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Interactions-based risk clustering methodologies and algorithms for complex project management

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ABSTRACT

Project risks have never been so present. First, projects are dealing with bigger stakes and facing stronger constraints. Moreover, projects must cope with an ever-growing complexity. Risks have then increased in number and criticality. Lists of identified project risks thus need to be decomposed, for smaller clusters are more manageable. Existing techniques are mainly mono-criteria, based on risks parameters such as nature or criticality value. Limits have appeared since project risk interactions are not properly considered. Project interdependent risks are indeed often managed as if they were independent. We thus propose an interactions-based clustering methodology with associated tools and algorithms. Our objective is to group risks, so that the interaction rate is maximal inside clusters and minimal outside. The final objective is to facilitate the coordination of complex projects by reducing interfaces when dealing with risks. We first model project risk interactions through binary matrix and numerical matrix representation. Then we define our objective function. A linear programming algorithm and two approximate iterative ones are then presented. Possible refinement through the concept of interactions similarity is also proposed. A case study in the entertainment industry is finally presented, providing us information and points of comparison for global conclusions and perspectives.

1. Introduction

A project is a temporary and unique endeavor undertaken to deliver a result, which generally corresponds to the creation of a unique product or service which brings about beneficial change or added value (PMI, 2004). A new organization within the firm is then needed to perform a project, new processes which must answer project finalities and objectives in terms of values creation must be set-up. These new processes are performed using resources (notably project actors) that belong to the created project organizational system. A project is in essence unique, which means that the project organizational system is to be conceived for each project within a firm (as it is specific to a project). Project organizations are thus in essence temporary organizations. They coexist with permanent organizations which exist within the firm. This coexistence (involving interfaces and dependencies) makes project and project management all the more complex. Moreover, the conception of the project organizational system follows the steps of project phases' identification and analysis, planning and monitoring.

Therefore, when thinking of projects in terms of systems following several phases, many dependencies and interdependencies between phases, sub-systems and other entities can be identified. This can lead to communication and coordination issues when facing decision-making situations. Namely, project complexity, described notably in (Baccarini, 1996; Edmonds, 1999; Laurikkala et al., 2001) involves issues in decision-making under complex situations (Phelan, 1995; Earl et al., 2001; Vidal et al., 2010). Then, as well as the uncertainty and instability which are inherent to projects, complexity appears to be one of the main risk drivers. Moreover, complexity reduces the awareness of decision-makers and thus the efficiency of their decisions.

As a consequence, this paper proposes an innovative method and its associated tool to assist project risk management under complex contexts by focusing on project risk interdependencies. Our research objective is to group risks into clusters in order to catch inside of them most of project interactions. This is notably to facilitate the coordination among actors involved in the project risk management process.

2. The need for a better consideration of project risk interactions

Project systems are in essence risky, as they are unique, constrained, subject to uncertainty and to complexity. They are composed of many interrelated objects of different natures and must reach many objectives which may be interdependent or even

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contradictory. This involves two things in terms of risk management. First, there are many risks of different natures, and it is even impossible to be completely exhaustive when identifying them. It is then mandatory to group risks into smaller and thus more manageable groups, which is detailed in Section 2.1. Second, these risks are interrelated, meaning that they are not independent events. This causes some issues in decision-making in project risk management, when decisions are to be made about the prioritization of risks and the risk mitigation actions. These issues are not well addressed by traditional approaches as shown in Section 2.2. Section 2.3 sets the resulting problem and methodology of this paper.

2.1. *Classifying project risks by nature and/or by value*

Project risk management is classically decomposed into four successive major steps: risk identification, risk analysis, risk response planning and risk monitoring (PMI, 2004).

Risk identification is the process of determining events which, may they occur, could impact positively or negatively project objectives. Risk identification methods are classified according to two different families: direct or indirect risk identification (Raz and Hillson, 2005). The number of risks in the generated list may vary from some tens to some hundreds. It is then mandatory to decompose it into subgroups in order to have more manageable items. This list is a priori (included in the methodology) or a posteriori classified according to the nature of the risks (financial, human, technical, schedule, etc.). This process is called clustering by nature.

During risk analysis, risks are prioritized, essentially according to their probability and impact. Risk evaluation scales are often defined in terms of criticality, which is generally a function of probability and impact. The main output of risk analysis is a list or graph, which enables decision-makers to categorize risks as high, medium or low in terms of the chosen indicator (criticality whatever its formulation, or other indexes). This is another kind of clustering, called by value.

Next steps are risk response planning and monitoring. We argue that these steps should be performed after an innovative project risk analysis based on risk interactions, since current methods have shown their limits.

2.2. *Limits of traditional approaches*

The initial goal of risk clustering processes is to facilitate the management of risks in terms of decision-making. In the case of clustering by nature, the main objective is to facilitate the identification of risk owners, whether individual or entities (due to their skills and competencies), and then to facilitate the allocation of additional or contingency resources. In the case of clustering by value, the main objective is to prioritize risks in order to make decisions about the future mitigation plan and the resulting resource allocation. As they are classifying risks based on one of their characteristics, those methods do not include their possible interactions. Therefore, in both cases, there are lots of interactions between clusters. This can result in a lack of coordination between actors when making decisions, due to the lack of awareness of the global impact of one's decision, mainly outside the considered cluster.

Actually, whatever the criteria used for the decomposition of an initial risk list, and whatever the rigor and detail level used, there will always be interactions between risks which do not belong to the same cluster (Marle, 2002). This can notably be underlined when looking at projects through systems thinking (Simon, 1981; Le Moigne, 1990).

Project management current techniques include classical principles underpinning scientific management: the fragmentation of work and the maximization of visibility and accountability. We can argue that today projects are generally managed with single-link trees (Work Breakdown Structure, PERT, Organizational Breakdown Structure, risk lists) and not as networks (Vidal et al., 2009). In the case of risk management, most of the methods use lists, screening or sorting risks, as seen before. The problem with current methodologies is that project risk interactions are not clearly included, e.g. in Fig. 1, where some links are existing though not managed (dotted lines). Risks are indeed interrelated with complex links.

A previous study we had conducted about 23 risk analysis methodologies enabled to identify complexity-related issues (Marle, 2008). For instance, there may be propagation from one "upstream" risk to numerous "downstream" risks, the climax of this phenomenon being the famous dangers of the domino effect. Traditional methodologies are mainly single-risk oriented, analyzing their multiple causes and multiple consequences. However, some works have been done to model more complex interdependencies between risks. Bayesian's Networks for instance link several risks, from multiple inputs to multiple outputs, but they have specific validity conditions: links must be oriented, and they are more adapted to acyclic networks. However, loops are a great danger during projects and are all the more complicated to understand, since risks which exist within a loop are likely to be heterogeneous (of different natures). It is possible to tackle this issue using dynamic Bayesian's Networks but the effort required to gather conditional probabilities and to run dynamic networks for the huge number of possible loops makes them unsuitable to real project environments.

There is thus crucial need for better awareness, consideration and management of project risks, knowing they are intertwined. We propose in this article such a methodology. Our ambition is not to give "exact" results: we want to assist day-do-day project risk management using our method. This one is notably not based on

Risk	Category	Proba	Impact	…
R1	Human			
R2	Human			
R3	Human			
R4	Technical			
R5	Technical			
R6	Financial			
R7	Financial			
R8	Financial			
R9	Financial			
R10	Schedule			
R11	Schedule			
R12	Schedule			
R13	User			
…	…			

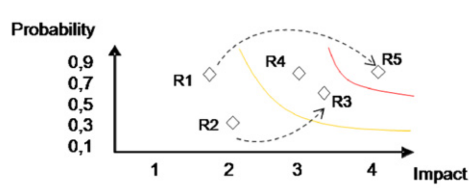

Fig. 1. Classification of projects risks by nature and/or by value.