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Fuzzy based risk assessment module for metropolitan construction project: An empirical study

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ABSTRACT

The work proposes an integrated risk assessment route in relation to metropolitan construction projects based on the fuzzy set theory. A hierarchical risk break-down structure has been conceptualized to facilitate the task of risk assessment. The risk extent (rating) corresponding to a particular risk source has been expressed as a function of two parameters: likelihood (possibility) of occurrence and impact (consequence of occurrence). The concept of risk matrix has been explored herein to categorise various risk factors at different levels of severity for the establishment of necessary actions requirement plan. A case study of a metropolitan construction project for building an underground metro rail station has been reported here to demonstrate application procedural steps of the proposed methodology.

1. Introduction

Recently, metro construction has gained tremendous momentum for rapid economic development worldwide (Zhang et al., 2014). Though execution of construction projects in metropolitan areas is very appealing; but it is highly risky, competitive, and dynamic due to the complicated surrounding environments such as heavy traffic, transportation, multiple stakeholders' competency, removal of existing pipelines utilities and other facilities (Kou and Lu, 2013). Underground construction in metro region is seen to be highly risky. The risks associated with such construction projects may eventually incur adverse consequences in terms of project delays and budget overruns. The term 'risk' can be understood by the potential for complications and problems with respect to the completion of a project task and the achievement of a project goal (Mark et al., 2004). Risk is inherent in every project under execution; it cannot be fully eliminated; rather, it can be effectively managed to mitigate the impacts that are likely to hamper the success of a project. Due to increased level of complexity as well as dynamic characteristics, it is being experienced that most of the massive construction projects are becoming a failure to complete within the stipulated timespan; as it involves lots of uncertainties which may not be taken care of adequately by the firm's risk management team leads.

In addition, lack of effective management of project risks may lead to cost overruns, project delays, and even termination prior to completion, and may also impose ill (adverse)-impact to the project team' reputation. In order to ensure success of a project, construction industries require adopting a proactive approach for managing inherent risks as well as uncertainties while carrying out construction tasks, especially in metropolitan areas. If potential risk factors are carefully identified, assessed and monitored at the initial phase; the probability of on-time and economic completion of a project can be increased remarkably.

Risks can be viewed as threats, but business exists to cope with risks (Olson and Wu, 2010). Different disciplines have different ways of classifying risks. Wu et al. (2014a) proposed the following general classification of risks: Field-based and Property-based (Baucells and Heukamp, 2009). Field-based types include financial risk (market risk, credit risk, operational risk, and liquidity risk) as well as non-financial risk (political risks, reputational risks, and disaster risks). In contrast to this, risks that are described by the property (Risks can have four properties: uncertainty, dynamics, interconnection and dependence, and complexity) are called property-based risks. In general, Risk is defined as the unknown change in the future value of a system (Wu and Olson, 2013). Drew (2007) has categorized Risks have been into five groups:

1. *Opportunities*- events presenting a favorable combination of circumstances giving rise to the chance for beneficial activity;

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2. *Killer risks*- events presenting an unfavorable combination of circumstances leading to hazard or major loss or damage resulting in permanent cessation of operations;
3. *Other perils*- events presenting an unfavorable combination of circumstances leading to hazard of loss or damage leading to disruption of operations with possible financial loss;
4. *Cross functional risks*- common risks leading to potential loss of reputation;
5. *Business process unique risks*- risks occurring within a specific operation or process, such as withdrawal of a particular product for quality reasons (Johansson, and Säfstren, 2013).

However, it is worth of mentioning that all aforesaid five risk types belong to the category of field-based risk.

According to (Wu et al., 2014a), risk management can be understood as the process of identification, analysis and either the acceptance or mitigation of uncertainty in investment decision making. Risk management is basically to manage uncertainty related to a threat. Traditional risk management focuses on risks stemming from physical or legal issues such as natural disasters or fires, accidents, death and lawsuits. Financial risk management deals with risks that can be managed using traded financial instruments; whilst, enterprise risks management, provides a tool to enhance the value of systems, both commercial and communal, from a systematic point of view. Wu et al. (2014a) provided different perspectives and tools in relation to business intelligence in risk management: (i) Early-warning systems, (ii) Neural networks-based risk analysis, (iii) Risk-based decision making, (iv) Game-based risk analysis, (v) Credit risk decisions, (vi) Data mining in enterprise risk management, (vii) Agent-based risk management, (viii) Engineering risk analysis based on optimization tools, and (ix) Knowledge management and data mining for natural disasters risk management in industry. The relevance to the special issue on risks could further be retrieved from (Wu et al., 2013, 2014b, 2016; Wu and Wu, 2016).

Risk management is, therefore, become a serious concern for every industry/enterprise. Effective risk management strategies and proper implementation of the same not only helps in achieving various organizational goals but also creates a healthy work environment and ensure workers' wellbeing. Identification of risks (or sources of risk) is of utmost important as prescribed in the risk management literature. Adequate experience and prior knowledge are indeed essential to identify sources of various risks in industrial context. Historical data or statistics on work related accidents, project-failures etc. are not always available unless the company maintains a strong data base and shares the information to others. In many cases, companies are not willing to share or reveal that sensitive information. In absence of adequate historical data, how decision and information sciences can contribute to risk management that has been articulated in this paper, through a case empirical research in relation to a metropolitan construction project.

Based on extensive literature review on risk management, the common questions that are generally faced by company's risk management team leads have been articulated herein. While developing an effective risk management strategy in industrial context, the following questions may definitely arise:

(1) What are the sources of risks, and what are factors that influence the risks? How they can be identified?
(2) What are the potential losses incur by the adverse consequence of risks?
(3) How can risk be estimated (assessed)?
(4) Which type of analysis: quantitative, qualitative, or semi-quantitative analysis to be considered towards effective risk assessment?
(5) How risk can be categorized? What is the critical level of risks?
(6) What type of control measures should be chosen to mitigate the severity of risks?
(7) What benefits an organization is likely to get, if risk management strategies are properly implemented?

Risk analysis and risk assessment are two essential components in any project risk management framework. Generally, the following two important approaches are frequently applied in construction project risk assessment such as probabilistic approach (Zhang et al., 2014; Adams, 2008; Ye and Tiong, 2000) and possibilistic approach (Pinto, 2014; Li et al., 2013; Rezakhani, 2011; Dikmen et al., 2007; Carr and Tah 2001). Probabilistic approach deals with the estimation of the likelihood and impact of any given risk, based on the historical numeric data; whereas, possibilistic approach deals with estimating likelihood and impact of a given risk based on qualitative (descriptive) data. Popular probability based techniques like sensitivity analysis, decision tree analysis, Bayesian network analysis, Monte Carlo simulation approach are commonly used to facilitate risk analysis for construction projects.

However, the limitation of probability theory is that it cannot deal with important aspect of project uncertainty; which may arise due to existence of uncertain and vague (ill-defined) risk factors during the risk assessment phase (Ebrat and Ghodsi, 2014; Pender, 2001). Therefore, it is felt that in order to estimate the degree of severity of construction project risks, more precisely, fuzzy set theory can effectively be explored to take care of the subjectivity associated with uncertain characteristics (vague and ill-defined) of risk factors and corresponding human judgment on assessing the same. An efficient fuzzy based decision making module seems indeed a necessity to estimate severity of potential risks in relation to a particular case metropolitan construction project, attempted in the present reporting.

The structure of the remaining part of the paper has been described below.

Section 2 has articulated prior state of art on the present problem context. Theoretical basis of risk assessment has been provided in **Section 3**. Preliminaries of fuzzy set theory have been presented in **Section 4**. **Section 5** has demonstrated the proposed risk assessment approach. A case empirical illustration has been provided in **Section 6**. Importance and application feasibility of the proposed approach has also been discussed in **Section 6**. Finally, conclusions and future scope of the work have been delineated in **Section 7**. In addition, this section highlights limitation of the current research followed by future scope of work.

2. State of art and problem formulation

Mandal and Maiti (2014) have developed a methodology for risk analysis by integrating the concepts of fuzzy similarity value measure and possibility theory. Similarity value measure has been applied for grouping together failure modes having similar amount of risk value whereas possibility theory has been used for checking the conformance guidelines. Purnus and Bodea (2014) have used a Monte Carlo Method for analysing the risks associated with in the construction projects. The correlation between the parameters of time, cost and resource limitation have been analysed, and perceived project risks have been estimated using Spider Project software. Pinto (2014) has developed a fuzzy based qualitative risk assessment model for the assessment of occupational safety risks in relation to a construction industry. The degree of risk extent has been estimated effectively considering the parameters of subjective evaluation of likelihood of occurrence and consequence of risk, using fuzzy set theory. The author has

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