial...).

On, the other hand, Burcar Dunović et al. (2013) suggest classification of risk sources in risk breakdown structure, classifying natural, economic, political, legal, social in external and management, human factor, technical, procurement and contractual as internal. Chen et al. (2009 and 2011) classified risks in developmental phases of megaprojects in STEEP categories social, technological, economic, environmental and political used by Boateng et al. (2012) for System Dynamics (SD) modeling for social and environmental (SE) risk management during megaprojects development.

Irimia-Dieguez et al. (2014) classified risks in megaprojects in 9 main categories: design, legal and/or political, contractual, construction, operation and maintenance, labour, clients/users/society, financial and/or economic and force majeure.

Looking from aspect of origin of risks, Atkinson et al. (2006), define three key-areas of uncertainty:

- i) uncertainty linked to estimations (of cost, schedule and demand);
- ii) uncertainty associated with project parties (related to infrastructure management) and
- iii) uncertainty regarding to project lifecycle stages (related with the failure of thoroughly carrying out the design and planning stages). As a result the project proceeds with insufficient detail and specifications.

These uncertainties have negative effects on costs, schedule and performance of the projects because they lead to additional design and planning tasks during project implementation. In fact, the project construction phase is frequently the most critical part as far as risks are concerned. During this stage, substantial funds are spent without any project's cash flow and technical and economic viability could be compromised. Besides, the construction could be negatively affected by environmental changes as natural disasters and/or geological unforeseen conditions due to geology.

Chapman and Ward (2003a) present 5 areas where uncertainty is prevalent:

- i) Variability associated with estimates.
 - a. Lack of clear specification what is required
 - b. Novelty or lack of experience of this particular activity (project)

- c. Complexity in terms of number of influencing factors and interdependencies
- d. Limited analysis of the processes involved in the activity (project)
- e. Possible occurrence of particular events and conditions that might affect the activity (project)
- ii) Uncertainty about the basis of estimates.
 - a. Who produced estimates
 - b. What form they are in
 - c. Why, how and when they are produced
 - d. What resources and experience are based on
 - e. How they take into account “known unknowns”, “unknown unknowns”, “bias”
- iii) Uncertainty about design and logistics.
 - a. Uncertainty about project deliverable
 - b. Uncertainty about process of delivery
- iv) Uncertainty about objectives and priorities.
 - a. Uncertainty about objectives
 - b. Uncertainty about priority of objectives
 - c. Trade-offs/compromises
 - d.
- v) Uncertainty about the fundamental relationships between project parties
 - a. Specification of responsibilities
 - b. Perceptions of roles and responsibilities
 - c. Communication across interfaces
 - d. Capability of the parties
 - e. Formal contractual conditions and their effects
 - f. Informal understanding on top of, or instead of, formal contracts
 - g. Mechanisms for coordination and control

The complexity of a project, along with the level of uncertainty, is the characteristic most commonly associated with large-scale projects (Burcar Dunović et al., 2014). In the literature one can find various types of relationships between complexity and risk, i.e. uncertainty, which can be categorized in the three groups:

- Uncertainty and complexity are independent characteristics (Clegg et al., 2002),(van Marrewijk et al., 2008),
- Complexity is compounded by uncertainty (Williams, 2002)
- Project complexity is the source of uncertainty in project. (Danilovic and Browning, 2007),(Secretariat, 2007)

Looking at this relationship from epistemological aspect it is best described with Williams, while taking into account ontology of risks the third statement is the most appropriate. Therefore, complexity can be considered both, compounded by uncertainty and as source of uncertainty.

Case study analysis results

Case Studies Profiles

Megaproject 1: Offshore Platform EPCI in the Mediterranean Sea

Due to sensitivity of project data the project cannot be named.

Megaproject 2: Sava Zagreb, The River, Croatia

Project “Zagreb on the Sava River” is a multifunctional program of regulation, protection and utilization of river Sava from Slovenian border to the town of Sisak. The experts have been dealing with the regulation of Sava River for some decades now. It all started with a big flood in Zagreb in 1964. Several multifunctional concepts have been made throughout the years, including power plants, trying to resolve flood protection problems. Probably one of the reasons why none of the concepts ever started construction is that there wasn't a management model which would gather, coordinate and manage all Program stakeholders. In 2012 a new company was established as a subsidiary of HEP Group (Croatian Energy Utility Company) to manage the project. The project manager created a model that puts together stakeholders at one side and experts council, as verification body, on the other side, connecting them through the operational team. Zagreb on the Sava River is a long-term sustainable solution to the problems related to the Sava River and the hinterland area of the Slovenian border to Sisak, and the project benefits are environmental, social and economic. Potentials and benefits of the project will be realized in water management, transportation, energy and space and will enable long-term sustainable development of the area. From the WBIF Program the Project management company received a grant funds in the form of Feasibility, Environmental and Social Impact Study. It will evaluate three different solutions/concepts and will select the most acceptable one. The project is still under development, with current estimated budget of € 1.4 billion and a project estimate at completion of 15 years.

Megaproject 3: Danube Bridge 2 – Combined rail/road bridge between Bulgaria and Romania at Vidin-Calafat

Megaproject 4: FERTAGUS Train Concession – Railway Axis North/South Lisbon, Portugal

This railway service is known as FERTAGUS Train - Railway Axis North/South (Lisbon) linking the North and South railways of the Lisbon Metropolitan Area through the bridge “Ponte 25 de Abril”. The network started into operation in 1999 with a total of 14 stations and 54 km length. The whole project comprises buses and light rail services, several viaducts, renovation of the existing line and construction of elevated crossings. FERTAGUS rolling stock is characterized as a suburban train service, providing the operation between Lisbon and the South municipalities of the Tagus River.

The Project has been sponsored by the Ministry of Finance, Ministry of Public Works (through IMTT, Land Transport Regulator) and local/regional municipalities (the initial investments and infrastructure construction were 100% Government budget). The contract was awarded in competitive tendering procedure to FERTAGUS (the private company) operate the service in 30 years of concession period. The contract includes the supply of equipment and rolling stock, operation and maintenance. In 2005 there was a contract renegotiation and was done a public-private partnership between the operator and the State. The contract was again renegotiated in 2010. Although the contract value is around EUR 132.1 million, the total costs of the project are around EUR 632.1 millions, including EUR 250 million for bridge upgrades; EUR 255 million for infrastructure construction of South line Coima/Setubal (FERTAGUS/State, 2005; Gomes, 2012; Tribunal de Contas, 2002; REFER EP, 2004). Thus, this project is a transport infrastructure megaproject with a huge impact for the Portuguese railway transportation sector since it provides a new (first) link between the North and the South of the country. The interview partner was the chief project manager of FERTAGUS.

Megaproject 5: Industrial Zones, Bulgaria

Megaproject 6: Highway A1, Croatia

The A1 motorway (Croatian: Autocesta A1) is the longest motorway in Croatia, spanning 478.9 kilometers. As the route traverses rugged mountainous and coastal terrain the route, completed as of 2014, required 376 bridges, viaducts, tunnels and other similar structures, including the two longest tunnels in Croatia and two bridges comprising spans of 200 meters (660 ft) or more. A motorway connecting Zagreb and Split was designed in the early 1970s, and a public loan was started in order to collect sufficient funds for its construction. However, due to political upheavals in Croatia and Yugoslavia, construction of the motorway was cancelled in 1971. After Croatian independence and conclusion of the Croatian War of Independence, efforts to build the motorway were renewed and construction started in 2000. The Zagreb–Split section of the route was completed by 2005, while the first sections between Split and Dubrovnik opened in 2007 and 2008. Construction costs incurred over 3 billion euro. Data are gathered for this research interviewing project managers responsible for each part of highway which were mainly involved in construction phase which were constructed on the route Zagreb-Split.

Megaproject 7: City Tunnel Leipzig, Germany

A very big (mega project) double tube railway tunnel project of the Deutsche Bahn (German Federal Railway) in the City of Leipzig of about 1 billion €. All Regional trains can now cross the town directly, which reduces the running time up to 40 min. The tunnel is in operation since December 2013. It is 1,5 km long (9 m diameter) and includes 4 underground stations. He was “built” partially by 2 tunnel shield driving machines (TBM) and partially by mining technique. The ground situation across the city and under the houses was a big challenge. Another challenge was the mixture of national, regional, European and private financing of the project. The overall costs were 960 Mio €, with the following financial partners: State Saxonia (52%), European Union (23%), Federal Republic of Germany (22%), Deutsche Bahn (2%) and City of Leipzig (1%). Planning took about 15 years and construction

10 years. The interview partner was the project director of the project management company, who was doing the project owners job for the Deutsche Bahn – in this case it was the DEGES, a German PM company, which is normally doing road projects.

Megaproject 8: VDE 8 (HSR Berlin–Nurnberg), Germany

A very large railway project - may be the largest in Germany at all. It is the 515 km long High-speed Line (HSL) from Berlin to Munich of about 10 billion €. The projects consists partially of renewing an existing railway line (288km) for 200 km/h and a completely new line (227km) for 300 km/h. When all parts will be in operation, the travel time from Berlin to Munich will be reduced from 7 to 4 hours. As the HSL crosses in large parts German secondary mountain it contains a high percentages of tunnels (about 60km) and large bridges (35km). Planning time is about 23 years and construction time is about 20 years (design and realization was overlapping for individual sections from the beginning). Interview partner was the project director of the project management company – a subcompany from the Deutsche Bahn - who is doing the project owners job for the Deutsche Bahn.

Megaproject 9: Sofia Tech Park, Bulgaria

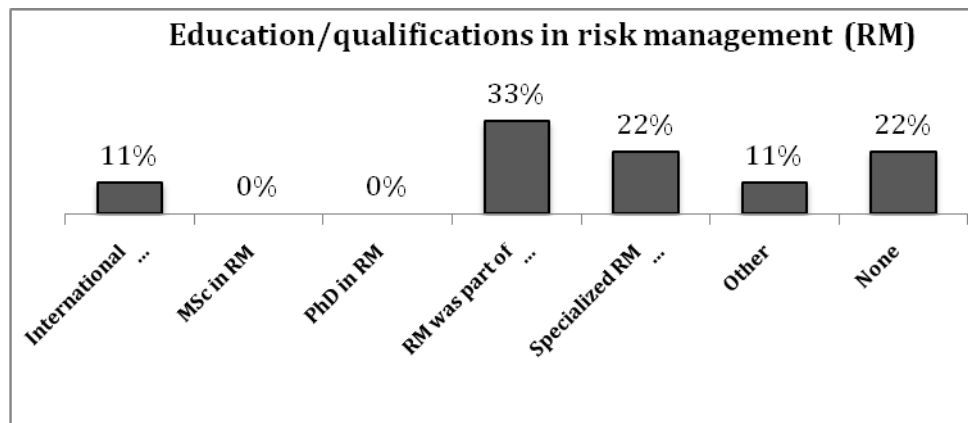
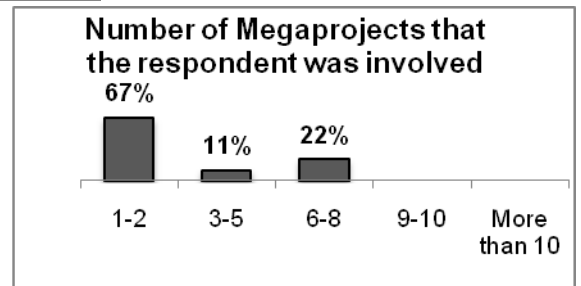
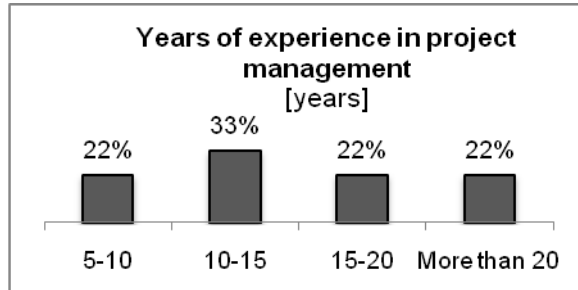
Quantitative Analysis

Megaproject quantitative template consists of an Excel spreadsheet with data about megaproject cases. A total of 35 questions (149 items) have been codified and analyzed. Each case contains information about respondent data, project data and risk management.

Respondent Data

This section is regarding to the respondents information: gender, how many years of experience they have in project management, how many megaprojects they have already participated, if they have any education/qualifications in Risk Management and so on and so forth.

The results are presented with following graphs and tables.



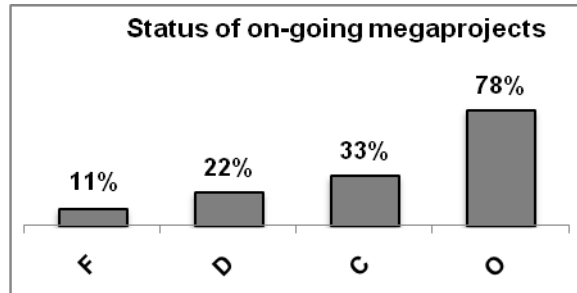
General, there is an unbalance in the managers' gender: more male managers (78%) than female managers (22%). They have a high experience in project management (78% have 10 years or more) but not many in megaproject management (67% have been involved in only 1 or 2 megaprojects during their career). Most of those project managers have no specialization, qualification or education in risk management. However, usually they are Project Managers, Project Coordinators or Directors.

Project Data

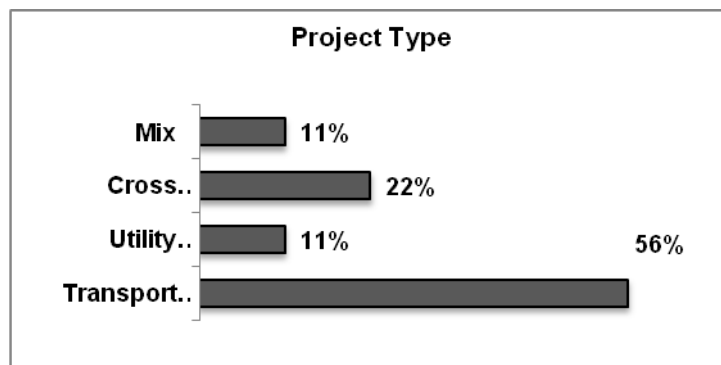
This section is regarding to the megaproject information: the type of megaproject, its situation (if it is on-going in front-end, design, construction or operation), the source of financing, which type of technology is used, and so on and so forth.

All of the cases are on-going megaprojects and 6 over 9 cases are in the operation phase.

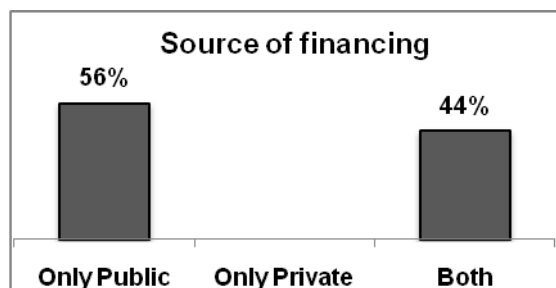
Although, some projects are in design and construction stages, at the same time that the operation stage.



The case studies are from diverse types: there are transport megaprojects (road and railways), cross-sectorial and mixture of them. However, the majority of the cases are transport megaprojects.



More than half of the megaprojects analysed have only public sources of financing, only 44% have both private and public sources; no one have only private financing. Additionally, there are a high variety of types of contracting and they are mainly financed by government or EU funds.

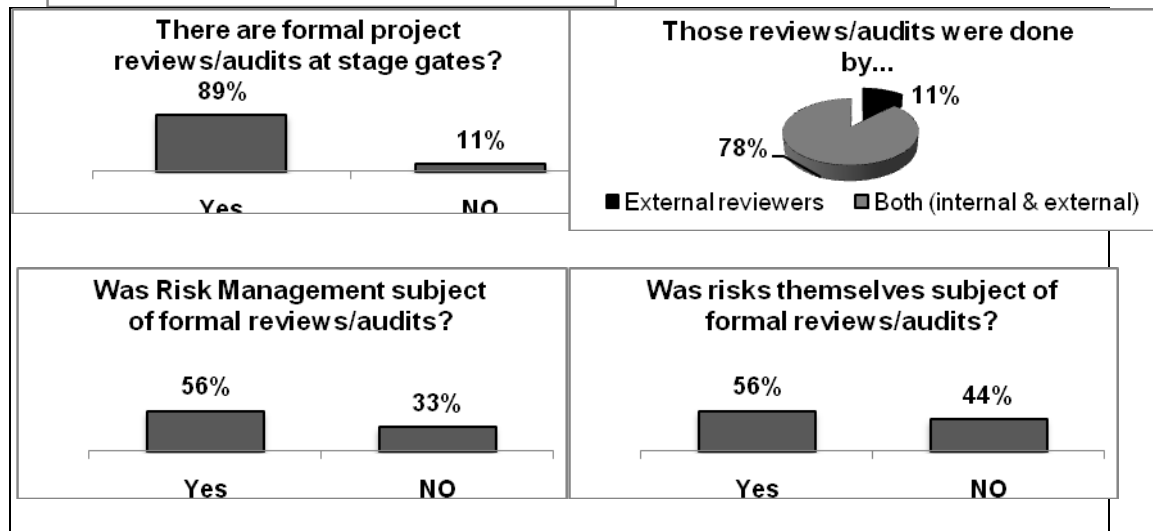
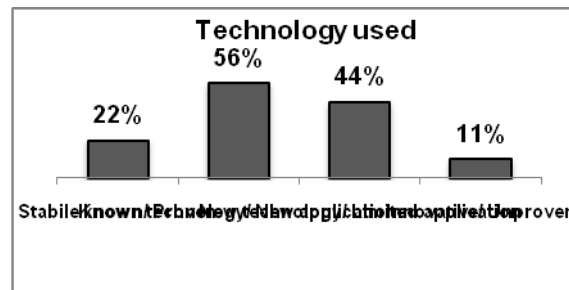


Type of contracting	MP [#]	Frequency [%]
Design-Bid-Build	4	44%
Design-Build	2	22%
Design- Build-Operate	1	11%
EPC/Turn Key	2	22%
Other	1	11%

Most sources of financing	MP [#]	Frequency [%]
Government budget	6	67%
Regional budget	3	33%
Development or investment bank	2	22%
EU funds	6	67%

Private investment	1	11%
Public-private partnership	2	22%

All the technology situations are presenting (stable known / proven technology; known technology / new application; new technology / limited application; innovative / unproven technology) but 56% of the cases present “Known technology / New application”.



Almost all cases analysed have formal project reviews/audits at stage gates, usually with both internal and external reviewers (78%). Only a 56% of the cases, which answered the question, have risk management and risks themselves subjects of formal reviews/audits.

Risk Management

In this section, it is possible to collect information related to risk management: the level of risk maturity model, which is the major source of uncertainty in megaproject front-end, which methodologies / tools and techniques are used for risk management, how risk management has been documented and so on and so forth. The results are the following.

Level of MoR risk maturity model

	MP 1	MP 2	MP 3	MP 4	MP 5	MP 6	MP 7	MP 8	MP 9	Average	Max.
Context of the organisation / activity	4	3	2	3	2	1	2		5	2.75	5
Involve all major stakeholders	3	5	1	4	3	2	2	1	4	2.78	5
Clear objectives	3	3	1	3	3	1	4	3	4	2.78	4
Policies, processes, strategies and plans	3	2	1	5	2	2	3	2	3	2.56	5
Risk management reports	4	1	1	2	2	1	3	3	3	2.22	4
Roles and responsibilities	2	3	2	4	1	1	3	4	2	2.44	4
Central risk function	2	4	1	2	2	1	2	1	3	2.00	4
Early warning indicators (EWIs)	2	1		1	2	1	1	1	1	1.25	2
Review the effectiveness of processes	2	2	1	4	2	1	2	3	5	2.44	5
Barriers to implementation	3	3	3	5	2	2	4	3	4	3.22	5
Risk culture	2	1	1	5	1	1	1	4	2	2.00	5
Strategies for improving risk management	3	1	1	5	1	1	2	2	2	2.00	5

The level of maturity is medium/low in the megaprojects analysed. The factors with higher level of maturity are:

- Context of the organisation / activity (mean 2.75)
- Involve all major stakeholders (mean 2.78)
- Clear objectives (mean 2.78)
- Policies, processes, strategies and plans (mean 2.56)
- Barriers to implementation (mean 3.22)

Rate what was the major source of uncertainty in front-end of your megaproject

	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8	MP9	Average
	Variability associated with estimates									3.21
• Lack of clear specification what is required	4	2	1	3	1	2	5	4	3	2.78
• Novelty or lack of experience of this particular activity (project)	3	5	3	3	2	3	3	3	4	3.22
• Complexity in terms of number of influencing factors and interdependencies	4	5	3	5	4		4	5	2	4.00
• Limited analysis of the processes involved in the activity (project)	2	3	3	4	2	5	1	1	1	2.44
• Possible occurrence of particular events and conditions that might affect the activity (project)	4	2	5	5	4	5		3	1	3.63

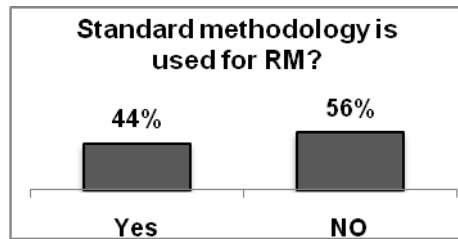
Rate what was the major source of uncertainty in front-end of your megaproject

	MP1	MP2	MP3	MP4	MP5	MP6	MP7	MP8	MP9	Average
	Uncertainty about the basis of estimates									3.06
• Who produced estimates	2	3	1	5	2	3	5	2	2	2.78
• What form they are in	2	3	1	3	3	4	4	2	2	2.67
• Why, how and when they are produced	2	2	2	5	2	5	5	2	2	3.00
• What resources and experience are based on	2	4		4	4	3	4	3		3.43
• How they take into account "known unknowns", "unknown unknowns", "bias"	3	2	4	4	4	5			2	3.43
	Uncertainty about design and logistics									2.78
• Uncertainty about project deliverable	1	3	1	3	3	2	3	4	3	2.56
• Uncertainty about process of delivery	3	3	4	3	3	5	3	1	2	3.00
	Uncertainty about objectives and priorities									2.04
• Uncertainty about objectives	1	2	1	1	2	1	1	4	2	1.67
• Uncertainty about priority of objectives	3	2	1	1	1	3	3	1	2	1.89
• Trade-offs/compromises	4	3	1	1	3	5	1	2	3	2.56
	Uncertainty about fundamental relationships between project parties									2.91
• Specification of responsibilities	4	5	2	1	4	3	1	1	3	2.67
• Perceptions of roles and responsibilities	4	5	3	4	2	4	1	1	3	3.00
• Communication across interfaces	4	5		4	3	4	1	3	2	3.25
• Capability of the parties	4	5	3	4	4	2	3	3	4	3.56
• Formal contractual conditions and their effects	4	1	2	1	3	4	1	2	2	2.22
• Informal understanding on top of, or instead of, formal contracts	4	1	4	1	4	5		1	3	2.88
• Mechanisms for coordination and control	5	1	4	1	3	3	1	3	4	2.78
Average	3.14	3.05	2.45	3.00	2.86	3.62	2.63	2.43	2.48	2.88

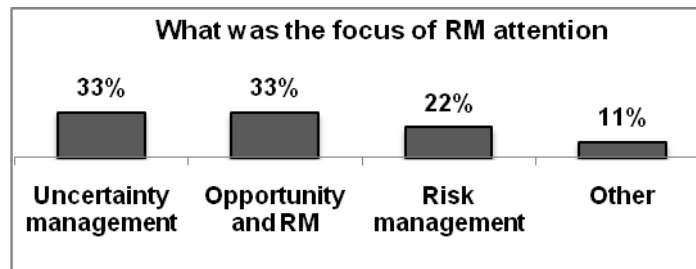
Legend: 5 - Major; 1 - minor

The main sources of uncertainty in front-end are the variability associated with estimates (mean 3.21) and the uncertainty about the basis of estimates (mean 3.06). The less one is the uncertainty about objectives and priorities (mean 2.04). When the analysis is done through each factor, the major source of uncertainty comes from "Complexity in terms of number of influencing factors and interdependencies" (4.00), followed by "Possible occurrence of particular events

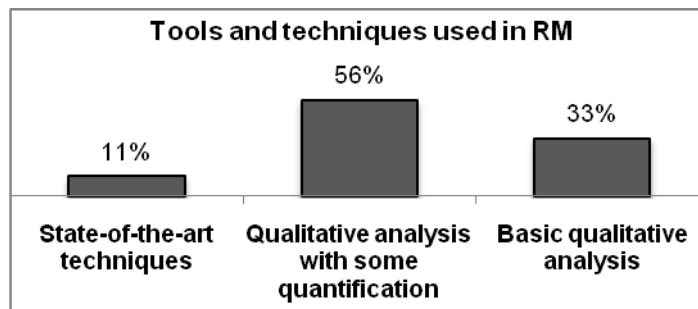
and conditions that might affect the activity (project)” (mean 3.63) and “Capability of the parties” (mean 3.56). Sources with less uncertainty associated are “Formal contractual conditions and their effects” (mean 2.22), “Uncertainty about priority of objectives” (mean 1.89) and “Uncertainty about objectives” (mean 1.67). More than half of the megaprojects don’t use standard methodology for risk management (56%).



There is also a variety of the risk focus of risk management attention where trend of risk management evolution is followed taking into account uncertainty management and opportunity and risks.



Plus, 55% of the cases analysed use qualitative analysis with some quantification to managed risk management; 33% use basic qualitative analysis and only 11% use state-of-art techniques.



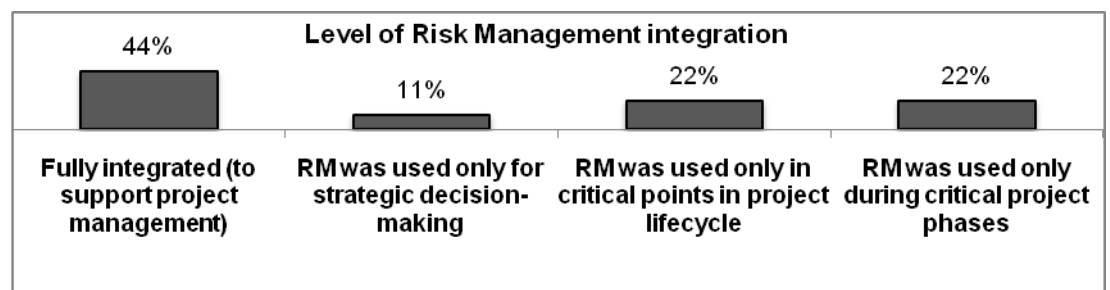
Risk management is fully integrated to support project management in 44% of the case studies analysed. However, more than half cases have no formal process in place to identify risk owners and to empower them for effective risk treatment.

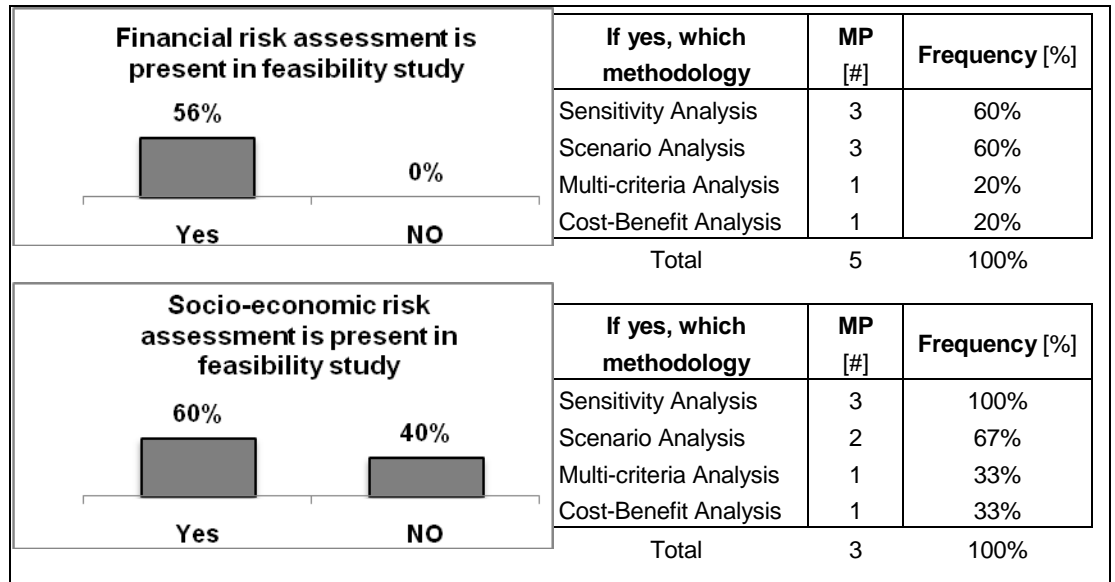
Parties involved and allocation of responsibilities	MP [#]	Frequency [%]
RM facilitated and involving stakeholders beyond the core project team	2	22%
RM facilitated throughout the core project team	5	56%
Specific functions with limited roles	0	0%
Scattered, ad hoc and left to individuals	2	22%
Other	0	0%
Total	9	100%

How was risk management documented?	Frequency [%]
Documentation reported and updated through whole lifecycle	56%
Limited documentation	33%
No documentation	11%

Was there formal process in place to identify risk owners and to empower them for effective risk treatment?	MP [#]	Frequency [%]
Yes	4	44%
NO	5	56%
Total	9	100%

Thirty per cent of the megaprojects analysed have limited documentation on risk management process; 56% have, in fact, risk management documented in reports and updated through whole lifecycle of the project.





The financial risk assessment is presented in megaproject feasibility studies in all the answers (5 megaprojects). Sixty seven per cent used a mix of methodologies; sensitivity analysis (60%) and scenario analysis (60%) are the most used. Three cases analysed present socio-economic assessment in their feasibility study. All used sensitivity analysis as methodology; 2 megaprojects also used scenario analysis as a methodology.

Who was involved in risk assessment process?	MP [#]	Frequency [%]
Project manager	5	56%
Project team members	7	78%
Consultants	2	22%
Owner	2	22%
Risk management specialist (internal)	2	22%
Risk management specialist (external)	1	11%
Possible contractors	2	22%
Legal/regulatory stakeholders	2	22%
Politicians	1	11%
Other (Commercial/ Proposal Team)	1	11%
Total	9	

Formal projects documents with risk management results	Megaproject [#]	Frequency [%]
Initial planning documents	1	11%
General risk management	4	44%
Status / Monitoring and technical	5	56%
Financial	4	44%
Audits	2	22%
Quality	3	33%
Others	2	22%

At the end, usually, project managers and project team members are involved in risk management process. In fewer case studies analysed, contractors, consultants and owner are also involved.

The data for risk assessment was gathered basically through the past experience and historical data. The megaprojects analysed have also a high heterogeneity of the formal project documents with risk management results: from initial planning documents to financial documents, audits and quality service.

Qualitative Analysis

This section aims to present a qualitative analysis of megaprojects case studies. Some questions in the survey (14, 15, 16, 29, 30 and 35) need to be analysed in a qualitative perspective, taking into account others variables.

The analysis of the question 14 will generate a list of success criteria. We will obtain a list of constraints (question 15) and critical factors (question 16), and their impact on success criteria.

Figure 1 explains the framework of the analysis. Basic components by which the risk mechanism is presented are the event/risk, source, driver, consequence, and impact. Each of these components has some characteristics by which it is described. Therefore, the risk is fully described through components and their characteristics.

Reflection on EU funded major projects

Risk Assessment on Major Projects

In this part of the report we present brief insights from guidelines about the procedure and requirements for risk assessment as a part of proposals preparation for major projects intended to be co-financed by EU funds.

Since the three EU funding programming periods mentioned in this part of the report (2000-2006, 2007-2013, 2014-2020) have different context and different set of rules in relation to major projects, the intention here was not to provide exhaustive cross-check conclusions, but only to offer short reminding on what-and-why was and is necessary when assessing risk in front-end of major projects, as per EU legislation.

Major project definition

Definition of a major project that may be co-financed by European Regional Development Fund (ERDF) and Cohesion Fund (CF) is the following (Common

provisions regulation (CPR) No 1303/2013 (European Parliament, 2013), Article 100):

An operation comprising a series of works, activities or services intended in itself to accomplish an indivisible task of a precise economic or technical nature which has clearly identified goals and for which the total eligible cost exceeds EUR 50 000 000 and in the case of operations contributing to the thematic objective under point (7) of the first paragraph of Article 9 (promoting sustainable transport and removing bottlenecks in key network infrastructures) where the total eligible cost exceeds EUR 75 000 000 (the 'major project'). Financial instruments shall not be considered to be major projects.

Comparing to the previous programming period (2007 – 2013), the financial criteria for defining major project have been enlarged from 25 and 50 EUR million to 50 and 75 EUR million respectively.

Cost and Time (non)Efficiency of Previous Major Projects Delivery

EU Cohesion Policy Synthesis report published in March 2010 presented ex post evaluation of Cohesion policy programmes 2000-2006 financed by the European Regional Development Fund (ERDF) in Objective 1 and 2 regions. In chapter 3 (POLICY OUTCOMES AND EFFECTS IN MAIN POLICY AREAS) it is stated:

*The investigation, which covered the construction of roads, railways, urban transport systems, infrastructure for water supply and treatment and energy supply, revealed, first, **that major projects were prone to have a high incidence of delays in completion and of cost overruns. Some three-quarters of projects were subject to some delay, with the average time amounting to around 26% of the initially estimated period of completion. Just over half of the projects investigated exceeded their budget, with an average cost overrun of 21%.***

These figures, however, are not unusual and are very much in line with the incidence and scale of delays and cost overruns of major projects funded from national sources across the EU or in other parts of the world. For the most part, they do not vary systematically between countries or different types of project. For the projects examined, however, some differences were evident:

- *costs overruns were less of a problem in Germany than elsewhere and more of one in Poland (averaging 50% for the four projects investigated);*
- *delays were particularly lengthy in Portugal (averaging 85% of the initial estimates for the 5 projects covered);*
- *urban transport projects tended to be subject to larger cost overruns and delays than other types, average 45-50% in each case.*

It is difficult to draw conclusions about efficiency from this evidence, since there are a wide range of potential reasons for both cost and time overruns, many of which are outside the control of contractors or contracting authorities. However, they clearly indicate the importance of building in sufficient allowance for contingencies and delays in the planning and budgeting of projects. This tended not to be done adequately for most of the projects investigated. Indeed, in most cases, there was a bias towards optimism which is typical for large-scale infrastructure projects.

Major Projects Risk Assessment Procedure

In the direction of the assessment of financial and economic risk and uncertainty in preparation of major projects that would be co-financed by Structural Funds and the Cohesion Fund, it can be seen that in all three programming periods covered by this study (2000-2020) of the ERDF and CF funds requirements for major project proposals, a Cost-Benefit Analysis (CBA) for major projects (including risks assessment part) was requested in the respective legislations for the corresponding programming period.

For the programming period 2007-2013, Article 40(e) of Reg. 1083/2006 required the Member State (or the managing authority) to provide the European Commission with a CBA for major projects and two main reasons are given why CBA is required for major projects:

- 1) To assess whether the project **is worth** co-financing; for that, an economic analysis is required. If the project's economic net present value (ENPV) is positive, then the society (region/country) is better off with the project because its benefits exceed its costs.
- 2) To assess whether the project **needs** co-financing; for that, financial analysis is required: if the financial net present value (FNPV) of the investment without the contribution of the Funds (FNPV/C) is negative then the project can be co-financed.

The Guidance on the Methodology for Carrying Out CBA for the Programming Period 2007-2013 (European Commission, 2006) has recommended two main steps to be undertaken in relation to risk assessment within CBA:

1. **Sensitivity analysis**, which aims to identify the project's critical variables. This is done by letting the project variables (input variables for financial and economic analysis) vary according to a given percentage change and observing the subsequent variations in both financial and economic performance indicators (FNPV / ENPV and Financial Rate of Return (FRR) / Economic Rate of Return (ERR)). Variables should be varied one at a time, while keeping the other parameters constant.
2. **Risk analysis**; assessing the impact of given percentage changes in a variable on the project's performance indicators does not say anything about the probability with which this change may occur. Risk analysis deals with this. By assigning appropriate probability distributions to the critical variables, probability distributions for the financial and economic performance indicators can be estimated. This enables the analyst to provide interesting statistics on the project's performance indicators: expected values, standard deviation, coefficient of variation, etc.

It should be noted that while it is always possible to do a sensitivity analysis, the same cannot be said for risk analysis. In some cases (e.g. lack of historical data on similar projects) it may prove rather difficult to come up with sensible assumptions on the critical variables' probability distributions. In such cases, a qualitative risk assessment should at least be done to support the results of the sensitivity analysis. In the same guidance it is underlined that European Commission's "**Guide to Cost-Benefit Analysis of investment projects**" should be considered as the main reference which can provide the reader with a thorough treatment of the subject of CBA procedure (including risk assessment part).

The *Guide to Cost-Benefit Analysis of Investment Projects* (European Commission, 2008), which should be looked together with the mentioned *Guidance on the Methodology for Carrying Out CBA for the Programming Period 2007-2013* updates and expands the previous edition of the same Guide (2002), which in turn was the follow up of a first brief document (1997) and of a subsequent substantially revised and augmented text (1999). The objective of the Guide reflects a specific requirement for the EC to offer guidance on project appraisals, as embodied in the regulations of the Structural Funds (SF), the Cohesion Fund (CF), and Instrument for Pre-Accession Assistance (IPA). The Guide, as said in the document, *should be seen primarily as a contribution to a shared European-wide evaluation culture in the field of project appraisal.*

It is stated in the Guide that risk, but not uncertainty, is subject to empirical measurement, and can be analyzed and possibly managed. Against this background, the Funds' regulations required a risk assessment for major infrastructure and productive investment projects (Article 40 1083/2006 EU Regulations).

The recommended steps for assessing the project risk are:

1. **Sensitivity analysis;** the Guide suggests generally considering as “critical” those input variables for which a 1% variation (positive or negative) gives rise to a corresponding variation of at least 1% in the financial/economic indicator base value. Variables' potential variability and its impact on financial/economic output should be assessed through elasticity analysis in a qualitative and/or quantitative form.
2. **Probability distributions for critical variables;** process of assigning probability distributions to each of the critical variables, defined in a precise range of values around the best estimate, used as the base case, in order to calculate the expected values of financial and economic performance indicators.
3. **Risk analysis;** calculation of the probability distribution of the FRR or NPV of the project. For this purpose, the use of the Monte Carlo method is suggested in the Guide. The method consists of the repeated random extraction of a set of values for the critical variables, taken within the respective defined intervals, and then calculating the performance indices for the project (FRR or NPV) resulting from each set of extracted values. By repeating this procedure for a large enough number of extractions (generally more than a few hundred) one can obtain a pre-defined convergence of the calculation as the probability distribution of the FRR or NPV.
4. **Assessment of acceptable levels of risk;** Generally, a neutral attitude towards risks is recommended in the Guide, because the public sector might be able to pool the risks of a large number of projects. In such cases, the expected value of the ERR could summarize the risk assessment. In some cases, however, the evaluator or the proposer can deviate from neutrality and prefer to risk more or less for the expected rate of return; there must, however, be a clear justification for this choice (for example, a very large project in a small country).

5. **Risk prevention**; a typical source of forecasting mistakes in project appraisal is optimism bias, i.e. the demonstrated systematic tendency for project appraisers to be over-optimistic about the estimation of the key project parameters: investment costs, works duration, operating costs and benefits. To minimize the level of optimism bias, specific adjustments in the form of increased cost estimates and decreased, or delayed, benefit estimates should be made. Such adjustments should not be seen as a substitute for risk assessment, but rather as a more accurate basis on which to develop risk analysis.

In the Guide additional topics have been considered:

- **The switching value** – indicates what percentage change in the variables would make the NPV (economic or financial) equal to zero.
- **Scenario analysis** – the specific form of sensitivity analysis. As opposed to sensitivity analysis, scenario analysis studies the combined impact of determined sets of values assumed by the critical variables. Combinations of ‘optimistic’ and ‘pessimistic’ values of a group of variables define the optimistic and pessimistic scenarios. Project performance indicators are then calculated for each combination.

Major Projects Risk Assessment in the Legislation for the Programming Period 2014-2020

While waiting for the new edition of *Guide to CBA of investment projects* (which will be built on previous version), it is presented here how CPR No 1303/2013 (European Parliament, 2013) and Commission Implementing Regulation (EU) 2015/207 (European Commission, 2015) define procedure of risk assessment in CBA.

In the Article 101 of CPR No 1303/2013, it is, i.a., stated:

Before a major project is approved, the managing authority shall ensure that the following information is available:

...

(e) a cost-benefit analysis, including an economic and a financial analysis, and a risk assessment;

(f) an analysis of the environmental impact, taking into account climate change adaptation and mitigation needs, and disaster resilience;

...

(h) the financing plan showing the total planned financial resources and the planned support from the Funds, the EIB, and all other sources of financing, together with physical and financial indicators for monitoring progress, taking account of the identified risks;

Commission Implementing Regulation (EU) 2015/207 states:

The cost-benefit analysis, including an economic analysis, a financial analysis and a risk assessment is a prerequisite for the approval of a major project. A methodology for carrying out the cost-benefit analysis should be developed based on recognized best practices and with a view to ensuring consistency, quality and rigour, both in carrying out the analysis and in its assessment by the Commission or independent experts. The cost-benefit analysis of major projects should show that the project is

desirable from an economic point of view and that the contribution from the ERDF and the Cohesion Fund is needed for the project to be financially viable.

Under heading 2.4. of Commission Implementing Regulation (EU) 2015/207 risk assessment procedure has been defined. As set out in Article 101(1)(e) of Regulation (EU) No 1303/2013, a risk assessment must be included in the CBA. Risk assessment enables the project promoter to better understand the way the estimated impacts are likely to change should some key project variables turn out to be different from those expected. A thorough risk analysis constitutes the basis for a sound risk-management strategy, which in turn feeds back into the project design. Particular attention should be paid to climate change and environmental aspects. According to Commission Implementing Regulation (EU) 2015/207, the risk assessment shall comprise two steps:

1. *Sensitivity analysis, which determines the ‘critical’ variables or parameters of the model i.e. those whose variations, positive or negative, have the greatest impact on the project’s performance indicators, shall take the following aspects into consideration: — the critical variables are the ones whose 1 % variation results in more than 1 % variation of the NPV; — the analysis is carried out by varying one element at a time and determining the effect of that change on the NPV;*
 - *the switching values are defined as the percentage change the critical variable should assume to make the NPV equal to zero;*
 - *scenario analysis allowing the study of the combined impact of determined sets of critical values and in particular, the combination of optimistic and pessimistic values of a group of variables to build different scenarios, which may hold under certain hypotheses.*
2. *Qualitative risk analysis including risk prevention and mitigation, which shall include the following elements:*
 - *a list of risks to which the project is exposed;*
 - *a risk matrix showing for each identified risk:*
 - *the possible causes of failure,*
 - *the link with the sensitivity analysis, where applicable,*
 - *the negative effects generated on the project,*
 - *the ranked (e.g. very unlikely, unlikely, about as likely as not, likely, very likely) levels of probability of occurrence and of the severity of impact,*
 - *the risk level (i.e. combination of probability and impact);*
 - *identification of prevention and mitigation measures, including the entity in charge of preventing and mitigating the main risks, standard procedures, where appropriate and taking into account best practices, where possible, to be applied to reduce risk exposure, where considered necessary;*
 - *interpretation of risk matrix including an assessment of the residual risks after the application of prevention and mitigation measures;*
 - *In addition the risk assessment may, where appropriate (depending on project size, data availability), and should, where the residual risk exposure is still significant, include the probabilistic risk analysis, which involves the following steps:*
 1. *Probability distributions for critical variables informing about the likelihood of occurring a given percentage change in the critical variables. Computing the probability distribution of critical variables is necessary to carry out a quantitative risk analysis.*

2. *Quantitative risk analysis based on Monte-Carlo simulation, providing probability distributions and statistical indicators for expected result, STD, etc. of project financial and economic performance indicators.*

What is more detailed in regulation for this programming period comparing to the previous is the list of the main risks per sector to be taken into account in the risk assessment, set out in the implementing regulation. In order to assist the project promoters in preparation of qualitative risk analysis, EU Member States are encouraged (if they consider this appropriate and/or feasible) to develop national guidelines on valuation of certain standard project risks, and list of mitigation and prevention measures across sectors.

On Figure 1 the required info about risk assessment as a part of submission of the information on a major project proposed for co-financing by ERDF / Cohesion Fund is presented. It may be seen that detailed info is required about methodology of risk assessment, sensitivity analysis, risk matrix and risk mitigation strategy and measures.

E.3. Risk assessment and sensitivity analysis

 E.3.1. *Please provide short description of the methodology and summary results including main risks identified*

 E.3.2. *Sensitivity analysis*

State the percentage change applied to the variables tested:

Present the estimated effect (as a percentage change) on results of financial and economic performance indexes.

Variable tested	Financial Net Present Value (FNPV(K)) variation (%)	Financial Net Present Value (FNPV(C)) variation (%)	Economic Net Present Value variation (ENPV) (%)
< type='S' maxlength='500' input='M'>	< type='P' input='M'>	< type='P' input='M'>	< type='P' input='M'>

Which variables have been identified as critical? State which criterion has been applied and mention the impact of the key variables on the main indicators — FNPV, ENPV.

What are the switching values of the critical variables? Please provide an estimated percentage change for FNPV or ENPV to become zero for each of the critical variables identified.

 E.3.3. *Risk assessment*

 Please present a short summary of the risk assessment including a list of risks to which the project is exposed, the risk matrix ⁽¹⁾ and interpretation and proposed risk mitigation strategy and the body responsible for mitigating the main risks such as cost overruns, time delays, demand shortfalls; special attention should be given to environmental risks, climate change related risks, and other natural disasters related risks.

 E.3.4. *Additional assessments carried out, if applicable*

If probability distributions for critical variables, quantitative risk analysis or options to assess climate risk and measures have been carried out, please provide details below.

⁽¹⁾ In case of a PPP project it should include the risk matrix as allocated under the PPP arrangements (if the operation has already been tendered) or the intended risk allocation under the PPP arrangements (if the operation has not yet been tendered).

Conclusions and recommendations

The bibliographical analysis shows that risk management of small and medium scale projects has been the subject of research on numerous occasions; however, this volume of papers is greatly reduced when considering only those studies that focus on megaprojects. This remains an area of research still in development and under expansion. Although the number of papers in this field has been increasing in recent years, topics such as 'stakeholders', 'governance', 'complexity' and 'sustainability' related to risk management need deeper research.

An additional research gap to be considered is the analysis of the possible differences existing between small and medium projects and megaprojects since many papers analyse these topics considering projects in general. Moreover, there is still work to be done in specifying how projects are distinct from other forms of organizing.

Analysis shows that megaprojects with the highest average value of uncertainty have variability associated with estimates and uncertainty about basis of estimates.

For the megaproject case studies that were compared and analysed in this investigation, it could be interesting to further take into account variables that could affect the risk management process such as:

- Sector (cross-sectorial, transport, utility,...)
- Source of financing (public, private, both...)
- Type of contracting (DBB, DB,...)
- Technology used
- Stage of the megaproject (Front-end, design, construction, operation)

Because the sample investigated here is, statistically speaking, very small and due to the importance of the subject, further research should be carried out in understanding risk management in megaprojects. This should focus on:

- Collecting more case studies to achieve a global database and to obtain statistic validation.
- Collecting more case studies to develop analysis taking into account the control variables.
- A qualitative approach to megaproject analysis.

Papers and other outputs produced by the Working Group

Recent publications done within the MEGAPROJECT COST Action include:

- SILVA, João de Abreu; PEDRO, Marisa J. G. (2012). “HSR Vigo-Oporto-Lisbon-Madrid” in the Megaproject Portfolio First Edition, ISBN 978-0-9576805-0-0, University of Leeds 2013.
- PEDRO, Marisa J. G.; SILVA, João de Abreu (2013). “A contextual analysis of the impacts of high speed rail on regional development and mobility”. WCTR13, World Conference on Transport Research 2013. Rio de Janeiro. Brazil; Acceptable to publish in Case Studies on Transport Policy.
- PEDRO, Marisa J. G.; MIKIC, Miljan (2015). “ORESUND LINK (Öresundsbron) Case Study” and “Channel Tunnel Rail Link Case Study” to be included in the Megaproject Portfolio Second Edition.
- PEDRO, Marisa J. G.; SILVA, João de Abreu (being drafted). “Uncertainty and Risk in megaprojects: The Portugal high speed rail network”. To be submitted in an International Journal.
- PEDRO, Marisa J. G.; SILVA, João de Abreu; BROOKES, Naomi (being drafted). “Exploring the influence of external stakeholders on transportation megaprojects: The case of the Portuguese high speed rail network”. To be submitted in an International Journal.

Articles:

- Ana I. Irimia-Diéguez, Alvaro Sanchez-Cazorla, Rafaela Alfalla-Luque (2014): Risk Management in Megaprojects, Procedia - Social and Behavioral Sciences, Volume 119, 19 March 2014, Pages 407-416. DOI: 10.1016/j.sbspro.2014.03.046.
<http://www.sciencedirect.com/science/article/pii/S1877042814021375>
- Irimia-Dieguez, A.I., Medina-Lopez, C., Alfalla-Luque, R. (2015): “Financial Management of Large projects: A Research Gap”, Procedia Economics and Finance (in press). ISSN: 2212-5671. Elsevier

Conferences:

- Irimia-Dieguez, A., Alfalla-Luque, R. & Sanchez-Cazorla, A. (2013): Risk management in megaprojects. 27th IPMA World Congress 2013. Dubrovnik, Croatia. September 2013
- Irimia-Dieguez, A., Ruiz Luna, A., Alfalla-Luque, R. & Medina-Lopez, C. (2013): Financial aspects of megaproject management. 27th IPMA World Congress 2013. Dubrovnik, Croatia. September 2013.

- Irimia-Diequez, A., Bernal-Gonzalez-Villegas, J. & Oliver Alfonso, M.D. (2013): The economic and financial performance of an innovative megaproject. 27th IPMA World Congress 2013. Dubrovnik, Croatia. September 2013.
- Irimia-Diequez, Ana; Medina-Lopez, Carmen; Alfalla-Luque, Rafaela (2014): Financial Management of Large Projects: a research gap. 3rd World Conference on Business, Economics and Management, 8-10 April, Rome, Italy.
- Rafaela Alfalla-Luque, Ana I. Irimia-Diéquez, Álvaro Sánchez-Cazorla and Marilyn Duarte-Acosta (2014): "A Systematic Review of the Research on Risk Management in Megaprojects". Contemporary Management Practices viii feasibility and risks in the business projects, Burgas Free University, Burgas, Bulgaria, June 6-7, 2014.
- Rafaela Alfalla-Luque, Ana I. Irimia-Diéquez, Álvaro Sánchez-Cazorla (2014): ¿Qué se investiga en gestión de riesgos en megaproyectos?. ACEDE Conference, Castellón, Spain, September 2014.

Master Thesis and Final Degree Thesis:

- Sánchez-Cazorla, A. (2013): La gestión de riesgos en megaproyectos. Master Thesis. Tutors: Rafaela Alfalla-Luque & Ana Irimia-Diéquez. Presented in October 2013. Mark: 10/10.
- Bernal González-Villegas, J. (2013): Análisis económico-financiero de un megaproyecto : Estudio del caso "Metro de Sevilla" . Master Thesis. Tutors: Ana Isabel Irimia Diéquez, María Dolores Oliver Alfonso.. http://encore.fama.us.es/iii/encore/record/C_Rb2604199_Strabajo%20fin%20de%20m%C3%A1ster%20en%20estudios%20avanzados%20en%20direcci%C3%B3n%20de%20empresas_P0%2C2_Orightresult_U_X3?lang=spi&suite=cobalt
- Robles Cantalejo, J. (2013): Análisis de un caso de megaproyecto: la alta velocidad en España. Degree Thesis. Tutors: Rafaela Alfalla-Luque & M.Mar González-Zamora. Presented in September 2013. Mark: 9/10. (http://encore.fama.us.es/iii/encore/record/C_Rb2598325_S%28alfalla%29_Orightresult_U_X4?lang=spi&suite=cobalt)
- García Olid, E. (2014): Análisis de un caso de megaproyecto: la Torre Pelli. Final Degree Thesis. Tutor: Rafaela Alfalla-Luque. September 2014.
- Mikić, M., Andrić, J., Ivković, B., 2013. An approach and software for analysis of financial and economic risks in feasibility study preparation, *Izgradnja (Serbian leading national journal)*, vol. 67, iss. 11-12, pp. 461-468.
- Rafindadi, A. D., Mikić, M., Kovačić, I., Cekić, Z., 2014. Global perception of sustainable construction project risks. *Procedia - Social and Behavioral Sciences*, Volume 119, pp. 456-465, Selected papers from the 27th IPMA (International Project Management Association), World Congress, Dubrovnik, Croatia, 2013.
- Mikić, M., Petojević, Z., Ivanišević, N. Critical Risks in Serbian Infrastructure Projects, Proceedings of 11th International Conference: Organization, Technology and Management in Construction, Dubrovnik, Croatia, September 2013, pp. 296-307, ISBN 978-953-7686-04-8.

References

Reference Group A

- Aaltonen, K. (2011). *Project Stakeholder Analysis as an Environmental Interpretation Process*. *International Journal of Project Management*, 29(2): 165–183.
- Atkinson, R., C. Lynn and W. Stephen. (2006). *Fundamental Uncertainties in Projects and the Scope of Project Management*. *International Journal of Project Management*, 24(8): 687–698.
- Bing, L., A. Akintoye, P. J. Edwards and C. Hardcastle. (2005). *The allocation of risk in PPP/PFI construction projects in the UK*. *International Journal of Project Management*, 23: 25-35.
- Boateng, P., Z. Chen, S. Ogunlana, and D. Ikediashi. (2012). *A System Dynamics Approach to Risks Description in Megaprojects Development Organization*. *Technology and Management in Construction · an International Journal*, 4(3): 593–603.
- Bruzelius, N., B. Flyvbjerg, and W. Rothengatter. (2002). *Big Decisions, Big Risks. Improving Accountability in Mega Projects*. *Transport Policy*, 9(2): 143–154.
- Curtis, J. A., D. D'Angelo, M. R. Hallowell, et al. (2012). *Enterprise Risk Management for Transportation Agencies*. *Transportation Research Record: Journal of the Transportation Research Board*, 2271(1): 57–65.
- Dimitriou, H. T. (2009). *Globalization, Mega Transport Projects and Private Finance*. VREF FUT Conference Paper
- El-Gohary, N. M., H. Osman and T. E. El-Diraby. (2006). *Stakeholder Management for Public Private Partnerships*. *International Journal of Project Management*, 24: 595-604.
- Fiori, C., and M. Kovaka. (2005). *Defining Megaprojects: Learning from Construction at the Edge of Experience* (pp. 1–10). American Society of Civil Engineers. <http://ascelibrary.org/doi/abs/10.1061/40754%28183%2970>, accessed July 20, 2013.
- Flyvbjerg, B. (2005). *Policy and Planning for Large Infrastructure Projects: Problems, Causes, Cures*. World Bank Policy Research Working. Paper 3781
- Flyvbjerg, B. (2007). *Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure*. *Transportation Planning and Technology*, 30(1): 9–30.

- Flyvbjerg, B., M. K. S. Holm and S. L. Buhl. (2002). *Underestimating Costs in Public Works Projects: Error or Lie?* Journal of the American Planning Association, 68(3): 279–295.
- Flyvbjerg, B., M. K. S. Holm and S. L. Buhl. (2005). *How (In)accurate Are Demand Forecasts in Public Works Projects?: The Case of Transportation.* Journal of the American Planning Association, 71(2): 131–146.
- Flyvbjerg, B., N. Bruzelius and W. Rothengatter. (2003). *Megaprojects and risk: an anatomy of ambition.* United Kingdom. New York: Cambridge University Press.
- Frick, K. T. et al. (2008). *Decision-Making on Mega-Projects. Cost-Benefit Analysis, Planning and Innovation.* Transport Economics, Management and Policy. pp. 239-262
- Haidar, A. and R. D. Jr. Ellis. (2010). *Analysis and Improvement of Megaprojects Performance.* Presented at the EPOC 2010 Conference.
- Han, S. H., S. Yun, H. Kim, et al. (2009). *Analyzing Schedule Delay of Mega Project: Lessons Learned From Korea Train Express.* IEEE Transactions on Engineering Management, 56(2): 243–256.
- Hertogh, M. et al. (2008). *Managing Large Infrastructure Projects. Research on Best Practices and Lessons Learnt in Large Infrastructure Projects in Europe.* Utrecht (AT Osborne BV).
- Kardes, I., A. Ozturk, S. T. Cavusgil, and E. Cavusgil. (2013). *Managing Global Megaprojects: Complexity and Risk Management.* International Business Review. <http://linkinghub.elsevier.com/retrieve/pii/S0969593113000048>, accessed July 19, 2013.
- Kendra, K. and T. Taplin. (2004). *Project success: a cultural framework.* Project Manage Journal, 35(1): 30–45.
- Locatelli, G., and M. Mancini. (2010). *Risk Management in a Mega-project: The Universal EXPO 2015 Case.* International Journal of Project Organisation and Management, 2(3): 236-253.
- Luu, V. T., Soo-Yong Kim, and Tuan-Anh Huynh. (2008). *Improving Project Management Performance of Large Contractors Using Benchmarking Approach.* International Journal of Project Management, 26(7): 758–769.
- Morrow, E. W. (1988). *Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects.* The RAND Corporation. Santa Monica. CA. US.
- Miller, R. and D. Lessard. (2007). *Evolving strategy: Risk management and the shaping of large engineering projects.* MIT Sloan School of Management. Working Paper: 4607-4639.

OMEGA. (2012). *Mega projects executive summary Lessons for Decision-makers: An Analysis of Selected International Large-scale Transport Infrastructure Projects*. OMEGA Centre.

Park, H. et al. (2008). *Approaches for performance measurement of urban renewal megaprojects*. The 25th International Symposium on Automation and Robotics in Construction. June 26-29.

Priemus, H. (2010). *Decision-making on Mega-projects: Drifting on Political Discontinuity and Market Dynamics*. EJTIR, 10(1): 19-29.

Seon-Gyoo K. (2010). *Risk performance indexes and measurement systems for mega construction projects*. Journal of Civil Engineering and Management, 16(4): 586-594

Van Marrewijk, A. (2007). *Managing project culture: The case of Environ Megaproject*. International Journal of Project Management. 25: 290-299

Van Marrewijk, A., S. R. Clegg, T. S. Pitsis, and M. Veenswijk. (2008). *Managing Public-private Megaprojects: Paradoxes, Complexity, and Project Design*. International Journal of Project Management, 26(6): 591-600.

Williams, T. M., C. L. Eden, F. R. Ackermann and A. Tait. (1995). *The effects of design changes and delays on project costs*. Journal of the Operational Research Society, 46(7): 809-818.

Chen, Z., Khumpaisal, S. (2009) "An analytic network process for risks assessment in commercial real estate development", Journal of Property Investment & Finance, Vol. 27 Iss: 3, pp.238 - 258

Chen, Z.; Li H.; Hong, R.; Xu; Q.; Hong J. (2011) Total environmental risk assessment for international hub airport projects. International Journal of Project Management, 29(7) (2011) 856-866

Reference Group B

EU Cohesion Policy. *Ex Post Evaluation of Cohesion Policy Programmes 2000-2006 financed by the European Regional Development Fund in Objective 1 and 2 Regions, Synthesis Report*, March 2010.

European Commission, 2006. *Guidance on the Methodology for Carrying Out Cost-Benefit Analysis for the Programming Period 2007-2013*, Working Document No. 4.

European Commission, 2008. *Guide to Cost Benefit Analysis of Investment Projects*. Directorate General Regional Policy.

European Commission, 2015. Commission Implementing Regulation (EU) 2015/207, *Official Journal of the European Union*, L38, Volume 58.

European Parliament, Council of the European Union, 2006. Regulation (EC) 1083/2006 laying down general provisions on the European Regional Development Fund, the European Social Fund and the Cohesion Fund and repealing Regulation (EC) No 1260/1999.

European Parliament, Council of the European Union, 2013. Regulation (EU) No 1303/2013 laying down common provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund and laying down general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund and the European Maritime and Fisheries Fund and repealing Council Regulation (EC) No 1083/2006.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of XXXXXXXX

Title of book

First published in hardback 2014

First published in paperback 2014

© XXXXXXXXXXXXXXX

ISBN

01234 5678910 (hardback)

01234 5678910 (paperback)

RRP: \$XX.XX

APM 2006. *APM Body of Knowledge, 5th Edition*, Association for Project Management (APM).

BOATENG, P., CHEN, Z., OGUNLANA, S. & IKEDIASHI, D. 2012. A system dynamics approach to risks description in megaprojects development. *Organization, technology and management in construction: an international journal*, 4.

BURCAR DUNOVIĆ, I. 2012. *Risk management in large infrastructure projects*. PhD, University of Zagreb.

BURCAR DUNOVIĆ, I., RADUJKOVIĆ, M. & VUKOMANOVIĆ, M. 2013. Development and implementation of Risk register system for construction projects. *Građevinar: Journal of Croatian Society of Civil Engineers*, 65, 23-35.

BURCAR DUNOVIĆ, I., RADUJKOVIĆ, M. & ŠKREB, K. A. 2014. Towards a New Model of Complexity – The Case of Large Infrastructure Projects. *Procedia - Social and Behavioral Sciences*, 119, 730-738.

BURCAR, I. 2005a. *Risk register structure for construction projects*. M.Sc., University of Zagreb, Faculty of Civil Engineering.

BURCAR, I. 2005b. *Risk register structure for construction projects*. M.Sc., University of Zagreb.

BURCAR, I. & RADUJKOVIĆ, M. Risk model for construction projects Risk register system. In: CERIĆ, A. & RADUJKOVIĆ, M., eds. *Construction facing worldwide challenges - Joint 2008 CIB W065/W055 Commissions Symposium Proceedings*, 2009 Dubrovnik. Faculty of Civil Engineering, University of Zagreb, 1050-1059.

CHAPMAN, C. & WARD, S. 2002. *Managing Project Risk and Uncertainty: A constructively Simple Approach to Decision Making*, West Sussex, John Wiley & Sons.

CHAPMAN, C. B., WARD, S. & WARD, S. C. 2003. *Project Risk Management: Processes, Techniques and Insights*, Wiley.

CLEGG, S. R., PITSIS, T. S., RURA-POLLEY, T. & MAROSSZEKY, M. 2002. Governmentality Matters: Designing an Alliance Culture of Inter-organizational Collaboration for Managing Projects. *Organization Studies (Walter de Gruyter GmbH & Co. KG.)*, 23, 317.

- DANILOVIC, M. & BROWNING, T. R. 2007. Managing complex product development projects with design structure matrices and domain mapping matrices. *International Journal of Project Management*, 25, 300-314.
- FLANAGAN, R. & NORMAN, G. 1993. *Risk Management and Construction*, Blackwell Scientific.
- FLYVBJERG, B. & BANK., W. 2005. Policy and planning for large infrastructure projects problems, causes, cures. *Policy research working paper 3781*. World Bank.
- HILLSON, D. & SIMON, P. 2007. *Practical Project Risk Management: The Atom Methodology*, Management Concepts, Incorporated.
- IRIMIA-DIÉGUEZ, A. I., SANCHEZ-CAZORLA, A. & ALFALLA-LUQUE, R. 2014. Risk Management in Megaprojects. *Procedia - Social and Behavioral Sciences*, 119, 407-416.
- KERZNER, H. 2009. *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, John Wiley & Sons.
- MILLER, R. & HOBBS, B. 2005. Governance Regimes for Large Complex Projects. *Project Management Journal*, 36, 42-50.
- MILLER, R. & LESSARD, D. R. 2000. *The Strategic Management of Large Engineering Projects: Shaping Institutions, Risks and Governance*, Massachusetts, Massachusetts Institute of Technology.
- PMI 2000. *A Guide to the Project Management Body of Knowledge (PMBOK)*, Upper Darby, PA., Project Management Institute (PMI).
- SECRETARIAT, T. B. O. C. 2007. Standard for Project Complexity and Risk.
- SMITH, P. G. & MERRITT, G. M. 2002. *Proactive Risk Management: Controlling Uncertainty in Product Development* Productivity Press.
- SOLOMON, M. 2006. *Pmp Exam Cram 2, 2/E (With Cd)*, Pearson Education.
- VAN MARREWIJK, A., CLEGG, S. R., PITISIS, T. S. & VEENSWIJK, M. 2008. Managing public-private megaprojects: Paradoxes, complexity, and project design. *International Journal of Project Management*, 26, 591-600.
- VOSE, D. 2005. *Risk Analysis - A Quantitative guide*, West Sussex, John Wiley and Sons.
- WIDEMAN, R. M. 1992. *Project and Program Risk Management: A Guide to Managing Risk and Opportunities*, Drexel Hill, PA, Project Management Institute (PMI).
- WILLIAMS, T. 2002. *Modelling Complex Projects*, West Sussex, John Wiley & Sons.