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Improving risk assessment in financial feasibility of international engineering projects: A risk driver perspective

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Abstract

Major engineering projects characterized by intensive technologies and high investment are becoming more complex with increasing risks in a global market. Because incorrect investment decision-making can cause great losses to investors, quantitative risk assessment is widely used in establishing the financial feasibility of projects. However, existing methods focus on the impact of uncertain parameters, such as income, on decision variables of investment, neglecting assessing the impact of risk events, such as the sales of products falling short of expectations. In the context of international engineering projects from a risk driver perspective, this paper presents an improved quantitative risk assessment model to help risk managers identify the direct relationships between specific risk events and decision variables of investment. Stress testing is also introduced to assess the negative impact of extreme risks. The new model is applied to an on-going international petrochemical project to demonstrate its use and validate its applicability and effectiveness.

Keywords: Quantitative risk assessment; Investment decision-making; Risk driver perspective; Monte Carlo simulation; Stress testing

1. Introduction

The global operation of engineering companies has resulted in increasing foreign trade and investment. Due to the changing external environment and the complexity and high level of investment needed for projects, investment risks are becoming greater and more worrying for investors as wrong investment decisions, characterized by irreversibility and uncertainty, often exert a long-term impact, such as considerable financial losses and reputational damage (Kim et al., 2012; Alkaraan, 2015; Hallegatte et al., 2012). Consequently, it is considered vitally important to conduct a detailed risk assessment when making such investment decisions (Virlics, 2013).

Risk assessment is a systematic, evidence-based approach for assessing uncertain or risky future events. Here, uncertainty refers to a state where an exact numerical value cannot be given for an activity as some variation in values may occur due to unpredictable circumstances, while a risk event is defined as the probability that an event will occur and considers the impact on corresponding objectives when the event occurs (Samson et al., 2009). A widely used method for risk assessment of investment decisions for international engineering projects is Monte Carlo simulation. Practically, it is very common for individuals to evaluate the impact of uncertain parameters (such as costs, price of raw materials, sales price, construction period and productivity) on decision variables (Hacura et al., 2001; Ye and Tiong, 2000; Rezaie et al., 2007; Suslick et al., 2008). This commonly involves calculating the variation in net present value (NPV) and internal rate of return (IRR) under the condition that uncertain parameters vary within a specific range

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and then to obtain the probability distributions of NPV and IRR.

The values of the uncertain parameters involved vary with the occurrence of risk events. That is, it is the risk events rather than the uncertain parameters that are the root causes of the variation in the decision variables of investment. However, the traditional quantitative risk assessment model does not take into account the influence of risk events on decision variables and so no targeted measures are developed to prevent losses that might subsequently be incurred.

To overcome this defect, this paper presents an improved model to assess investment risks quantitatively for international engineering projects from a risk driver perspective. Stress testing is introduced to assess the negative impact of extreme risk events. The input and output information and specific processes of the model are firstly elaborated, followed by a case study to demonstrate its use and validate its applicability and effectiveness. Final remarks concern the potential of the model to provide more practical decision-making support for investment in international engineering projects as a means of reducing the prospects of investment failure.

2. The traditional quantitative risk assessment model

Risk assessment can be divided into qualitative and quantitative methods, with the traditional academic focus being on the latter (Tah and Carr, 2001). Quantitative risk assessment is inherently related to risk modelling (Taroun, 2013). Risk modelling has developed along with the shift of risk perception from an estimation variance initially (Edwards and Bowen, 1998; Taroun, 2013) to a project attribute later (Dikmen et al., 2007; Merna and Al-Thani, 2008). As a result, risk is mainly evaluated on two dimensions: the probability of occurrence and impact. Correspondingly, risk assessment tools have evolved from statistical methods based on probability theory (e.g., Edwards and Bowen, 1998) to analytical tools (e.g., Lazzerini and Mkrtchyan, 2011; Nieto-Morote and Ruz-Vila, 2011), such as the Analytical Hierarchy Process (AHP) and decision trees, and stochastic simulation (e.g., Choudhry et al., 2014)—used to simulate independent variables based on a set of random values to obtain probability distributions of the forecast variables, such as Monte Carlo simulation.

The most common quantitative risk assessment tools for investment decision-making are *decision trees* and *Monte Carlo simulation*. A *decision tree* model predicts target variables through a set of prediction rules that are arranged in a tree-like structure (Syachrani et al., 2012). It is used to represent different decision alternatives and their consequences. However, the analysis of decision trees is based on a single-value point estimate as an average outcome for the long run, which limits their real-life applications to a narrow scope of decision problems (Moussa et al., 2006). *Monte Carlo simulation*, on the other hand, is suitable for use with objects with probabilistic characteristics and is able to generate additional data (Shen et al., 2011) to produce probability distributions of possible outcome values and also indicate which inputs affect the outcome the most, which makes it the most common and applicable tool for quantifying investment risks in major engineering projects.

Investors need to make decisions based on the likely values of the financial results of investment, using metrics such as NPV and IRR (Li and Sinha, 2009; Warszawski and Sacks, 2004; Hartman and Schafrick, 2004), and the use Monte Carlo simulation enables risk managers to determine their probability distributions by specifying influencing factors or independent variables (IVs), such as capital expenditure, operation costs, maintenance costs, productivity, product prices, prices of raw materials and inflation indices (Ye and Tiong, 2000; Davidson et al., 2006; Girmscheid, 2009; Hawas and Cifuentes, 2014), as probability distributions and calculating the results repeatedly, each time using a different set of random values from the probability functions. To do this necessitates risk managers defining the form of the IV probability distributions and their associated parameters. However, these parameters are themselves uncertain. Product price, price of raw materials and the inflation index, for example, are affected by risk events, such as the breakout of the global financial crisis.

In traditional quantitative risk assessment practice, the values of these uncertain IV parameters are estimated based on predictions and assumptions about the future. Investors cannot lower the possible losses incurred from the variation of uncertain parameters by making an increased effort. Nevertheless, investors still can lower or eliminate risk by further efforts. Most engineering project risk events, such as delays in the supply of raw materials, are knowledge-related and partly due to an inability to understand the project and its surrounding environment (Flage et al., 2013). Such risk events can be managed by risk reduction countermeasures as distinct from pure parameter estimation to bring about improved forecasts of NPV and IRR.

Stewart and Deng (2014) argue that risk managers generally pay insufficient attention to the probability of occurrence of risk events when conducting risk analysis. To overcome this, both the probability of occurrence *and* impact of risk events need to be defined as IVs. In addition, as extreme events occur that are characterized by low-probability and high-impact, the corresponding financial results are prone to deteriorate significantly. Investors therefore need to reserve enough risk provision or make corresponding risk countermeasures in advance or else, when extreme events do occur, they may suffer huge losses and even investment failure. To do this involves calculating the incurred loss when a risk has low-probability but high-impact—termed here as "stress testing"—to determine the negative impact of extreme risks on NPV and IRR.

In short, the traditional quantitative risk assessment model has two important drawbacks in failing to (1) define risk events that are the root causes of losses as IVs of decision variables of investment and (2) assess the negative impact of extreme risk events. An advanced quantitative risk assessment model is therefore presented to overcome these drawbacks by building up the direct relationships between risk events and decision variables of investment from a risk driver perspective and providing stress testing on the likely variation of the decision variables of investment.