CONSTRUCTION RISK ASSESSMENT OF SMALL SCALE OBJECTS BY APPLYING TOPSIS METHOD WITH ATTRIBUTES VALUES DETERMINED AT INTERVALS

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The paper presents risk assessment in construction. The assessment of small scale construction objects in competitive environment is based on the multi-attribute method. Ranking of objects and determination of their optimality are calculated by applying TOPSIS method with attributes values determined at intervals. The risk evaluation attributes are selected taking into consideration the interests and goals of the stakeholders as well as factors that have influence of the construction process efficiency. A background and a description of the proposed model are provided and key findings from the analysis are presented.

Keywords: *TOPSIS attributes values determined at intervals, risk, assessment.*

1. Introduction

The construction business is risky. However, construction projects are perceived to have more inherent risks due to the involvement of many contracting parties such as stakeholders, designers, contractors, subcontractors, suppliers, etc. Construction projects are unique and built only once. They also involve a temporary project team that is assembled from different companies, place and etc. Moreover, the size and complexity of construction projects are increasing which adds to the risks. This is in addition to the political, economic, social conditions where the project is to be undertaken. Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost, quality [1]. The risks have been shown to cause cost and time overruns in construction projects.

2. Risk in Construction for Small Scale Objects

Project risks can be allocated into two groups: internal and external. Internal risks are those that are project related and usually fall under the control of the project management team. External risks are those risks that are beyond the control of the project management team. Internal risks are then divided according to the party who might be the originator of risk events such as stakeholders, designer, contractor and etc. There are various classification ways of risk management methods. Schieg [2] analysed project risk in construction.

The model of small scale objects risk assessment is presented in Figure 1.

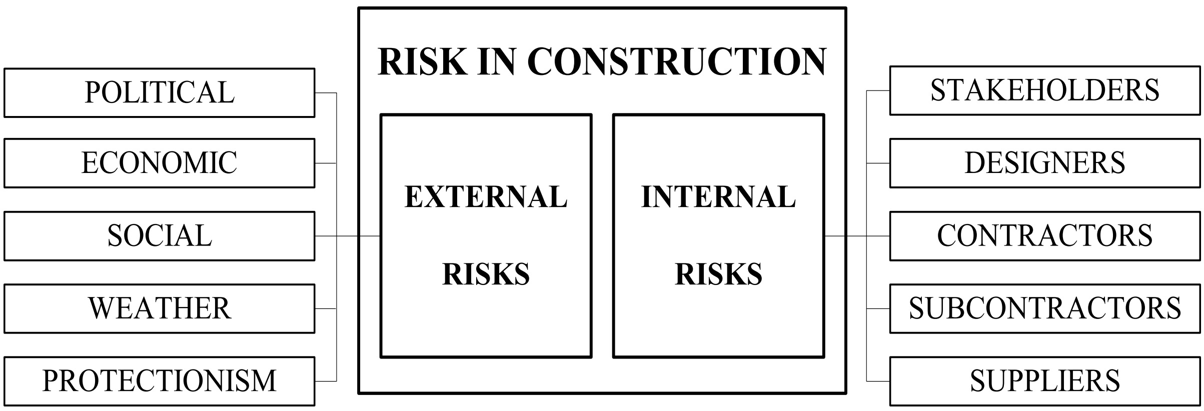

Figure 1. Risk allocation structure in construction for small scale objects

3. TOPSIS Method with Attributes Values Determined at Intervals

3.1. TOPSIS and values determined at intervals literature survey

Multiple attributes decision aid provides several powerful solution tools [3, 4] for confronting sorting problems. There can be used very simplified techniques for the evaluation) of a decision support methods base including methods such as the Simple Additive Weighting — SAW; TOPSIS — Technique for Order Preference by Similarity to Ideal Solution [3, 5].

More detail survey of Multi-attribute decision-making methods in the construction context is presented by many authors. Construction objects renewal modelling by applying game theory [6], multi-attribute evaluation model of retail centres influence on the city structure [7], ranking accuracy evaluation in multi-attribute decisions [8], multi-attribute evaluation of rural building's regeneration alternatives [9], a multi-variant and multi-attribute approach [10], normalization of quantities of various dimensions [11], selection of the effective dwelling house walls by applying attributes values determined at intervals [12].

TOPSIS is a multi-attribute 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. TOPSIS can incorporate relative weights of attributes. The TOPSIS method was developed by Hwang and Yoon in 1981 [3]. This method is attractive in that limited subjective input is needed from decision makers. The only subjective input needed is weights.

In 1982 Deng [13] developed grey system theory. In 1988 [14] Deng presented grey decision-making systems. Grey relational analysis possesses advantages [15]:

a) involves simple calculations,
b) requires smaller samples,
c) a typical distribution of samples is not needed,
d) the quantified outcomes from the Grey relational grade do not result in contradictory conclusions to qualitative analysis,
e) and the Grey relational grade model is a transfer functional model that is effective in dealing with discrete data.

Wang et al. [16] used an evidential reasoning approach for solving multiple attribute decision analysis (MADA) problems under interval belief degrees. Lin et al. [17] applied TOPSIS method with grey number operations to the contractor selection problem solution with uncertain information.

3.2. TOPSIS method with attributes values determined at intervals

Lin et al. proposed the model of TOPSIS method with attributes values determined at intervals includes the following steps [17]:
Grey number matrix, D^k can be defined as:

$$D^k=\begin{bmatrix} \otimes x_{11}^k & \otimes x_{12}^k & \dots & \otimes x_{1m}^k \\ \otimes x_{21}^k & \otimes x_{22}^k & \dots & \otimes x_{2m}^k \\ \vdots & \vdots & \vdots & \vdots \\ \otimes x_{n1}^k & \otimes x_{n2}^k & \dots & \otimes x_{nm}^k \end{bmatrix}. \quad (1)$$

where $\otimes x_{ij}^k$ denotes the grey evaluations of the *i*-th alternative with respect to the *j*-th attribute by decision maker *k* (k=1, …, K); $\left[\otimes x_{i1}^k,\ \otimes x_{i2}^k,\ \dots,\ \otimes x_{im}^k\right]$ is the grey number evaluation series of the *i*-th alternative given by decision maker *k*. It is noted that there should be *K* grey decision matrices for the *K* members of the group.

Step 1: Construct the normalized grey decision matrices:

$$\otimes r_{ij}^k = \frac{\otimes x_{ij}^k}{\max(\overline{x}_{ij}^k)} = \left(\frac{\underline{x}_{ij}^k}{\max(\overline{x}_{ij}^k)},\ \frac{\overline{x}_{ij}^k}{\max(\overline{x}_{ij}^k)} \right). \quad (2)$$

On the other hand, the normalization of the smaller-the-better type attribute can be calculated as:

$$\otimes r_{ij}^{k} = -\frac{\otimes x_{ij}^{k}}{\min(\underline{x}_{ij}^{k})} + 2 = \left(\frac{-\overline{x}_{ij}^{k}}{\min(\underline{x}_{ij}^{k})} + 2;\ \frac{-\underline{x}_{ij}^{k}}{\min(\underline{x}_{ij}^{k})} + 2 \right). \tag{3}$$

Step 2: Determine the positive and negative ideal alternatives for each decision maker. The positive ideal alternative - A^{k+}, and the negative ideal alternative - A^{k-}, of decision maker *k* can be defined as:

$$A^{k+} = \left\{ \left(\max_{i} \overline{r}_{ij}^{k} \,|\, j \in J \right), \left(\min_{i} \underline{r}_{ij}^{k} \,|\, j \in J' \right) \middle| \ i \in n \right\} = \left[r_1^{k+},\ r_2^{k+},\ \ldots,\ r_m^{k+} \right] \text{ and} \tag{4}$$

$$A^{k-} = \left\{ \left(\min_{i} \underline{r}_{ij}^{k} \,|\, j \in J \right), \left(\max_{i} \overline{r}_{ij}^{k} \,|\, j \in J' \right) \middle| \ i \in n \right\} = \left[r_1^{k-},\ r_2^{k-},\ \ldots,\ r_m^{k-} \right]. \tag{5}$$

Step 3: Calculate the separation measure from the positive and negative ideal alternatives, d_i^{k+} and d_i^{k-}**,** for the group. There are two sub-steps to be considered in Step 3. The first one concerns the separation measure for individuals; the second one aggregates their measures for the group.
Step 3.1: Calculate the measures from the positive and negative ideal alternatives individually. For decision maker k, the separation measures from the positive ideal alternative - d_i^{k+} and negative ideal alternative - d_i^{k-} are computed through weighted grey number as:

$$d_i^{k+} = \left\{ \frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^{k+} - \underline{r}_{ij}^{k} \right|^p + \left| r_j^{k+} - \overline{r}_{ij}^{k} \right|^p \right] \right\}^{1/p} \text{ and} \tag{6}$$

$$d_i^{k-} = \left\{ \frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^{k-} - \underline{r}_{ij}^{k} \right|^p + \left| r_j^{k-} - \overline{r}_{ij}^{k} \right|^p \right] \right\}^{1/p}. \tag{7}$$

In equations (6) and (7), for p≥1 and integer, w_j is the weight for the attribute *j* which can be determined by attribute weight determination methods. If p=2, then the metric is a weighted grey number Euclidean distance function. Equations (6) and (7) will be as follows:

$$d_i^{k+} = \sqrt{\frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^{k+} - \underline{r}_{ij}^{k} \right|^2 + \left| r_j^{k+} - \overline{r}_{ij}^{k} \right|^2 \right]} \text{ and} \tag{8}$$

$$d_i^{k-} = \sqrt{\frac{1}{2} \sum_{j=1}^{m} w_j \left[\left| r_j^{k-} - \underline{r}_{ij}^{k} \right|^2 + \left| r_j^{k-} - \overline{r}_{ij}^{k} \right|^2 \right]}. \tag{9}$$

Step 3.2: Aggregate the measures for the group. The group separation measure of each alternative will be aggregated through an operation, $\otimes$ for all decision makers. Thus, the two group measures of the positive and negative ideal alternatives: d_i^{*+} and d_i^{*-}, respectively, are the following two equations:

$$d_i^{*+} = d_i^{1+} \otimes \ldots \otimes d_i^{K+} \text{ for alternative } i \text{, and} \tag{10}$$

$$d_i^{*-} = d_i^{1-} \otimes \ldots \otimes d_i^{K-} \text{ for alternative } i. \tag{11}$$

Geometric mean is adopted, and the group measures of each alternative will be:

$$d_i^{*+} = \left(\prod_{k=1}^{K} d_i^{k+} \right)^{1/K} \text{, for alternative } i, \text{ and} \quad (12)$$

$$d_i^{*-} = \left(\prod_{k=1}^{K} d_i^{k-} \right)^{1/K} \text{, for alternative } i. \quad (13)$$

Step 4: Calculate the relative closeness C_i^{*+}, to the positive ideal alternative for the group. The aggregation of relative closeness for the *i*-th alternative with respect to the positive ideal alternative of the group can be expressed as:

$$C_i^{*+} = \frac{d_i^{*-}}{d_i^{*+} + d_i^{*-}}, \quad (14)$$

where $0 \le C_i^{*+} \le 1$. The larger the index value is the better the evaluation of alternative will be.

Step 5: Rank the preference order. A set of alternatives now can be ranked by the descending order of the value of C_i^{*+}.

4. Case Study: Construction Risk Assessment

The TOPSIS method with attributes values determined at intervals is demonstrated on a practical problem for small scale construction objects risk assessment. Risk assessment of five small scale objects was made by three experts. The objects are of different design, architecture, construction technology, area, different number of the floors and they are in different site of the Vilnius.

In order to select the best alternative, it is necessary to have formed the decision matrix and to perform the object‘s multiple attributes analysis. The initial decision making data are presented in Table 1. In the table 1 q_j is the attribute weight and alternative objects are $v_1, \ldots, v_5$.

To determine the weights of the attributes, the expert‘s judgment method is applied [18], which has been successfully used in research by the authors since 1987 [5; 19-20]. In order to establish the weights, a survey has been carried out and 43 experts have been questioned. These experts, basing their answers on their knowledge, experience and intuition, had to rate attributes of effectiveness starting with the most important ones. The rating was done on a scale from 1 to 5, where 5 meant "very important" and 1 "not important at all". The weights of attributes were established according to the rating methods [5] of these experts and also demonstrated the priorities of the user (stakeholder). The weights of the attributes obtained by this method are presented in Table 1.

In the Table 1 there are presented data of the following attributes:

a) external risk assessment:

- $\otimes x_1$ - political,
- $\otimes x_2$ - economic,
- $\otimes x_3$ - social,
- $\otimes x_4$ - weather and
- $\otimes x_5$ - protectionism;

b) internal risk assessment:

- $\otimes x_6$ - stakeholders,
- $\otimes x_7$ - designers,
- $\otimes x_8$ - contractors,
- $\otimes x_9$ - subcontractors and
- $\otimes x_{10}$ - suppliers.

Table 1. The initial decision making data for risk assessment in construction of small scale objects

	Attribute			q_j	EXPERT 1 v_1	EXPERT 1 v_2	EXPERT 1 v_3	EXPERT 1 v_4	EXPERT 1 v_5	EXPERT 2 v_1	EXPERT 2 v_2	EXPERT 2 v_3	EXPERT 2 v_4	EXPERT 2 v_5	EXPERT 3 v_1	EXPERT 3 v_2	EXPERT 3 v_3	EXPERT 3 v_4	EXPERT 3 v_5
EXTERNAL RISK	Political	$\otimes x_1$	$\underline{x}_1$	0.10	5.00	5.50	4.50	5.00	6.00	6.00	6.50	5.00	6.00	7.50	7.00	7.50	6.50	7.00	6.00
			$\bar{x}_1$		6.00	7.00	5.50	6.50	8.00	7.00	7.50	5.50	6.50	8.00	8.00	8.00	8.50	8.00	6.50
	Economic	$\otimes x_2$	$\underline{x}_2$	0.15	5.50	6.00	4.50	5.50	7.50	6.00	7.00	5.00	6.00	8.00	7.00	7.00	6.00	6.50	6.00
			$\bar{x}_2$		6.50	7.50	5.00	6.00	8.00	6.50	7.50	6.00	7.00	8.50	8.00	7.50	7.00	7.00	8.00
	Social	$\otimes x_3$	$\underline{x}_3$	0.10	5.00	4.50	4.00	4.50	6.00	6.00	5.00	4.00	5.50	7.00	8.00	7.00	7.50	8.00	8.00
			$\bar{x}_3$		6.50	5.00	4.50	5.00	7.00	6.50	5.50	5.00	6.00	7.50	8.50	8.00	8.50	8.50	8.50
	Weather	$\otimes x_4$	$\underline{x}_4$	0.07	4.50	4.50	4.50	4.50	4.50	5.00	5.00	5.00	5.00	5.00	4.50	4.50	4.50	4.50	4.50
			$\bar{x}_4$		5.00	5.00	5.00	5.00	5.00	5.50	5.50	5.50	5.50	5.50	5.00	5.00	5.00	5.00	5.00
	Protectionism	$\otimes x_5$	$\underline{x}_5$	0.08	5.00	4.00	5.00	4.00	5.50	5.50	4.50	5.50	4.50	4.00	6.00	7.00	6.00	7.00	7.50
			$\bar{x}_5$		6.00	5.00	6.00	5.00	6.00	6.50	5.00	6.00	5.00	6.50	7.00	7.50	8.00	8.00	8.00
INTERNAL RISK	Stakeholders	$\otimes x_6$	$\underline{x}_6$	0.12	7.00	8.00	7.00	7.50	8.00	8.00	8.00	7.00	7.00	8.00	6.00	8.00	7.00	7.50	7.00
			$\bar{x}_6$		8.00	8.50	7.50	8.00	8.50	8.50	8.50	8.00	8.00	9.00	7.00	8.50	8.50	8.00	7.50
	Designers	$\otimes x_7$	$\underline{x}_7$	0.10	8.00	7.00	6.50	8.00	6.50	7.00	7.00	7.00	6.00	7.00	8.00	8.00	7.00	7.50	6.50
			$\bar{x}_7$		8.50	8.00	7.00	8.50	7.50	7.50	7.50	8.00	7.00	8.50	9.00	8.50	8.00	8.00	7.00
	Contractors	$\otimes x_8$	$\underline{x}_8$	0.13	8.00	7.00	8.00	7.00	6.50	8.00	7.00	6.00	8.00	6.00	8.00	7.00	8.00	8.00	8.00
			$\bar{x}_8$		8.50	7.50	8.50	8.50	7.00	8.50	7.50	8.00	9.00	7.50	8.50	7.50	8.50	8.50	9.00
	Subcontractors	$\otimes x_9$	$\underline{x}_9$	0.10	6.50	7.00	8.00	6.50	6.00	6.00	6.00	6.00	5.00	4.00	4.00	6.00	5.00	5.00	6.00
			$\bar{x}_9$		7.00	7.50	8.50	7.50	7.00	6.50	7.00	7.00	5.50	5.50	5.00	7.00	5.50	6.00	6.50
	Suppliers	$\otimes x_{10}$	$\underline{x}_{10}$	0.05	6.00	7.00	8.00	5.00	6.00	5.00	5.00	6.00	5.00	4.00	3.00	4.00	4.00	5.00	5.50
			$\bar{x}_{10}$		7.00	8.00	8.50	7.00	8.00	6.50	6.00	6.50	7.00	4.50	4.00	4.50	5.00	6.00	6.00

The problem has been solved according to TOPSIS method. The results are shown in Figure 2.

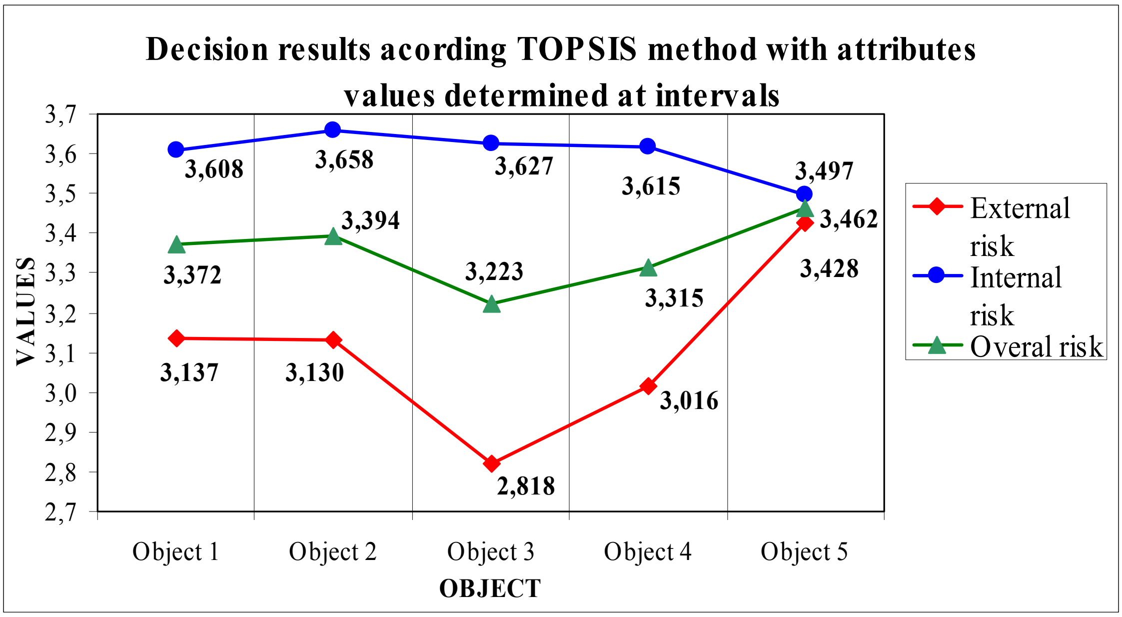

Figure 2. External, internal and overall risk assessment of small scale construction objects according to TOPSIS method with attributes values determined at intervals. The best alternative is with the biggest value

According to the external least risk assessment objects ranks as follows:

$\text{Object } 5 \succ \text{Object } 1 \succ \text{Object } 2 \succ \text{Object } 3 \succ \text{Object } 4$.

According to the internal least risk assessment objects ranks as follows:

$\text{Object } 2 \succ \text{Object } 3 \succ \text{Object } 4 \succ \text{Object } 1 \succ \text{Object } 5$.

According to the overall least risk assessment objects ranks as follows:

$\text{Object } 5 \succ \text{Object } 2 \succ \text{Object } 1 \succ \text{Object } 4 \succ \text{Object } 3$.

Conclusions

In real life multi-attribute modelling of multi-alternative assessment problems some attribute values, which deals with the future, must be expressed in intervals.

The research results show the different risks level in small scale objects construction business.

This model and solution results have both practical and scientific interest. It allows to all members of the construction business to make decision evaluating multiple attributes when values of initial data are given in the intervals.

The results of problem solution showed that in construction process of small scale objects, internal risk is more important than external risk.

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