Choosing project risk management techniques. A theoretical framework

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The pressure for increasing quality while reducing time and costs places particular emphasis on managing risk in projects. To this end, several models and techniques have been developed in literature and applied in practice, so that there is a strong need for clarifying when and how each of them should be used. At the same time, knowledge about risk management is becoming of paramount importance to effectively deal with the complexity of projects. However, communication and knowledge creation are not easy tasks, especially when dealing with uncertainty, because decision-making is often fragmented and a comprehensive perspective on the goals, opportunities, and threats of a project is missing. With the purpose of providing guidelines for the selection of risk techniques taking into account the most relevant aspects characterising the managerial and operational scenario of a project, a theoretical framework to classify these techniques is proposed. Based on a literature review of the criteria to categorise risk techniques, three dimensions are defined: the phase of the risk management process, the phase of the project life cycle, and the corporate maturity towards risk. The taxonomy is then applied to a wide selection of risk techniques according to their documented applications. This work helps to integrate the risk management and the knowledge management processes. Future research efforts will be directed towards refining the framework and testing it in multiple industries.

Keywords: Project management, risk management, corporate risk maturity, technique selection, knowledge creation.

1. Introduction

Risk is defined as an uncertain event or condition that, if it occurs, has either positive or negative effects on project objectives (Hillson and Simon 2007; Project Management Institute 2008). Nowadays a sound management of risk is a crucial determinant of the success of a project due to an increased attention to the variability of actual quality, time, and cost performance compared to the expected one as a consequence of a growing pressure on reducing time and costs. It has been demonstrated that failure to deal with risk is a main cause of budget exceeding, falling behind schedule, and missing performance targets (Carbone and Tippet 2004). In several industries, such as the construction and information and communication technology ones, this situation is exacerbated because projects characterised by huge investments, long execution processes, many resources and stakeholders, and instable economic and political environments introduce a high level of complexity (Guofeng, Min and Weiwei 2011).

Therefore, there is a strong need for assessing and controlling risk throughout all the phases of a project. Different perceptions, attitudes, and requirements have led to a variety of definitions and approaches. To be more precise, risk management processes and supporting techniques have been extensively developed and implemented in both literature and practice. The multitude of different methods asks for instruments suggesting under what circumstances each of them should be adopted and criteria for choosing among risk techniques have been identified. However, these criteria usually do take into account neither a comprehensive set of the peculiar characteristics of a project and of its surrounding environment nor the attitude of an organisation towards risk.

The present work develops a theoretical taxonomy supporting the selection of risk management techniques. The classification is based on the significant features of the context of analysis derived from the study of literature about project and risk management (Association for Project Management 2004; Chapman and Ward 2003; Project Management Institute 2008): phase of the risk management process, phase of the project life cycle, and corporate maturity towards risk. This contributes to enhance the knowledge about how to treat risky events and in turn to improve the risk knowledge management process in order to allow risk management processes to give the expected benefits. The research focuses on projects according to their general definition provided by the Project Management Institute: ‘A project is a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of projects indicates a definite beginning and end. The end is reached when the project’s objectives have been achieved or when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists' (Project Management Institute 2008).

After discussing the pertinent literature, a set of dimensions reflecting the managerial and operational conditions characterising a project is defined. Widely applied techniques to support project risk management are classified according to such framework. Finally, implications, ramifications, and future research directions are elaborated and conclusions drawn.

2. Literature review

With the aim of understanding the context of the work, this section presents the main processes for dealing with risk in projects together with the techniques they rely on and the available criteria for selecting such techniques. Also, the risk knowledge management process is introduced highlighting the necessity to improve it so that it can support an effective risk management.

2.1 Processes for project risk management

Several contributions have developed systematic project risk management processes since the Nineties.

Project Uncertainty MAnagement (PUMA) (Del Cano and De La Cruz 2002), Risk Analysis and Management for Projects (RAMP) (The Institution of Civil Engineers & The Faculty and Institute of Actuaries 2005), the Two-Pillar Risk Management (TPRM) process (Seyedhoseini and Hatefi 2009), the Active Threat and Opportunity Management (ATOM) process (Hillson and Simon 2007), Shape, Harness And Manage Project Uncertainty (SHAMPU) (Chapman and Ward 2003), and Project Risk Analysis and Management (PRAM) (Association for Project Management 2004) have very similar structures and common goals. In fact, they could be summarised into three macro-phases. The first steps of these processes are aimed at understanding the characteristics and objectives of the project at issue and planning the risk management effort by deciding its level, scope, and purpose. The intermediate steps are intended to identify risks together with their causes, effects, and how they relate to each other, assess their probabilities of occurrence and impacts, prioritise them, devise risk response strategies, and establish contingency plans. The final steps are in general dedicated to carrying out the identified responses to risk, monitoring and refining them, identifying, evaluating, and treating new emerging risks as well as to communicating the results of the risk management process and recording all the knowledge, experience, and lessons learned during its implementation.

However, there are also processes, such as Multi-party Risk Management Process (MRMP) (Pipattanapiwong and Watanabe 2000) and the risk management process developed by the Project Management Institute (Project Management Institute 2008), that just include activities related to risk identification, qualitative and quantitative analysis, and response and do not present phases specifically aimed at clarifying project goals or formalising the knowledge acquired during risk management.

2.2 Risk management techniques and their classification criteria

Each risk management process requires specific tools to be applied. To this end, a great variety of techniques have been developed in literature: the most widely adopted ones are presented in Table 1.

Table 1. Risk management techniques

The reviewed techniques have different goals. For example, some of them are aimed at evaluating multiple scenarios, depending on which risky events occur, such as Decision Tree Analysis, Expected Monetary Value, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, SWIFT Analysis, and What-if Analysis. Other techniques, instead, focus on the investigation of origins and implications of risky events in order to establish chains of causes and consequences. They include Cause and Effect Diagram or Cause Consequence Analysis, Event and Causal Factor Charting, the 5 Whys Technique, Event Tree Analysis (ETA), Fault Tree Analysis (FTA), and Human Reliability Assessment among others.

Multiple aspects may be taken into account when choosing among techniques for managing risk in a project.

A commonly used criterion looks at the nature of information that is available. Qualitative techniques require qualitative information and present results in form of descriptions and recommendations, while quantitative techniques rely on quantitative information and numerically analyse the occurrence and effects of risks (Project Management Institute 2008). Another criterion suggests selecting techniques according to the subject of the information needed by a project (Association for Project Management 2004)

Also, the nature, size, complexity, degree of innovation, and phases of the life cycle of a project determine which techniques should be used. In particular, risk management is crucial in the planning stage of a project and its scope and depth increase as the project moves towards the execution phase, while they decrease in the termination phase (Chapman and Ward 2003).

Furthermore, every single phase of a risk management process implies a different level of information and detail, thus requiring proper techniques (Hillson 2004).

The goal of the risk analysis, for instance monitoring economic and financial outcomes, checking quality variance, or tracking time delays, may also be a criterion for identifying appropriate risk management techniques (Kmec 2011).

Finally, techniques supporting risk management need appropriate levels of corporate maturity in order to yield the expected benefits and this may constitute a further criterion according to which they can be selected (Del Cano and De La Cruz 2002).

2.3 The risk knowledge management process

Besides the processes presented in Section 2.1, a further one is acquiring prominence in risk management, namely the knowledge management process (Botet 2012; Macgillivray et al. 2007).

Nowadays, creating, maintaining, transferring, and increasing knowledge are of paramount importance to efficiently deal with the complexity of projects (Disterer 2002). This is even more relevant when addressing risks because of the high variability and the scarce available information.

Nevertheless, managing data, information, and in general the knowledge generated during the life cycle of a project is a difficult task and an inappropriate way of doing that may be a cause of failure. In particular, projects are often organised in ways that create information disconnects, thus leading to a very poor communication about risk, in the same way as it happens in many other fields (Smillie and Blissett 2010; Tah and Carr 2001; Thompson and Bloom 2000).

Several techniques exist in literature to assist in extracting information and data from multiple and heterogeneous sources and organising them to increase risk knowledge. The most common example is given by expert judgement elicitation, where the term expert refers to those people to whom special knowledge about specific issues is attributed and from whom it is possible to obtain information that is useful for risk investigation. They are also named ‘specialists’, opposite to ‘generalists’ who collect and integrate the information from the specialists (Le Coze, Salvi and Gaston 2006). Elicitation of implicit expert knowledge is a core component of qualitative risk assessment by means for instance of Delphi or SWOT analysis, where it is used to define probability distributions for the occurrence and the impact of risky events.

However, in order to support an effective management of risk (Karadsheh, Alhawari and Talet 2012), the knowledge management process should go beyond gathering and structuring information. One crucial aspect is the ability of this process to guide the choice of the techniques that should be applied in different contexts depending on both the project itself and the maturity towards risk of the company that carries it out, which is in turn a function of the amount of available information.

The review of literature reveals the existence of a great amount of diverse risk management processes whose implementation can be supported by different techniques, leading to the need for providing guidelines on when each of them should be used. However, the classifications of techniques proposed by the contributions discussed in Section 2.2 focus on just one single or few aspects and there is a substantial lack of taxonomies that simultaneously look at all the key issues that should be taken into account when choosing an appropriate means of treating risk. Such kind of classifications enables a better decision-making about the specific tools to be adopted, thus improving the risk knowledge management process and stimulating a more comprehensive view on the factors affecting risk management and the performance of the associated activities. In order to contribute to fill the identified gap, the developed framework puts forward a categorisation of techniques founded on the most significant elements characterising the scenario in which project risk is approached.

3. Defining dimensions for selecting project risk management techniques

In order to identify the relevant aspects to take into account when choosing among project risk management techniques, the features of such tools and of the available criteria for their classification were considered. It is widely proved and accepted that no risk management technique fits every phase of the risk management process but each gives its best results if applied to one or few phases (Project Management Institute 2008, Chapter 11). Also, according to the Association for Project Management (2004), risk management should be defined within the context of its application: the lifecycle is to be considered in the case of a project. The studies of Chapman and Ward (2003) reveal that moving from one project lifecycle stage to another implies more detailed and quantitative information available, leading to a different degree of uncertainty. Thus, the focus of any risk analysis and the adopted risk management techniques need to vary with the phases of the project lifecycle. Finally, the Association for Project Management (2004) recommends considering the risk maturity of the staff of a company carrying out a project when selecting risk management techniques in order to ensure that the approach taken is appropriate to the people that will apply it and analyse its results.

Based on this analysis, the following three dimensions are proposed:

- the phase of the risk management process;
- the phase of the life cycle of a project;
- the corporate maturity towards risk.

In fact, the focus of the analysis is on 'risks' that occur in 'projects' which are in turn run by 'companies'(Grimaldi, Rafele and Cagliano 2012). .

The next sections discuss the three proposed dimensions in depth.

3.1 Phases of the risk management process

Any risky event unfolds through an escalation process composed of causes, an occurrence, and consequences (Hillson 2004) which are addressed by the phases of the risk management process, namely planning, identification, analysis, response, and monitoring and control.

Risk management planning identifies the objectives, the approach, and the resources to carry out risk treatment activities. Risk identification defines the causes of the risks to which the project is exposed. Risk analysis determines the probabilities of occurrence and the associated impacts on project outcomes in terms of cost, schedule, scope, and quality variance. Risk response develops actions to increase opportunities and decrease threats. Finally, the risk monitoring and control phase is the on-going identification and management of new risks that become known during a project, the tracking of already identified risks, the implementation of planned responses and the review of their effectiveness, the development of additional actions, if needed, and the formalisation of lessons learned about risk (Project Management Institute 2008).

The different goals and levels of detail of each phase of the risk management process require the application of appropriate techniques, also according to the level and nature of information, that will increase as the risk management process progresses.

3.2 Phases of the project life cycle

The notion of life cycle allows to structure projects into a number of phases that assure better management control. For the kinds of projects this work refers to such phases can be defined as conceptualisation, planning, execution, and termination (Chapman and Ward 2003; Project Management Institute 2008).

In the conceptualisation phase an opportunity or a need is identified, the purpose of the project defined and its feasibility assessed. The planning phase includes undertaking the basic design of the project, defining targets and milestones, developing performance criteria, and allocating internal and external resources to achieve the plan. The main tasks of the execution step are coordinating and controlling the performing of the project, monitoring progress, and changing targets, milestones, and resource allocation as required. The termination phase involves commissioning and handover, reviewing the lessons learned during the project, and assuring the necessary support to the product of the project until it is discarded or disposed.

Different risk management activities can be associated to each phase of the life cycle of a project (Chapman and Ward 2003). For instance, identification of sources of uncertainty takes place in the conceptualisation phase, while managing foreseen risks and monitoring changes in the risk profile of the project are typical tasks of the execution phase. Moreover, the degree of information accuracy is heterogeneous along the project life cycle. The still scarce level of information associated with the feasibility study makes the probability of risk occurrence difficult to be evaluated. By contrast, in the following phases, when risks are mainly related to the consequences of decisions made in the previous steps of the project or are the effects of risks already manifested, their sources, occurrence, and impacts can be characterised in a more accurate way due to the more pieces of information available.

These considerations support the need to enable project managers to focus on each stage of a project by means of suitable techniques to identify, assess, and treat risks in order to meet cost, schedule, and performance requirements (Tah and Carr 2001). Also, a project life cycle-oriented view of risk management techniques helps to avoid compartmentalisation, which occurs when each participant approaches risks with a perspective exclusively based on his own goals, irrespective of the other project parties (Walewski and Gibson 2003).

3.3 Corporate maturity towards risk

Maturity towards risk is achieved through awareness, the consideration that risk management is on the same level as cost, time, and scope management tasks, commitment to high quality of data, systematic implementation of instruments to deal with risk, development of responses, and assessment of the obtained results (Hulett 2001). A scarce awareness towards risk drives occasional applications of informal risk management techniques to specific projects and problems are dealt with only when they occur. Understanding the relevance of risk, instead, allows to proactively manage uncertainty (Hopkinson 2011). The degree of maturity towards risk of an organisation depends on its risk culture, which is stimulated by the available informational context and the type and size of the organisation itself.

Several models to assess risk maturity exist in literature (Hillson 1997; Macgillivray et al. 2007). Among them, Hillson (1997) proposes four stages: Naïve, Novice, Normalised, and Natural. Naïve means that an organisation does not feel the need for managing risk and does not use structured approaches for this purpose. Novice defines an organisation that recognises the benefits of managing risk and is implementing some form of risk governance but it lacks a formalised process to perform this task. Normalised is the degree of maturity characterised by a formalised risk process included in routine business activities whose benefits, however, are not consistently achieved in every project. Finally, the Natural maturity level refers to an organisation that is completely aware of risk and proactively manages opportunities and threats through consistent risk information.

Moving from one level to the upper one in a maturity scale implies that an organisation is willing to perform a more thorough and systemic analysis of the escalation processes of project risks with more sophisticated and detailed techniques (Hopkinson 2011; Hulett 2001). In particular, a high level of risk awareness together with an appropriate availability of knowledge makes it possible to obtain that objective information allowing the quantification of risk. Based on this, it can be stated that the more mature an organisation towards risk, the more the phases of the risk management process it will implement. Companies with a low maturity degree only perform risk identification or qualitative risk analysis, while organizations with a highlevel of maturity deal with all the stages of the risk management process.

4. Classifying techniques supporting project risk management

The three defined dimensions guiding the choice of project risk management practices are applied to the techniques discussed in Section 2.2 . The techniques are matched with the dimensions based on the existing literature and on the different level of information availability required by each tool. The amount of information increases as the risk management process and the project lifecycle progress and as the corporate maturity towards risk grows, making possible the use of more detailed and quantitative risk management techniques (Association for Project Management 2004; Chapman and Ward 2003; Project Management Institute 2008). Thus, the mapping between risk management techniques and the three defined dimensions presented in Table 2 can be defined.

In order to be as general as possible and allow the potential application to a wide range of projects, the classification is based on the project definition given by the Project Management Institute (2008, 5)

During the project life cycle and in every stage of the risk management process, the nature and the quantity of available information determine which techniques should be applied. In the conceptualisation phase decision-makers have a high degree of freedom in defining project goals. However, owing to the lack of specifications about how to meet the set objectives, all the necessary information for a complete investigation of risk is not always available in this stage of the project. Thus, decision-makers face either an uncertain scenario characterised by a limited amount of information or a context where the source of information is subjective. Such situation requires the building of a systematic framework to obtain subjective judgements from experts in a clear and straightforward way. Extractors of information like Interviews or the so called ‘group techniques’, such as Brainstorming, Delphi, and Expert Judgment, can be applied for this purpose. At the same time, experts should be trained so that they can make good judgements. Moreover, this context may just allow to define the strengths and weaknesses of the project and the decision-makers may stop their risk investigation at the identification phase by using a SWOT analysis. However, in the case of repetitive projects, the greater availability of information allows the use of detailed tables like FMEA (Grubisic et al. 2011) and makes it possible to define occurrence probabilities and economic and/or time impacts for every alternative event. In this situation, decision-makers could move on to a quantitative analysis of risks through the use of FMECA tables, Decision Trees, and Event Tree Analysis. Therefore, the quantity and kind of information in the conceptualisation phase usually allow risk identification and they seldom enable also risk analysis. The ways and means to achieve the project objectives become clearer in the planning phase thanks to a considerable increase in the available information, which allows a complete investigation of risks. All the techniques for risk management can be used in this project stage based on the phases of identification, analysis, and response to risk and on the type of information available. In general, the degree of knowledge and the ability to influence the course of a project are inversely proportional to each other as the project develops. Thus, in the execution phase there will be a high level of knowledge about project constraints but a low ability to influence events because all the most important project and risk management decisions have been already made in the previous phases. In this stage the time and economic performance resulting from the project choices and the actions undertaken to either mitigate or exploit risk can be mainly controlled and monitored. Therefore, in the execution phase the results of the techniques applied in risk identification, analysis, or response will be revised and the outcomes of the implementation of designed actions will be monitored by means of careful and sensible human action. In addition, the risk management techniques used in the planning phase can be applied again to identify new risks that have not emerged before. The termination phase is not considered by the classification in Table 2 because the risk management effort is more relevant in the previous stages of the project life cycle. Also, the risk management planning phase is not included being less operational in nature than the subsequent phases and more focused on the strategy to deal with risk and the project goals.

The level of maturity is connected to the level of communication in the organisation and the availability of data/information about the project. The higher the maturity towards risk management of the project team the more common the use of various techniques, especially the quantitative ones, during the entire risk management process. For example, the Monte Carlo simulation technique is usually applied by companies with a high level of maturity towards data and information management and hence project risk. The last column of Table 2 refers to the maturity levels proposed by Hillson (1997): the Naïve stage is not taken into account because it does not imply the use of any risk management technique. Also, Table 2 is based on the following notation: I = 'risk Identification', QlA = 'Qualitative risk Analysis', QtA = 'Quantitative risk Analysis, and R = 'risk Response'.

Table 2. Classification of project risk management techniques

Table 2 does not succeed in providing a global view of how the analysed techniques fit into the three proposed dimensions. In order to overcome this limitation, two bi-dimensional charts are built. Figure 1 places the techniques on a Cartesian plane according to the phases of the project life cycle (x-axis) and the phases of the risk management process (y-axis). Figure 2 compares the same techniques but against the levels of corporate maturity towards risk (x-axis) and the risk management phases (y-axis).

These charts are intended to stimulate knowledge creation about risk. They may be used by an organisation to focus on a set of techniques, discuss when they are appropriate, decide which of them could be used in which part of the project and risk management processes, and determine the correct sequence in which they should be applied. Furthermore, the proposed risk technique mapping may help in combining together multiple tools to address the complexity and multidimensionality of risk with proper solutions (Wilkinson and Elahi 2003). Such characteristics make the present framework a valid enabler for the creation of a structured risk knowledge management process.

Also, the two representations suggest further considerations about the appropriateness of each technique. Figure 1 highlights that numerous techniques can be used in the Planning phase of a project. In fact, in this stage more time can be spent on strategic issues such as risk management than in the Conceptualisation stage, which has usually a quite limited duration, and in the Execution stage, which is mainly focused on the achievement of the project objectives from an operational point of view. Figure 2 graphically proves the relationship between the maturity towards risk and the phases of the risk management process that are carried out by a company. A Novice level of maturity usually implies performing just risk identification. A Normalised maturity also involves a qualitative risk analysis and, in some limited cases, risk response and monitoring and control. Finally, a Natural maturity is associated with undertaking the complete risk management process, from identification to monitoring and control, including the quantitative risk analysis. Therefore, the quantitative analysis of risk distinguishes companies with a Natural maturity level from companies having a Normalised maturity level. Additionally, in the Natural maturity level there is a complete integration between the project management and the risk management processes that allows a regular revision of the outputs of the applied risk techniques.

Figure 1. Risk technique mapping: project life cycle and risk management phases

Figure 2. Risk technique mapping: corporate maturity levels and risk management phases

5. Discussion

Knowledge is a fundamental element for an attitude towards project risk management that goes beyond an informal approach limited to qualitative investigation. A systematic acquisition and organisation of information is a necessary step in order to move from a subjective knowledge about risk, that has to be elicited from experts, to an objective and easily accessible knowledge forming the condition for a quantitative risk analysis (Al Khattab et al. 2011). This work aims to help such transition by proposing a framework providing structured information about the potentiality of application of widely diffused project risk management techniques, thus stimulating the integration between the risk management and the knowledge management processes.

The present taxonomy assists in understanding how the risk management techniques are related to the phases of the risk management process that are undertaken in a project, the phase of the lifecycle the project is in, and the maturity towards risk of the organisation performing such project. Also, the suggested scheme overcomes the limitations of the existing criteria to classify techniques by providing a comprehensive set of dimensions that cover the most important aspects that should be taken into account in a risk management process. This generates knowledge based on the degree of maturity towards risk of the organisation running the project and such knowledge in turn increases the level of corporate awareness towards the instruments to tackle risk. The relationship between organisational culture and knowledge is critical to an effective risk management system (Yaraghi and Langhe 2011). Furthermore, the developed framework benefits from being quite general and flexible, so that it can be easily adapted to reflect the requirements of different industries and projects, from those that are particularly unique in scope to those that have many repetitive elements . Finally, it is suitable to both small-scale and large-scale projects and can support the selection of operational means to carry out various steps of the risk management processes proposed in literature.

A number of advantages can be derived from the application of the framework. From a decision-making perspective, it contributes to gain an improved understanding of projects, giving as a consequence a better control over resources, provides a support to develop and implement monitoring strategies, and stimulates a better use of means to identify and assess risk with an inherent positive impact on the evaluation of contingencies. The framework also facilitates a rational risk taking by improving communication about how to manage uncertainty (Klinke and Renn 2001; Strydom 2008). Additionally, the developed taxonomy of techniques encourages a more proactive approach to risk as a result of a well planned management process. All these characteristics ultimately promote the integration between project and risk management.

However, the criteria and the classification of the techniques to support risk management have been derived exclusively from the available literature. An empirical test of the outcomes of this study is needed to validate and refine the framework.

Therefore, future research efforts will be directed towards the implementation of the framework in multiple project settings in representative industries. Enhancing the taxonomy by introducing further dimensions such as the level of complexity of a project and the degree of innovation of its product will be considered. The degree of innovation of the product of a project is particularly interesting because it may be connected with the phases of the project life cycle. In fact, the more innovative the outcome, the more the risk management process will be concentrated in the planning phase. Conversely, the less innovative the product the more the focus on risk in the execution phase. An additional evolution will be concerned with extending the framework to include new techniques to support risk management. Finally, a further research line could deal with the integration of the proposed framework into a global project management process with the aim of overcoming the traditional separation between running a project and identifying, assessing, and controlling the associated risks.

6. Summary

A multitude of project risk management processes and supporting techniques have been proposed in the last decades, thus leading to the need for understanding under what circumstances each of them should be applied and for improving the risk knowledge management process in order to obtain the expected benefits from such instruments.

The present work develops a theoretical framework classifying techniques based on the phases of the risk management process, the phases of the life cycle of a project, and the corporate maturity towards risk. The aim is assisting in the selection of the appropriate risk management technique by considering all the relevant aspects characterising the context of analysis. This enhances knowledge about the most appropriate operational ways to implement risk management processes. The proposed scheme is general and can be applied to projects in numerous industries.

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Table 1. Risk management techniques

No.	Technique	Reference
1	Brainstorming	Chapman and Ward 2003
2	Cause and effect diagram or Cause Consequence Analysis (CCA)	Project Management Institute 2008
3	Change Analysis (ChA)	Mullai 2006
4	Checklist	Project Management Institute 2008
5	Decision Tree Analysis	Lyons and Skitmore 2004
6	Delphi	Project Management Institute 2008
7	Event and Causal Factor Charting (ECFCh)	Mullai 2006
8	Event Tree Analysis (ETA)	Mullai 2006
9	Expected Monetary Value (EMV)	Project Management Institute 2008
10	Expert Judgement	Project Management Institute 2008

11	Fault Tree Analysis (FTA)	Eidesen, Sollid and Aven 2009
12	Failure Mode and Effects Analysis (FMEA)	Bouti and Kadi 1994
13	Failure Mode and Effects Criticality Analysis (FMECA)	Bouti and Kadi 1994
14	Fuzzy Logic	Bellagamba 1999
15	Hazard and Operability (HAZOP)	Kletz 1999
16	Hazard Review (HR)	Mullai 2006
17	Human Reliability Assessment (HRA)	Lyons et al. 2005
18	Incident Reporting (IR)	Cinotti 2004
19	Interviews	Project Management Institute 2008
20	Monte Carlo	Project Management Institute 2008
21	Pareto Analysis (PA) or ABC analysis	Rebernik and Bradač 2008
22	Preliminary Hazard Analysis (PHA)	Adler et al. 2003

23	Risk Breakdown Matrix (RBM)	Hillson, Grimaldi and Rafele 2006
24	Risk Breakdown Structure (RBS)	Hillson 2002a
25	Risk Mapping, Risk Matrix, Probability and Impact Matrix	Project Management Institute 2008
26	Risk Probability and Impact Assessment, Risk Ranking/ Risk Index	Project Management Institute 2008
27	Sensitivity analysis	Chapman and Ward 2003
28	Strengths, Weaknesses, Opportunities, and Threats (SWOT)	Emblemsvåg and Kjølstad 2002
29	SWIFT Analysis	Mullai 2006
30	What-if Analysis	Mullai 2006
31	“5 Whys” Technique	Mullai 2006

Table 2. Classification of project risk management techniques

		Dimensions		
No.	**Technique**	**Risk Management Phase**	**Project Life Cycle Phase**	**Level of Corporate Maturity**
1	**Brainstorming**	**I** (Gupta 2011; Project Management Institute 2008), **QlA** (Berg 2010)	Conceptualisation (Grubisic et al. 2011), Planning, Execution	Novice (Grubisic et al. 2011), Normalised, Natural
2	**Cause and –effect diagram or Cause Consequence Analysis (CCA)**	**I** (Dey and Ogunlana 2004; Project Management Institute 2008), **QlA** (Del Cano and De La Cruz 2002)	Planning, Execution	Normalised, Natural
3	**Change Analysis (ChA)**	**I** , **QlA**, **R** (Mullai 2006)	Planning, Execution	Normalised (Mullai 2006), Natural
4	**Checklist**	**I** (Association for Project Management 2004; Lyons and Skitmore 2004), **QlA** (Del Cano	Conceptualisation, Planning (Grubisic et al. 2011)	Novice (Mullai 2006), Normalised, Natural

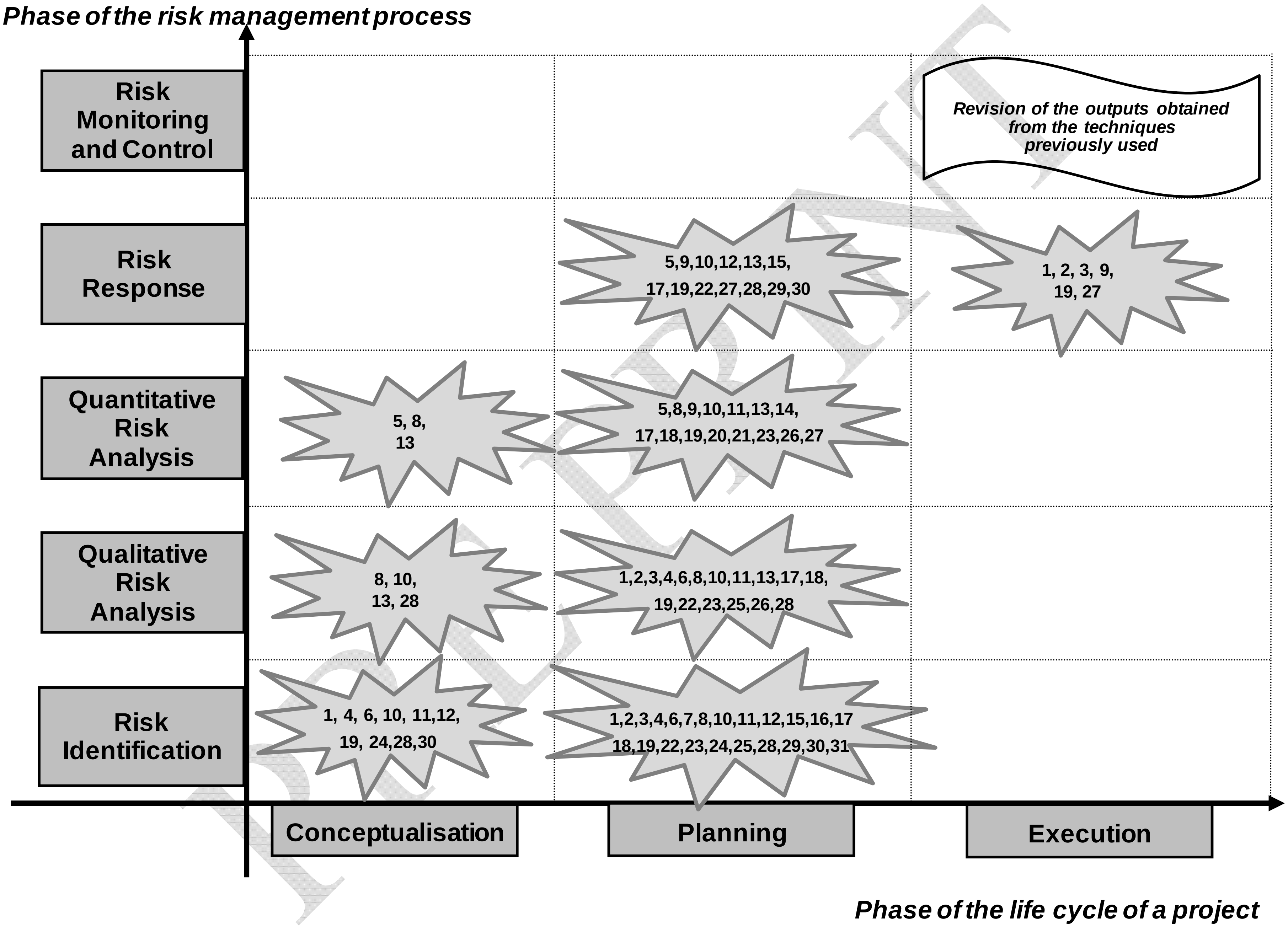
		and De La Cruz 2002)		
5	**Decision Tree Analysis**	**QtA**(Del Cano and De La Cruz 2002; Hillson 2002b; Project Management Institute 2008), **R** (Dey 2001)	Conceptualisation, Planning	Normalised, Natural
6	**Delphi**	**I** (Dey and Ogunlana 2004; Project Management Institute 2008), **QlA** (Berg 2010; Macgillivray et al. 2007)	Conceptualisation (Grubisic et al. 2011), Planning	Novice (Grubisic et al. 2011), Normalised, Natural
7	**Event and Causal Factor Charting (ECFCh)**	**I** (Mullai 2006)	Planning	Normalised (Mullai 2006), Natural
8	**Event Tree Analysis (ETA)**	**I**, **QlA** (Del Cano and De La Cruz 2002)**, QtA** (Mullai 2006)	Conceptualisation, Planning	Normalised, Natural (Mullai 2006)
9	**Expected Monetary Value**	**QtA** (Lyons and Skitmore 2004), **R** (Dey 2001)	Planning, Execution	Natural
10	**Expert Judgement**	**I, QlA, QtA** (Macgillivray et al.	Conceptualisation,	Normalised,

		2007; Project Management Institute 2008), **R** (Dey 2001)	Planning	Natural
11	**Fault Tree Analysis (FTA)**	**I** (Dey and Ogunlana 2004), **QlA** (Del Cano and De La Cruz 2002), **QtA** (Del Cano and De La Cruz 2002; Mullai 2006)	Conceptualisation (Grubisic et al. 2011), Planning	Normalised, Natural (Mullai 2006)
12	**Failure Mode and Effects Analysis (FMEA)**	**I, R** (Bouti and Kadi 1994; Sinha, Whitman and Malzahn 2004)	Conceptualisation (Grubisic et al. 2011), Planning	Normalised (Mullai 2006)
13	**Failure Mode and Effects Criticality Analysis (FMECA)**	**I, QlA** (Macgillivray et al. 2007), **QtA, R** (Bouti and Kadi 1994; Sinha, Whitman and Malzahn 2004)	Conceptualisation (Grubisic et al. 2011), Planning, Execution	Normalised (Mullai 2006), Natural
14	**Fuzzy Logic**	**QtA** (Bellagamba 1999)	Planning	Natural
15	**Hazard and Operability (HAZOP)**	**I** (Berg 2010; Kletz 1999), **R** (Mullai 2006)	Planning	Normalised (Mullai 2006), Natural
16	**Hazard Review (HR)**	**I** (Mullai 2006)	Planning	Novice, Normalised (Mullai

				2006), Natural
17	**Human Reliability Assessment (HRA)**	**I, QlA,QtA, R** (Mullai 2006)	Planning, Execution	Normalised, Natural
18	**Incident Reporting**	**I**, **QtA**	Planning	Normalised, Natural
19	**Interviews**	**I** (Dey and Ogunlana 2004; Gupta 2011), **QlA, QtA** (Project Management Institute 2008)**, R** (Association for Project Management 2004)	Conceptualisation, Planning, Execution	Novice, Normalised, Natural
20	**Monte Carlo**	**QtA** (Hillson 2002b; Macgillivray et al. 2007; Project Management Institute 2008)	Planning	Natural
21	**Pareto Analysis (PA) or ABC analysis**	**QtA** (Mullai 2006)	Planning	Natural
22	**Preliminary Hazard Analysis (PHA)**	**I** (Adler et al. 2003), **QlA** (Adler et al. 2003), **P** (Adler et al. 2003)	Planning	Novice, Normalised (Mullai 2006), Natural

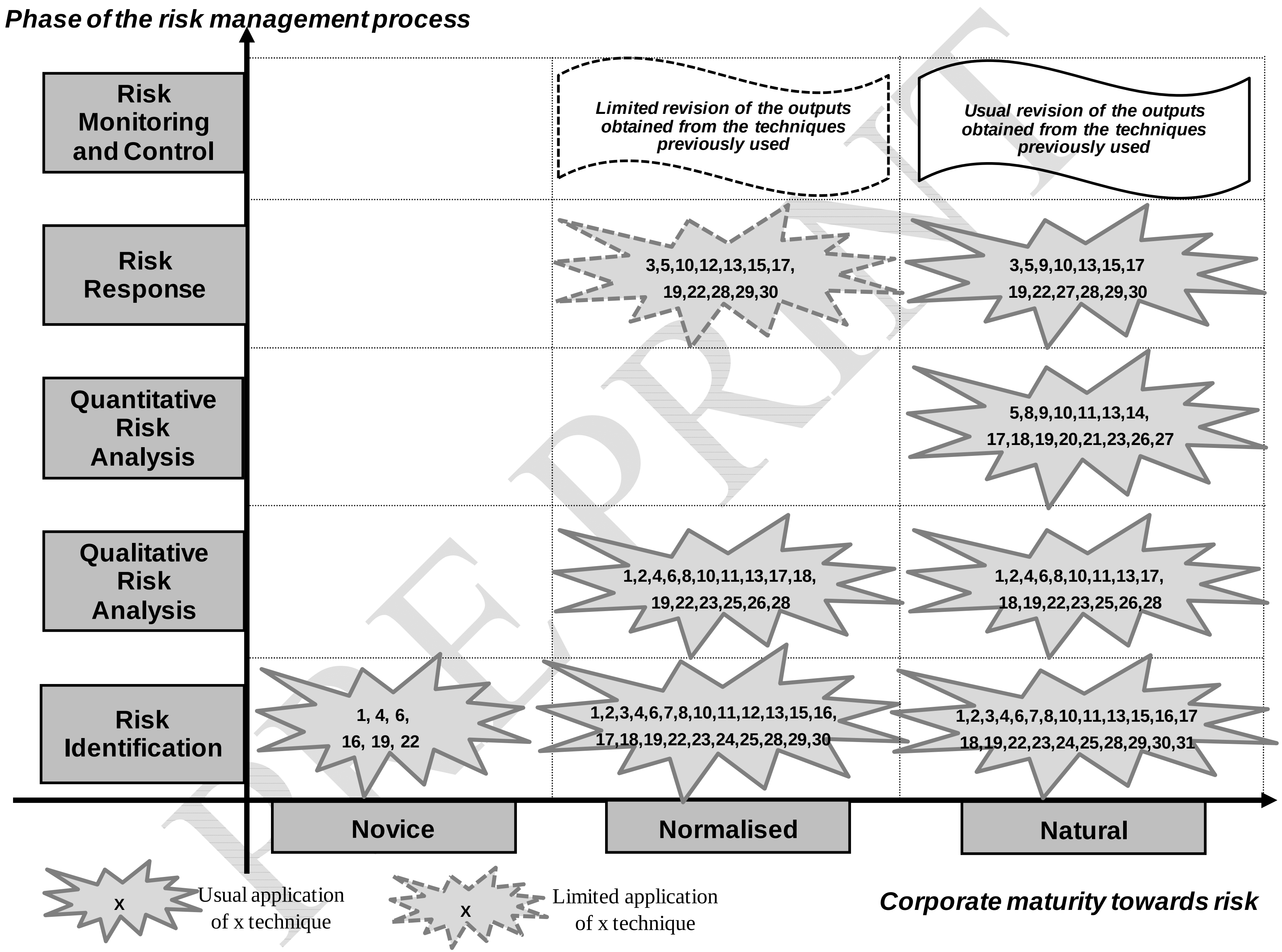
23	**Risk Breakdown Matrix (RBM)**	**I** (Cagliano et al. 2012)**, QlA** (Cagliano et al. 2012)**, QtA** (Hillson, Grimaldi and Rafele 2006)	Planning	Normalised, Natural
24	**Risk Breakdown Structure (RBS)**	**I** (Hillson 2004)	Conceptualisation, Planning	Normalised, Natural
25	**Risk Mapping, Risk Matrix Probability and Impact Matrix,**	**I, QlA** (Del Cano and De La Cruz 2002; Project Management Institute 2008)	Planning	Normalised, Natural
26	**Risk Probability and Impact Assessment, Risk Ranking/ Risk Index**	**QlA** (Project Management Institute 2008), **QtA**	Planning	Normalised (Mullai 2006), Natural
27	**Sensitivity analysis**	**QtA** (Hillson 2002b; Lyons and Skitmore 2004; Project	Planning, Execution	Natural

		Management Institute 2008), **R**		
28	**Strengths, Weaknesses, Opportunities, and Threats (SWOT)**	**I** (Gupta 2011), **QlA** (Berg 2010; Macgillivray et al. 2007), **R**	Conceptualisation, Planning	Normalised, Natural
29	**SWIFT Analysis**	**I, R** (Mullai 2006)	Planning	Normalised, Natural
30	**What-if Analysis**	**I, R** (Mullai 2006)	Conceptualisation, Planning	Normalised (Mullai 2006), Natural
31	**“5 Whys” Technique**	**I** (Mullai 2006)	Planning	Natural



Phase of the risk management process
Risk Monitoring and Control
Risk Response
Quantitative Risk Analysis
Qualitative Risk Analysis
Risk Identification
Revision of the outputs obtained from the techniques previously used
5,9,10,12,13,15,
17,19,22,27,28,29,30
1, 2, 3, 9,
19, 27
5, 8,
13
5,8,9,10,11,13,14,
17,18,19,20,21,23,26,27
8, 10,
13, 28
1,2,3,4,6,8,10,11,13,17,18,
19,22,23,25,26,28
1, 4, 6, 10, 11,12,
19, 24,28,30
1,2,3,4,6,7,8,10,11,12,15,16,17
18,19,22,23,24,25,28,29,30,31
Conceptualisation
Planning
Execution
Phase of the life cycle of a project

Figure 1



Phase of the risk management process
Risk Monitoring and Control
Risk Response
Quantitative Risk Analysis
Qualitative Risk Analysis
Risk Identification
Limited revision of the outputs obtained from the techniques previously used
Usual revision of the outputs obtained from the techniques previously used
3,5,10,12,13,15,17,
19,22,28,29,30
3,5,9,10,13,15,17
19,22,27,28,29,30
5,8,9,10,11,13,14,
17,18,19,20,21,23,26,27
1,2,4,6,8,10,11,13,17,18,
19,22,23,25,26,28
1,2,4,6,8,10,11,13,17,
18,19,22,23,25,26,28
1, 4, 6,
16, 19, 22
1,2,3,4,6,7,8,10,11,12,13,15,16,
17,18,19,22,23,24,25,28,29,30
1,2,3,4,6,7,8,10,11,13,15,16,17
18,19,22,23,24,25,28,29,30,31
Novice
Normalised
Natural
x
Usual application of x technique
x
Limited application of x technique
Corporate maturity towards risk
PREPRINT

Figure 2