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Selecting risk response strategies considering project risk interdependence

Yao Zhang

Department of Operations and Logistics Management, School of Business Administration, Northeastern University, Shenyang 110167, China

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Abstract

In risk response analysis, risks are often assumed independently. In fact, however, risks in a project mutually affect and the independent risk seldom exists in reality. This paper provides an approach to quantitatively measure the risk interdependence. Based on the analysis of the risk interdependence, we construct an optimization model for selecting risk response strategies considering the expected risk loss, risk interdependence and its two directions. Further, the effects of the risk interdependence on risk response can be investigated. There are two major findings by the analysis of the case project. First, the expected utility would be more sensitive to the risk interdependence itself than to the directions of it. Second, the insufficient attention paid to or neglect of the risk interdependence would lower the expected utility and increase the implementation cost.

Keywords: Project risk management; Risk interdependence; Risk response strategy; Optimization; Expected utility

1. Introduction

Projects are, by nature, exposed to multiple risks in practice. If the risks are not dealt with effectively in the process of project management, the poor performance with increasing cost and time delays will appear. Therefore, project risk management (PRM) is an important topic for practitioners and academic scholars. In general, PRM consists of three phases (Buchan, 1994): risk identification, risk assessment and risk response. Risk identification is the process of recognizing and documenting associated risks. Risk assessment is the process of evaluating project risks according to their characteristics such as the probability and impact. Risk response refers to developing, selecting and implementing strategies in order to reduce risk exposure. The risk response plays a proactive role in mitigating the negative impact of project risks (Miller and Lessard, 2001). Appropriate risk response strategies must be selected to reduce global risk exposure in project implementation once the risks have been identified and analyzed (Zou et al., 2007). Therefore, the risk response analysis can be regarded as an important issue in PRM (Ben-David and Raz, 2001).

E-mail address: yzhang@mail.neu.edu.cn.

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In risk response analysis, risks are often assumed independently and then analyzed according to their individual characteristics in response strategy selection (Fan et al., 2008; Seyedhoseini et al., 2009). In fact, however, project risks are not always independent (Adner, 2006; Kwan and Leung, 2011), and risks in a project mutually affect (Ren, 1994). This leads to the need to consider risk interdependences as a part of risk analysis (Ackermann et al., 2007). The interdependences, as one of important elements of defining project complexity (Baccarini, 1996), make projects are becoming increasingly complex (Loch and Terwiesch, 1998; Archer and Ghasemzadeh, 1999; Williams, 1999). With the growing complexity of projects, more and more issues in decision-making about the prioritization of risks and development of the strategies may arise (Marle et al., 2013). Thus, it can be said that if the risk interdependences can be correctly analyzed, the project managers will be able to make more effective risk response decisions (Kwan and Leung, 2011).

In this paper, we firstly provide an approach to measuring risk interdependence. The approach avoids the need to moderate divergences in evaluations of different experts or test the consistency of the evaluation results. Further, we propose an optimization model considering the risk interdependence and its two directions for selecting risk response strategies. On the basis of these, we can investigate the effects of the risk interdependence on the decisions about project risk response. The computation results and discussions through a case study show that the expected utility is more sensitive to the risk interdependence itself than to the directions of it. Moreover, more attention paid to the risk interdependence can increase the expected utility and reduce the implementation cost. The numerical and analytical results indicate that, in practical PRM, it is important to understand the interdependences between project risks.

The remaining of this paper starts from reviewing the previous studies related to the risk interdependence and project risk response. Then it moves to an introduction of the formulae and properties of the strength of risk interdependence. Subsequently, we propose an optimization model for selecting risk response strategies considering the risk interdependence. Thereafter, the application of the proposed methodology to an engineering project is illustrated and related results and discussions are here reported. Conclusions and perspectives appear in the last section.

2. Literature review

2.1. Relevant literature on risk interdependence

Project execution is always accompanied by risks and the studies on project risks and risk interdependence have always been the topics of concern in academia and practice. Some scholars study on the project risk interdependence from qualitative perspectives. Badenhorst and Eloff (1994) consider the risk dependence as one of the risk factors in the process of IT risk management. Adner (2006) points out that the success of a company's growth strategy hinges on the assessment of the ecosystem's risks of the company. And the ecosystem is characterized by three fundamental types of risks: initiative risks, interdependence risks and integration risks. Ackermann et al. (2007) develop the 'Risk Filter' which is a tool to evaluate risks in projects considering the interaction between risks as a part of risk analysis. The 'Risk Filter' has been used on many projects since its introduction. Kwan and Leung (2011) propose methods to estimate risks by taking account of risk dependence effects, and risk response strategies focusing on risk dependences should also be developed. Correa-Henaoa et al. (2013) describe a methodology for risk management in electricity infrastructures considering interdependences between the infrastructure assets. Cavallo and Ireland (2014) advocate the need for disaster preparedness strategies using a networked approach which can deal with interdependent risk factors. Besides, in the context of project portfolios, Keisler and Linkov (2010) describe what makes a set of risks worth considering as a portfolio. And they further point out that the ignorance of important risk interdependences can lead to underestimating the remaining portfolio risks or overlooking ways to eliminate more risks with a fixed budget, or otherwise getting the wrong answer. Teller (2013) points out that project risk management alone is insufficient in the context of project portfolios, and it is necessary to understand the interdependences and cross-portfolio risks within the project portfolio. An empirical investigation is also applied to show that it is necessary and important to understand the interdependences between projects and their risks for project portfolio success (Teller and Kock, 2013). Pajares and López (2014) argue that new methodologies should be developed in order to deal with project-portfolio interactions in terms of risk, schedule or cash-flow.

In addition, there are approaches quantitatively assessing risk interdependences, which can be mainly classified into the following categories: the Monte Carlo simulation approach, the nature language assessment approach, the matrix-based approach and the Delphi-based approach. The Monte Carlo simulation approach is mainly used to establish interdependence among different project risks (Rao and Grobler, 1995; Touran and Wiser, 1992). However, some major shortcomings have been mentioned (Wirba et al., 1996): the linear correlation is assumed to establish interdependences between random variables, but the linear correlation does not completely account for the interdependencies; it is not always practical to estimate the correlation because of the lack of readily available data, and the correlations are best used in situations where the necessary relationships must be developed empirically while this is hardly ever the case in risk analysis. To overcome these shortcomings, linguistic variables are used to assess the interdependence (Wirba et al., 1996). In the assessment process, linguistic variables have to be transformed into fuzzy numbers because the algorithms are designed to handle the mathematics of fuzzy set operations. After the computation, the obtained fuzzy numbers need to be transformed into linguistic variables once again since the results are difficult to understand. It can be seen that there are loss of information in the transformation. In recent years, the approach based on Design Structure Matrix (DSM) (Steward, 1981) which represents relations and dependences among objects, is developed (Fang and Marle, 2012; Fang et al., 2012, 2013; Marle and Vidal, 2011; Marle et al., 2013). The core of the approach is to capture and represent project risk interdependences by building up matrices. The approach mainly includes two steps. First, a binary matrix representing the existence of potential interdependence between each pair of risks is built. Secondly, the binary matrix is transformed into a numerical one to assess the strength of risk interdependence, in which a Likert scale using expert judgments or the Analytic Hierarchy Process (AHP) (Satty, 1980) is used. The last approach is based on the Delphi technique (Linstone and Turoff, 1975). In the approach (Aloini et al., 2012a, 2012b), questionnaire respondents are asked to assess the strength of interdependence among the risks. Then the experts' judgments are elaborated in order to define a unique map of relationships and the process is reiterated until a consensus is reached although it takes time to reach the consensus.

The above approaches have made significant contributions to risk interdependence analysis. However, from quantitative perspectives, there are some limitations in the existing approaches. For example, 0 and 1 are used to indicate whether the interdependence exists between two risks in the matrix-based approach and Delphi-based approach. This could lead to underestimation for relatively weak interdependence and overestimation for relatively strong interdependence. And it would be somewhat unrealistic that the complex risk interdependence is assigned either a numerical