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Multi-criteria risk assessment of a construction project

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Abstract

The paper presents risk assessment of construction objects for the project of commercial center construction. The risk assessment is based on the multi-criteria decision making methods with fuzzy information. The risk evaluation criteria are selected taking into consideration the macro, mezzo and micro levels of a construction project. Ranking of objects and determination of their optimality are determined by applying TOPSIS-F method with criteria values with fuzzy information. The background and presented criteria of construction project risk assessment of the proposed model are provided and key findings from the analysis are presented.

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1. Introduction

The risk factor in construction business is very high. Construction objects are unique and built only once. Life cycle of construction objects is full of various risks. Risks come from many sources: temporary project team that is comprised of employees from different enterprises, construction site and etc. Moreover, the size and complexity of construction objects are increasing, which adds to the risks [1].

Risk management is an operational process comprising definition of sources of uncertainty (risk identification), estimation of the consequences of uncertain events/conditions (risk analysis), generation of response strategies in the light of expected outcomes and, finally, based on the feedback received on actual outcomes and risks, carrying out identification, analysis and response generation steps repetitively throughout the life cycle of an object to ensure that the project objectives are met [2].

Construction development, technology and management conditions are different. Environment may change the conditions in the country. Furthermore, specific buildings, projects, and firms face markedly different level of risks. The variables that have been identified to contribute to the level of risks can be categorized into the

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followings groups: country, industry, project, and enterprise specific risks. Risk groups are presented in the Table 1 and Fig. 1.

Table 1. Risk assessment of a construction project

Macro	*Mezzo*	*Micro*
Country	Project	Management
Industry	Enterprises	Organization

Fig. 1. Risk allocation structure by level in construction projects

In the relevant period, risk assessment was analysed considering the uncertain environment [3–5].

2. Risk assessment under fuzzy environment, by applying TOPSIS-F method

Multi criteria decision aid provides several powerful solution tools [6] for sorting problems. Simplified techniques can be used for evaluation, such as the Simple Additive Weighting — SAW; TOPSIS — Technique for Order Preference by Similarity to Ideal Solution [6], COPRAS — COmplex PRoportional ASsessment [7]. The COPRAS method determines a solution with the ratio to the ideal solution and the ratio with the ideal-worst solution. In 2008, COPRAS-G method was developed with grey numbers [8, 9]. More detail survey of multi-criteria decision-making methods in the construction context has been presented by many authors in numerous articles [1]. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision-making method, which was originally developed by Yoon in 1980 [10] with further developments by Hwang and Yoon in 1981 [6], Yoon in 1987 [11], and Hwang, Lai and Liu in 1993 [12,13]. The TOPSIS method is based on assumptions that:

- Each criterion in the decision-making takes either monotonically increasing or monotonically decreasing utility;
- A set of weights for the criteria is required;
- Any outcome, which is expressed in a non-numerical way should be quantified through the appropriate scaling technique.

TOPSIS is a method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a negative ideal point. The only subjective input needed is relative weights of criteria. The method TOPSIS an extension for group decision making [14] and incremental analysis for MCDM with an application to group TOPSIS [15], applied TOPSIS method with grey number operations [16].

The principle behind TOPSIS is simple: The chosen alternative should be as close to the ideal solution as possible and as far from the negative-ideal solution as possible. The ideal solution is formed as a composite of the best performance values exhibited (in the decision matrix) by any alternative for each criterion. It is a method that compares a set of alternatives by identifying weights for each criterion, normalising scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalisation is usually required as the parameters or criteria are often of incongruous dimensions in multi-criteria problems [10]. The TOPSIS process is carried out as follows:

Step 1. Create an initial decision-making matrix consisting of m alternatives and n criteria.

Step 2. The initial decision-making matrix is then normalised using a normalisation method. The aim is to transform the various criteria dimensions into non-dimensional criteria, which allows comparison across the criteria.

Step 3. Calculate the weighted normalised decision matrix.

Step 4. Determine the negative-ideal and ideal best alternatives.

Step 5. Calculate the separation measure between the target alternative and the negative-ideal alternative, and the negative-ideal solution.

Step 6. Calculate the similarity to the negative-ideal solution.

Step 7. Rank the alternatives according to similarity to the negative-ideal solution.

In general case, the elements of the initial decision-making matrix are real numbers (not negative) or linguistic expressions from the given group of expressions. Linguistic criteria have to be quantified within previously determined and agreed value scale. The most commonly used scales, which could be used, are as follow:

- Ordinal scale (the ranking of actions, whereas the relative distances between the ranks are not taken into account);
- Interval scale (equal differences between the criterion values and defined benchmarks are determined);
- Ratio scale (equal relations between the criterion values but the benchmarks are not defined beforehand).

Interval scale represents the suitable tool to be used when performing quantification of qualitative criteria. The most commonly used scale is 1 to 9, since the extremes of the criteria for the criteria being analyzed are usually unknown. Table 2 bellow shows one of the methods of translating the qualitative criteria into quantitative criteria.

Table 2. The quantification of qualitative criteria

Qualitative estimation	***Small (bad)***			***Average***			***Very high (very good)***			***Extremely high (excellent)***			***Type of criteria***
Symbol	***α***	***β***	***γ***	***α***	***β***	***γ***	***α***	***β***	***γ***	***α***	***β***	***γ***	
Quantitative estimation	1	1	2	4	5	6	6	7	8	8	9	9	Benefit (max)
	9	9	8	6	5	4	4	3	2	1	1	2	Cost (min)

Quantification of qualitative criteria can be performed in many different ways. One of them is fuzzyfication. Values from 1–10 of the standard scale, which is used to determine criteria weights, are presented in Table 3.

Table 3. The standard scale of values

Linguistic variable	*Very bad*	*Bad*	*Sufficient*	*Satisfactory*	*Good*	*Very good*	*Very good indeed*	*Excellent*	*Extraordinary*	*Perfect*
α	1	1	2	3	4	5	6	7	8	9
β	1	2	3	4	5	6	7	8	9	10
γ	2	3	4	5	6	7	8	9	10	10

3. Risk assessment under fuzzy environment

The TOPSIS-F method [17] with fuzzy criteria values determined is applied for risk assessment of commercial objects in construction. Risk assessments for three commercial objects are presented. The commercial objects are of different design, architecture, construction technology, area, different number of floors and located at different places of the city. The initial fuzzy decision-making matrix and solution results for risk assessment of a construction project are presented in Table 3. Weight coefficients were determined for the above criteria within the scale 1–10, as shown in Table 4:

Table 4. Initial fuzzy decision-making matrix and solution results for risk assessment of construction project

	Type of the risks	*Criteria weights*			*Project 1*			*Project 2*			*Project 3*			A^+	A^-
		α	*β*	*γ*	*α*	*β*	*γ*	*α*	*β*	*γ*	*α*	*β*	*γ*		
x_1	Economic Performance in Country	0.044	0.065	0.089	4	5	6	4	5	6	2	3	4	2	6
x_2	Project Specificity	0.03	0.056	0.089	4	5	6	3	4	5	1	2	3	1	6
x_3	International Environment Change	0.044	0.065	0.089	3	4	5	1	2	3	2	3	4	1	5
x_4	Firm Specificity	0.015	0.034	0.059	2	3	4	1	1	2	3	4	5	1	5
x_5	Labor Force	0.015	0.034	0.059	2	3	4	1	2	3	3	4	5	1	5
x_6	General Contracting	0.015	0.04	0.074	3	4	5	1	2	3	1	1	2	1	5
x_7	Consultancy Services	0.044	0.058	0.074	2	3	4	1	2	3	1	1	2	1	4
x_8	Management Contracting	0.044	0.058	0.074	3	4	5	1	2	3	1	2	3	1	5
x_9	Subcontracting	0.044	0.065	0.089	3	4	5	1	2	3	2	3	4	1	5
x_{10}	Design-Build	0.044	0.065	0.089	4	5	5	1	2	3	1	2	3	1	5
x_{11}	Analysis of Opportunities	0.044	0.065	0.089	4	5	6	1	2	3	3	4	5	1	6
x_{12}	Contracting Negotiation	0.044	0.065	0.089	3	4	5	1	2	3	1	1	2	1	5
x_{13}	Construction	0.044	0.065	0.089	4	5	6	3	4	5	2	3	4	2	6
x_{14}	Feasibility Study	0.015	0.034	0.059	3	4	5	2	3	4	1	2	3	1	5
x_{15}	Design	0.015	0.034	0.059	4	5	6	3	4	5	2	3	4	2	6
x_{16}	Operation	0.044	0.058	0.074	3	4	5	3	4	5	1	2	3	1	5
x_{17}	Pre-contracting	0.044	0.065	0.089	1	2	3	2	3	4	3	4	5	1	5
x_{18}	Procurement	0.015	0.034	0.059	2	3	4	1	2	3	2	3	4	1	4
x_{19}	Post-Evaluation	0.015	0.04	0.074	2	3	4	1	1	2	1	1	2	1	4
S^+	Separation measure between the target alternative and the ideal alternative A^+							12.99			8.06			8.21	
S^-	Separation measure between the target alternative and the negative-ideal alternative A^-							6.66			11.89			12.12	
C	Similarity to the negative-ideal solution							0.3389			0.5959			0.5964	
Rank								3			2			1	

Overall least risk according to calculation results by applying TOPSIS-F method (Table 3) ranks as follows: Project 3 $\succ$ Project 2 $\succ$ Project 1 . The calculation results demonstrated that the first project is one of the most risky. The third project is the last risky.

4. Conclusion

Decision making — such as risk assessment results in construction projects, contractor and supplier selection and etc. — is very important in the construction management. In real life, multi-criteria modelling of multi-alternative assessment problems with some criteria values, which deal with the future, must be calculated under a fuzzy environment. The presented model and solution results have both a practical and a scientific interest. The calculation results showed that the first project is the most risky.

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