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Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies

Osman Taylan[a,*], Abdallah O. Bafail[b], Reda M.S. Abdulaal[a], Mohammed R. Kabli[a]

[a] Department of Industrial Engineering, Faculty of Engineering, King Abdulaziz University, P.O. Box 80204, Jeddah 21589, Saudi Arabia
[b] Vice President of King Abdulaziz University for Projects, P.O. Box 80200, Jeddah 21589, Saudi Arabia

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ABSTRACT

Construction projects are initiated in dynamic environment which result in circumstances of high uncertainty and risks due to accumulation of many interrelated parameters. The purpose of this study is to use novel analytic tools to evaluate the construction projects and their overall risks under incomplete and uncertain situations. It was also aimed to place the risk in a proper category and predict the level of it in advance to develop strategies and counteract the high-risk factors. The study covers identifying the key risk criteria of construction projects at King Abdulaziz University (KAU), and assessing the criteria by the integrated hybrid methodologies.

The proposed hybrid methodologies were initiated with a survey for data collection. The relative importance index (RII) method was applied to prioritize the project risks based on the data obtained. The construction projects were then categorized by fuzzy AHP and fuzzy TOPSIS methodologies. Fuzzy AHP (FAHP) was used to create favorable weights for fuzzy linguistic variable of construction projects overall risk. The fuzzy TOPSIS method is very suitable for solving group decision making problems under the fuzzy environment. It attempted to incorporate vital qualitative attributes in performance analysis of construction projects and transformed the qualitative data into equivalent quantitative measures. Thirty construction projects were studied with respect to five main criteria that are the time, cost, quality, safety and environment sustainability. The results showed that these novel methodologies are able to assess the overall risks of construction projects, select the project that has the lowest risk with the contribution of relative importance index. This approach will have potential applications in the future.

1. Introduction

Problems arising in construction projects are complicated and are usually involving massive uncertainties and subjectivities. Compared with many other industries, the construction industry is subject to more risks due to the unique features of construction activities, such as being long period projects including complicated processes, abominable environment, financial intensity and dynamic organization structures [1]. Previous researches have mainly focused on examining the impacts of risks on one aspect of project strategies with respect to cost [2], time [3] and/or safety studies [4]. Some researchers investigated risk management for construction projects in the context of a particular project phase, such as conceptual/feasibility phase [5], design phase [6], construction phase [7], rather than from the perspective of a project life cycle. Construction projects are perceived to have more inherent risks due to the involvement of many contracting parties such as owners, designers, contractors, subcontractors, suppliers, etc., in addition to the economic, political, social and cultural conditions where the project is to be undertaken [8,9]. Project risk can be defined as an uncertain event or condition. Occurrence of project risk may have positive or negative effects on one of the following project objective, such as time, cost, safety, quality or sustainability. On the other hand, risks are threats to project success [10], failure to adequately dealing with risks has been shown to cause higher costs and time overruns in construction projects [11]. Eliminating all risks in construction projects is impossible. Thus, there is a need for a formal risk assessment and control process to manage all types of risks in the projects. Risk management is a formal and orderly process of systematically classifying, identifying, assessing and responding to risks throughout the life cycle of a project to obtain the optimum degree of risk elimination, mitigation and/or control [12]. Perry and Hayes [13] presented a list of factors extracted from several sources which were divided in terms of risks retainable by contractors, consultants and clients.

For classifying and managing risks effectively, many approaches have been suggested in the literature. Chapman [6] grouped risks into different subclasses which are environment, industry, client

* Corresponding author. Tel.: +966 500031056.
E-mail addresses: otaylan@kau.edu.sa, osman_taylan@yahoo.com (O. Taylan).

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Table 1
Fuzzy linguistic variables and their term set for the weights of criteria.

Fuzzy linguistic variables	Linguistic terms	Relative importance index
Time (C_1)	Short, average, long, very long	(0.64, 0.73, 0.82)
Cost (C_2)	Low, average, high, very high	(0.64, 0.73, 0.82)
Quality (C_3)	Poor, average, high, very high	(0.45, 0.60, 0.75)
Safety (C_4)	Unsafe, average, safe, very safe	(0.40, 0.61, 0.82)
Environmental sustainability (C_5)	Unsustainable, little-sustainable, sustainable, highly-sustainable	(0.50, 0.66, 0.82)

and project. Shen [3] categorized risks into six groups in accordance with the nature of the risks, i.e. financial, legal, management, market, policy and political, as well as technical risks. He stated eight major risks for project delay and ranked them based on survey questionnaires with industrial practitioners, and proposed risk management actions to cope with risks and to validate their effectiveness through individual interview surveys. Risk assessment has also numerous ways. Chen et al. [2] identified fifteen risk factors about project cost and divided them into three groups such as resources factors, management factors and parent factors. There are a number of researches on construction risks in several countries such as USA [14], Kuwait [15], China [16], and India [17].

Tam et al. [4] conducted a survey to examine the elements of poor construction safety management. Patrick et al. [18] presented eighty-eight risk factors associated with construction projects objectives in terms of cost, time, quality, environment, and safety. Tah and Carr [19] proposed the application of fuzzy logic for risk assessment of construction projects. Similarly, fuzzy inference system is a very useful technique in tackling the complex problems of construction risk assessment. On the other hand, Kuchta [20] applied fuzzy numbers in risk evaluation of construction projects. Zeng et al. [21] applied fuzzy set theory to evaluate the performance of cost and time in management of construction projects' risk management and utilization. Ebrat and Ghodsi [22] designed an adaptive neuro-fuzzy system for evaluation of project risks. Meredith and Mantle [23] discussed various qualitative and quantitative project selection models. Danila [24] surveyed some of the project selection methodologies in which various articles were discussed for the application of operation research tools in project selection. Hence, a large literature survey was carried out by Zeydan et al. [25] claiming that Multi-Criteria Decision Making techniques such as TOPSIS/fuzzy TOPSIS, AHP/fuzzy AHP and DEA do not have variety of applications in the literature.

The aim of this study is to determine the key risk factors of construction projects at King Abdulaziz University (KAU), and evaluate the projects for their risks using an integrated fuzzy AHP and fuzzy TOPSIS method. KAU construction projects are divided into four categories such as academic buildings, staff members housing, streets and roads of KAU campus, and all the infrastructure projects. The aim of administration is to complete all the on-hand construction projects on time with minimum cost and high quality. On the other hand, KAU construction projects are initiated in a dynamic that carry high uncertainty, and budget constraints. Therefore, managing risks in KAU construction projects is considered a very important issue to achieve the project objectives. Time, cost, quality, safety and environmental sustainability are the basic parameters for assessment of construction projects. The General administration of construction projects at the vice presidency of KAU for projects, conducted a survey to identify the elements of risks in the construction projects at KAU and identified the main factors affecting safety performance. It was determined that 'poor safety awareness of top management, lack of training, poor safety awareness of project managers, reluctance to input resources of safety and reckless operations' are the most important risk parameters [8]. In this study, an integrated hybrid methodology of fuzzy AHP and fuzzy TOPSIS was employed for construction project risk assessment. Fuzzy AHP method was used to create favorable weights for fuzzy linguistic variable of construction project risk assessment. Fuzzy AHP method is a systematic approach to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis [26]. The decision maker can specify preferences in the form of natural language or numerical value about the importance of each performance criteria. The system combines these preferences using FAHP with existing data. In the FAHP method, the pair-wise comparisons in the judgment matrix are fuzzy numbers. It uses fuzzy arithmetic and fuzzy aggregation operators, then the procedure calculates a sequence of weight vectors is used to choose the main attributes [27]. These methodologies were usually studied and applied individually in real life problems, its hybrid applications with fuzzy TOPSIS and data envelopment analysis (DEA) are seldom in literature.

Construction projects overall risk assessment is a multi criteria decision making (MCDM) problem. In multi criteria decision making problems, the attribute values and the relative weights are usually characterized by fuzzy numbers [28]. A fuzzy number is a convex fuzzy set, characterized by a given interval of real numbers, each with a grade of membership between 0 and 1. The most commonly used fuzzy numbers are triangular and trapezoidal fuzzy numbers. The membership or non-membership to a fuzzy set is smooth and gradual. The membership degree of set is characterized by membership functions that give fuzzy sets flexibility in modeling with commonly used linguistic expressions, such as '*the project risk is high*' or '*the time duration of project is short*,' and '*the quality of construction project is poor*' or '*the cost of project is high*', etc. Membership function of a fuzzy set maps fuzziness of each construction project's element and range space which, in most cases, is a set to the unit interval. As it is presented in Table 1, fuzzy linguistic values are usually presented by terms in the real life, but they can also be represented by fuzzy numbers. It is usually suitable to represent the degree of subjective judgment in qualitative aspect than in crisp value [29]. The word risk is a qualitative and vague concept that can be defined by fuzzy linguistic terms rather than numerical values.

The TOPSIS method can also be used to deal with fuzzy MCDM problems. Several extensions of this method have been suggested. The simplest extension is to change a fuzzy MCDM problem into a crisp one by applying the defuzzification method [29]. However, this approach can cause some information lost and gives only a crisp point estimate for the relative closeness of each criteria. Although the extension gives a fuzzy relative closeness for each criteria, it was determined that the supports of the derived fuzzy relative closeness are over exaggerated [26]. The extension principle is therefore not advisable either. To overcome these shortcomings, the TOPSIS method and the extension principle were combined to solve fuzzy MCDM problems. Zeydan, and Colpan [30] carried out a large literature survey on AHP/fuzzy AHP, TOPSIS and fuzzy TOPSIS. They have stated that there were some advantages and disadvantages when these techniques were compared with each other. It was claimed that the advantages of combined fuzzy TOPSIS and fuzzy AHP were far more than comparing the performance of these techniques. In the combined methodology, the qualitative and quantitative data relating to the criteria were collected and used as inputs into fuzzy TOPSIS approach. This approach transforms the qualitative