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A Fuzzy AHP Model in Risk Ranking

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Abstract
The signification risks associated with construction projects need special attention from contractors to analyze and mange the risks. Risk management is the art and science of identifying, analyzing and responding to risk factors throughout the life cycle of the project and in the best interest of its objectives.
In proposed model, we firstly identify risks in the construction projects and suitable criteria for evaluate risks and then structure the proposed AHP model. Finally we measure the significant risks in construction projects (SRCP) based on the project's objectives by using fuzzy analytical hierarchy process (FAHP) technique.
Keyword: Construction projects, Project Risk Management, Fuzzy AHP

1. Introduction

The increasing growth of the construction projects calls for massive development of infrastructures and assets. While this brings opportunities to project stakeholders, employing effective risk management techniques coped risks associated with variable construction activities is of importance to implement the projects aligning with project objectives including time, cost, quality, scope sustainability. Therefore, it is important to identify and assess the significant risks in the construction projects in order to help local companies and international companies who do or plan to work in the construction projects to pay attention to these significant risks.

1.1. Construction Projects

Flanagan & Norman [1] expressed that construction projects are one-off endeavors with many unique features such as long period, complicated processes, abominable environment, financial intensity and dynamic organization structures and such organizational and technological complexity generates enormous risks.
The number, size and complexity of new projects have created an extra burden on construction participants and resulted in lots of risks.
Zhi [2] developed a method of managing various risks for overseas construction projects. In this research he discussed how to effectively identify the vital risks in overseas projects and introduced a useful risk assessment technique which combines risk probability analysis with risk impact assessment.
Uher & Toakley [3] set out the results of a study into the use of risk management in the conceptual phase of the construction project development cycle in the Australian construction industry. Their study consisted of a literature review, a survey to examine skill levels and attitudes of key players to risk management, and their attitude to change. They found that while most respondents were familiar with risk management, its application in the conceptual phase was relatively low, even though individuals were willing to embrace change.
Carr & Tah [4] presented a paper that uses a fuzzy approach to construction project risk assessment and analysis. In this paper, a hierarchical risk breakdown structure is described to represent a formal model for qualitative risk assessment. The relationships between risk factors, risks, and their consequences are represented on case and effect diagrams.
Harmon & Stephan [5] stated that complex construction projects are high-risk ventures involving multiple parties with different interests, thus producing a high potential for conflict.
Moyst & Das [6] have applied the risk classification of the land-based construction industry to the shipbuilding industry with the aim of determining the factors affecting ship design and construction.
Motawa et al.[7] proposed a fuzzy system for evaluating the risk of change in construction projects.
Zou et al. [8] stated that a major source of risk in construction is the potential changes occurring during the project lifetime. Changes in construction projects often result from the uncertainty associated with the imprecise and vague knowledge of much project information at the early stages of projects.

1.2. Projects Risk Management

Burke [9] argued that project risk management is defined by the project management body of knowledge: 'the processes concerned with identifying, analyzing, and responding to uncertainty throughout the project life cycle. It includes maximizing the result of positive events and minimizing the consequences of adverse events.'
Perry [10] broke down the process of risk management into: identification of risk sources, assessment of their effects (risk analysis), development of management response to risk, and providing for residual risk in project estimates.
Clark et al. [11] suggested that an identified risk is not a risk unless it is a management problem.
Flanagan and Norman [1] proposed three ways of classifying risk: by identifying the consequence, type and

impact of risk.

Turner [12] proposed that risk management can be classified into five stages: (i) identifying the source of risk; (ii) determining the impact of individual risks; (iii) assessing the overall impact of risks; (iv) determining if the risk can be reduced; and (iv) controlling the identified risk.

Willams [13] described a complete, integrated risk-analysis and management scheme based around the register that assists in time, cost and technical analyses, helps in the devising of a risk-management plan, and prompts decisions on risk transfer.

Kangari [14] realized that important risks in construction projects are those relating to safety, quality of work, defects, productivity and competence.

Abdou [15] classified construction risks into three groups, i.e. construction finance, construction time and construction design, and addressed these risks in detail in light of the different contractual relationships existing among the functional entities involved in the design, development and construction of a project.

UNIDO [16] developed a BOT project risk checklist under two major categories (general/country risks and specific project risks) with three sub-categories under each.

Chapman & Ward [17] said ‘project risk is the implications of the existence of significant uncertainty about the level of project performance achievable’.

Edwards & Bowen [18] presented a broad classification of land-based construction project risks using natural (weather systems and geological systems) and human (social, political, economic, financial, legal, health, managerial, technical, and cultural) categories.

Dey [19] proposed that project risk management processes are categorized : (i) identifying risk factors; (ii) analyzing their effect; and (iii) responding to risk.

Wang et al. [20] carried out research to evaluate and manage foreign exchange and revenue risks in China’s BOT projects based on the findings of an international survey on risk management of BOT projects in developing countries.

Alquier & Tignol [21] classified the risks into internal and external risks, which are respectively those that are supposed to be under company control (e.g. manufacturer’s risk of products, processes and resources) and those that the company does not control (e.g. regulation, legal context, currency fluctuations, and environmental protection).

Raz & Michael [22] showed the results of a study to identify the tools that are most widely used and those that are associated with successful project management in general, and with effective project risk management in particular.

Keil et al. [23] investigated the issue of IT project risk from the user perspective and compares it with risk perceptions of project managers.

Ward & Chapman [24] in their paper argued that all current project risk management processes induce a restricted focus on the management of project uncertainty. This paper outlines how project risk management processes might be modified to facilitate an uncertainty management perspective.

McDowall [25] in his paper presented a scheme for undertaking risk management for laboratory automation projects.

Liebreich [26] used Risk management in financing renewable energy projects.

Yean et al. [27] identified the risks that Singapore-based architecture, engineering and construction (AEC) firms face when working in India and investigates the risk response techniques adopted by them.

Zou et al. [8] found out the key risks in construction projects in China and to develop strategies to manage them.

Wyk et al. [28] documented the risk management practice of a utility company for its Recovery Plan project to address the risks of power interruptions due to a shortfall of supply and increasing electricity demand.

Lee et al. [29] proposed a scheme for large engineering project risk management using a Bayesian belief network and applies it to the Korean shipbuilding industry.

1.3. AHP

The AHP is one of the extensively used multi-criteria decision-making methods. One of the main advantages of this method is the relative ease with which it handles multiple criteria. In addition to this, AHP is easier to understand and it can effectively handle both qualitative and quantitative data. AHP involves the principles of decomposition, pair wise comparisons, and priority vector generation and synthesis. Though the purpose of AHP is to capture the expert’s knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems.

There are many fuzzy AHP methods proposed by various authors [30, 31, 32, 33, 34, 35, 36, 37, 38].

In this study, we choose Mikhailov’s [36,37] fuzzy prioritization approach because this method has advantages over other fuzzy AHP approaches. The most important of these advantages is the measurement of consistency indexes for the fuzzy pair wise comparison matrixes. It is not possible to determine the consistency ratios of fuzzy pair wise comparison matrixes in other AHP methods without conducting an additional study.

The rest of this paper is organized as follows. In Section 2, we introduced the proposed model. In Section 3, we presented case study . the paper is concluded in Section 4.

2. The Proposed model

The suggested model for the measurement of SRCP includes the steps as following:
Step 1: Identify the criteria (project objectives) and alternatives (risks) to be used in the model.
Step 2: Structure the AHP model.
Step 3: Determine the local weights of the criteria and alternatives by using pair wise comparison matrices. The fuzzy scale regarding relative importance to measure the relative weights is given in Fig. 1and Table 1. This scale is proposed by Kahraman et al. [39] and used for solving fuzzy decision-making problems [39, 40] in the literature. This scale will be used in Mikhailov [36,37] fuzzy prioritization approach.

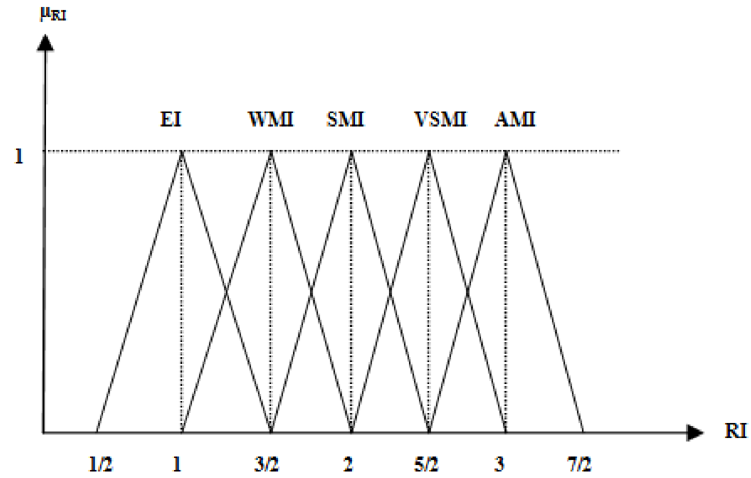

Fig. 1. Linguistic scale for relative importance

Table1. Linguistic scales for difficulty and importance

Linguistic scales for difficulty	Linguistic scale for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	Just equal	(1,1,1)	(1,1,1)
Equally difficult (ED)	Equally difficult (ED)	(1/2,1,3/2)	(2/3,1,2)
Weakly more difficult (WMD)	Weakly more difficult (WMD)	(1,3/2,2)	(1/2,2/3,1)
Strongly more difficult (SMD)	Strongly more difficult (SMD)	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strongly more difficult (VSMD)	Very strongly more difficult (VSMD)	(2,5/2,3)	(1/3,2/5,1/2)
Absolutely more difficult (AMD)	Absolutely more difficult (AMD)	(5/2,3,7/2)	(2/7,1/3,2/5)

Step 4: Calculate the global weights for the risks. Global risks weights are computed by multiplying local weight of the risks with the local weight of the criteria.
Step 5: Measure the risks. Linguistic variables proposed by Cheng et al [41] are used in this step. The membership functions of these linguistic variables are shown in Fig. 2, and the average value related with these variables are shown in Table 2.

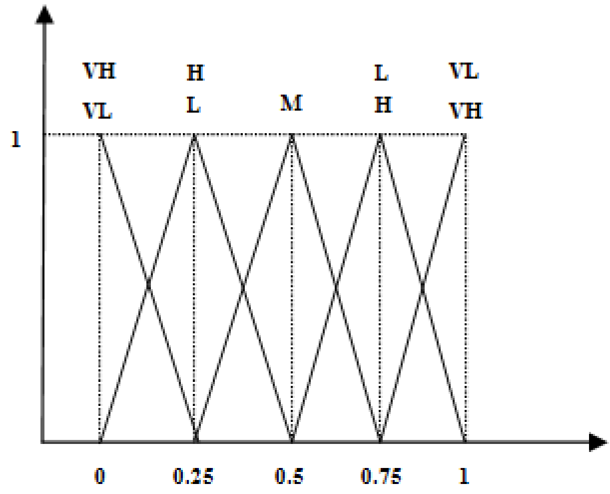

Fig. 2. Membership functions of linguistic values for risks rating

Table2.Linguistic values and mean of fuzzy numbers

linguistic values for negative alternatives	Linguistic values for positive alternatives	The mean of fuzzy numbers
Very low (VL)	Very low (VL)	1
Low (L)	Low (L)	0.75
Medium(M)	Medium(M)	0.5
High (H)	High (H)	0.25
Very high (VH)	Very high (VH)	0

Step 6: Calculate the SRCP by using the global risks weights and linguistic values. Depending on the determined values the following decisions are made:

- $0.80 \leq$ SRCP ≤ 1.0: The significant risks in construction projects is very good for the period of calculation.
- $0.60 \leq$ SRCP < 0.80: The significant risks in construction projects is good for the period of calculation.
- $0.40 \leq$ SRCP < 0.60: The significant risks in construction projects is moderate for the period of calculation.
- $0.0 \leq$ SRCP < 0.40: The significant risks in construction projects is bad for the period of calculation.

3 .Case study

Step1:

Step1.1. Identification of risk

Recognition process of possible risks in construction projects and determination of their characteristics is an effective step in risk identification. This process is carried out by assistance and cooperation of project group, risk management group and experts of this field out of the organization. By using Brain storming technique, at first 35 events or risks that affect on construction operations, have been recognized. Then by using Delphi method, number of these technical risks was decreased to 5. The finalized risks are presented in Table 3. We consider these risk factors as “alternatives” in proposal AHP model.

Table3. Finalized risks of construction projects

Final risks	Description
R_1	Economical inflation
R_2	International relations
R_3	Design failures
R_4	Communication matters between consortium members
R_5	Lack of attention to contract requirements

Step1.2. Determination of the suitable criteria for ranking risk

Like any human undertaking, projects need to be performed and delivered under certain constraints. Traditionally, these constraints have been listed as "scope," "time," and "cost". These are also referred to as the "Project Management Triangle," where each side represents a constraint. One side of the triangle cannot be changed without affecting the others. A further refinement of the constraints separates product "quality" or "performance" from scope, and turns quality into a fourth constraint.(Fig.4)

The time constraint refers to the amount of time available to complete a project.

The cost constraint refers to the budgeted amount available for the project.

The scope constraint refers to what must be done to produce the project's end result.

These three constraints are often competing constraints: increased scope typically means increased time and increased cost, a tight time constraint could mean increased costs and reduced scope, and a tight budget could mean increased time and reduced scope.

The discipline of Project Management is about providing the tools and techniques that enable the project team (not just the project manager) to organize their work to meet these constraints. We consider these constraints as "criteria" in our proposed AHP model.

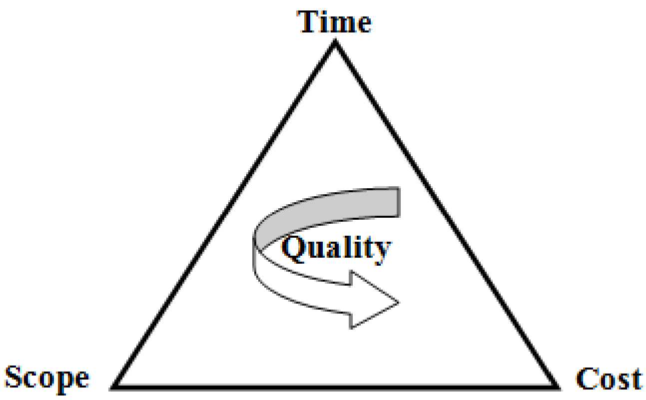

Fig. 3. Project Management Triangle

Step2: The proposed AHP model based on project objectives and risks.

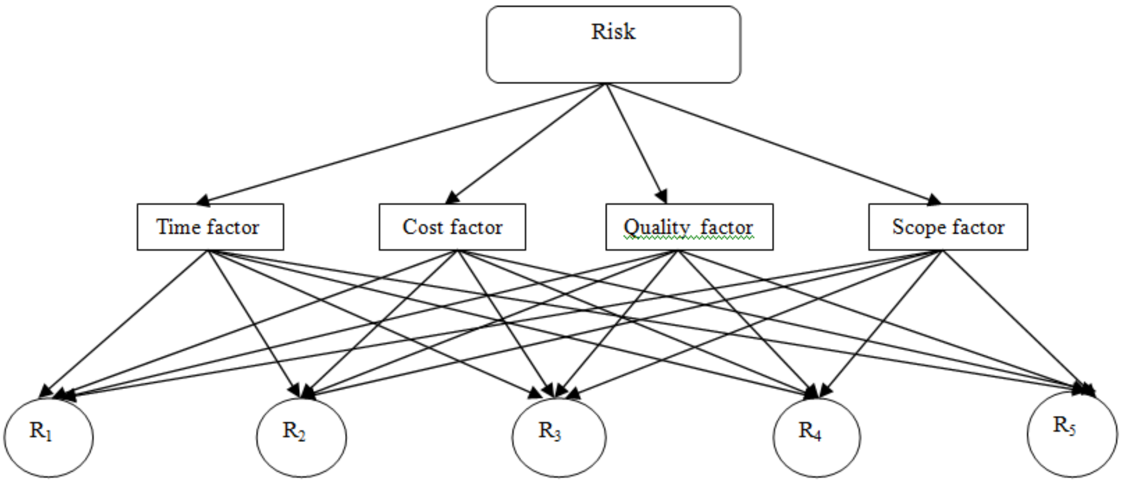

Fig.4.The proposed AHP model for measurement of risks

Step3: In this step, local weights of the criteria and risks which take part in the second and third levels of AHP model (Fig. 4), are calculated.(Table 4 - 8)

Local weights of the risks are calculated by using the fuzzy comparison values presented in Table1 through Saaty & Takizawa [42], Saaty [43] fuzzy prioritization approach. Non-linear model shown below was established for calculating weights and the weights listed in Table5 were calculated by solving this model with LINGO [44] software.

Max = C;

(1/2) × C × w2 - w1 + w2 <= 0;

$(1/2) \times C \times w2 + w1 - (2) \times w2 <= 0;$
$(1/2) \times C \times w3 - w1 + w3 <= 0;$
$(1/2) \times C \times w3 + w1 - (2) \times w3 <= 0;$
$(1/2) \times C \times w4 - w1 + (1/2) \times w4 <= 0;$
$(1/2) \times C \times w4 + w1 - (3/2) \times w4 <= 0;$
$(1/2) \times C \times w5 - w1 + (1/2) \times w5 <= 0;$
$(1/2) \times C \times w5 + w1 - (3/2) \times w1 <= 0;$
$(1/6) \times C \times w4 - w2 + (1/2) \times w4 <= 0;$
$(1/3) \times C \times w4 + w2 - w4 <= 0;$
$(1/3) \times C \times w5 - w2 + (2/3) \times w5 <= 0;$
$C \times w5 + w2 - 2 \times w5 <= 0;$
$w1 + w2 + w3 + w4 + w5 = 1;$

Thus, for example the weight vector from the above model is calculated as $W_{criteria} = (0.25, 0.17, 0.17, 0.25, 0.17)^T$. Consistency index (C) was calculated as 1.0 and this rate suggested that the fuzzy pairwise comparison matrix was consistent.

Table 4. Local weights and pair wise comparison matrix of criteria

	T	C	Q	S	Weights
Time (T)	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1/2,1,3/2)	0.29
Cost (C)		(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	0.25
Quality (Q)			(1,1,1)	(1,3/2,2)	0.25
Scope (S)				(1,1,1)	0.21

C=0.32

Table 5. Local weights and pair wise comparison matrix of time

	R1	R2	R3	R4	R5	Weights
R1	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1/2,1,3/2)	(1/2,1,3/2)	0.25
R2		(1,1,1)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	0.17
R3			(1,1,1)	(1,1,1)	(1,1,1)	0.17
R4				(1,1,1)	(1,1,1)	0.25
R5					(1,1,1)	0.17

C=1.0

Table 6.Local weights and pair wise comparison matrix of cost.

	R1	R2	R3	R4	R5	Weights
R1	(1,1,1)	(1/2,1,3/2)	(1/2,1,3/2)	(1,3/2,2)	(1,3/2,2)	0.20
R2		(1,1,1)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	0.15
R3			(1,1,1)	(2/3,1,2)	(2/3,1,2)	0.29
R4				(1,1,1)	(1,1,1)	0.17
R5					(1,1,1)	0.17

C=0.35

Table 7. Local weights and pair wise comparison matrix of quality

	R1	R2	R3	R4	R5	Weights
R1	(1,1,1)	(1,3/2,2)	(3/2,2,5/2)	(1/2,1,3/2)	(1/2,1,3/2)	0.27
R2		(1,1,1)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	0.16
R3			(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	0.16
R4				(1,1,1)	(2/3,1,2)	0.21
R5					(1,1,1)	0.20

C=0.36

Table 8. Local weights and pair wise comparison matrix of scope

	R1	R2	R3	R4	R5	Weights
R1	(1,1,1)	(3/2,2,5/2)	(3/2,2,5/2)	(1,3/2,2)	(1,3/2,2)	0.30
R2		(1,1,1)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	0.16
R3			(1,1,1)	(2/3,1,2)	(2/3,1,2)	0.17
R4				(1,1,1)	(1,1,1)	0.20
R5					(1,1,1)	0.18

C=0.60

Step4: Computed global weights for risks are shown in Table 9.

Table 9.
Computed global weights for risks

Criteria and local weights	risks	Local weights	Global weights
T (0.29)	R1	0.25	0.07
	R2	0.17	0.05
	R3	0.17	0.05
	R4	0.25	0.07
	R5	0.17	0.05
C (0.25)	R1	0.20	0.05
	R2	0.15	0.04
	R3	0.29	0.07
	R4	0.17	0.04
	R5	0.17	0.04
Q (0.25)	R1	0.27	0.07
	R2	0.16	0.04
	R3	0.16	0.04
	R4	0.21	0.05
	R5	0.20	0.05
S (0.21)	R1	0.30	0.06
	R2	0.16	0.03
	R3	0.17	0.04
	R4	0.20	0.04
	R5	0.18	0.04

Step 5-6: Measure the risks and Calculate the SRCP that are shown in Table 10 and 11.

Table 10. the Linguistics variables related for each project

Final risks	Global Weight (gw)	Project1	Project2	Project3	Project4
R1	0.25	VL	M	M	L
R2	0.16	M	VL	H	VL
R3	0.2	VL	VL	VL	M
R4	0.2	VL	M	H	M
R5	0.18	L	L	L	L

Table 11. Computed SRCP with the proposed fuzzy AHP model for each project

Final risks	Global Weight	Project 1	Project 2	Project 3	Project 4	Project 1	Project 2	Project 3	Project 4
R1	0.25	1	0.5	0.5	0.75	0.25	0.125	0.125	0.1875
R2	0.16	0.5	1	0.25	1	0.08	0.16	0.04	0.16
R3	0.2	1	1	1	0.5	0.2	0.2	0.2	0.1
R4	0.2	1	0.5	0.25	0.5	0.2	0.1	0.05	0.1
R5	0.18	0.75	0.75	0.75	0.75	0.135	0.135	0.135	0.135
					SRCP:	0.865	0.72	0.55	0.6825

In this study based on step6

The SRCP of project 1 is 0.865 that is between 0.80 and 1.0, so this project is very good.
The SRCP of project 2 is 0.72 that is between 0.60 and 0.80, so this project is good.
The SRCP of project 3 is 0.55 that is between 0.40 and 0.60, so this project is moderate.
The SRCP of project 4 is 0.68 that is between 0.60 and 0.80, so this project is good.

4-Conclusion

Managing risks in construction projects has been recognized as a very important process in order to achieve project objectives in terms of time, cost, quality, scope.Decisions are made today in increasingly complex environments. In more and more cases the use of experts in various fields is necessary, different value systems are to be taken into account, etc. In many of such decision-making settings the theory of fuzzy decision making can be of use. Fuzzy group decision making can overcome this difficulty. we firstly identified risks in the construction projects and suitable criteria for evaluate risks and then structured the proposed AHP model. Finally we measured the significant risks in construction projects (SRCP) based on the project's objectives by using fuzzy analytical hierarchy process (FAHP) technique.

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