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MULTI-ATTRIBUTE CONTRACTORS RANKING METHOD BY APPLYING ORDERING OF FEASIBLE ALTERNATIVES OF SOLUTIONS IN TERMS OF PREFERABILITY TECHNIQUE

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Abstract. Contractor evaluation is a vital part of the project management cycle and deals with risk and risk management. One of the most important phases in the construction industry is the bidding process. In order to select the most appropriate contractor for the project and prepare the most realistic and accurate bid proposal, stakeholders have to know all financial, technical and general information about these contractors. The information can be determined as qualitative, quantitative or verbal data. This paper presents the multi-attribute contractors ranking method bay applying Ordering of feasible alternatives of solutions in terms of preferability technique. This method allows dealing with qualitative and quantitative data as well as with data expressed in words (verbal data). Finally, an illustrative example of contractor selection is used to demonstrate the feasibility and practicability of the proposed model.

Keywords: construction, contractor, multi-attribute, evaluation, pre-qualification, decision-making, permutation method.

1. Introduction

The rapid growth of the economy calls for massive development of infrastructures and assets. Construction projects are one-off endeavours with many unique features such as long period, complicated processes, changing environment. Contractor evaluation is a vital part of the project management cycle. As construction projects become more complex, the need for evaluating contractor performance becomes more crucial. Organizational and technological complexity of construction projects generates enormous risks. Contractor selection is the process of selecting the most appropriate contractor to deliver the project as specified so that the achievement of the best value for money is ensured. The selection of a qualified contractor gives confidence to the stakeholder that the selected contractor can achieve the project goals.

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However, the importance of contractor selection is mostly underestimated and neglected in construction (Kumaraswamy and Matthews 2000; Ng and Wan 2005). It is hard to analyze many tradeoffs involved in decision making, especially in times with so many uncertainties presented by environmental considerations. Insufficient time for execution, complicated procedures or poor information channels may be the reasons of problems in the selection of contractors (Shiau *et al*. 2002). Contractor evaluation has been recognized as a particularly complex task due to its ambiguity and difficult formalisation (Tserng and Lin 2002; Shiau *et al.* 2002; Albino and Garavelli 1998). It is usually based on intuition and past experience and carried out by the general contractor management (Albino and Garavelli 1998; Luu and Sher 2006). There have been no generalized sets of rules for the evaluation process.

Contractor selection deals with risk and risk management. Zou *et al*. (2007) and argues that the risks in construction projects can be classified as follows: cost overrun, time delay, quality, safety, environmental sustainability and funding, contractors' poor management ability, contractors' difficulty in reimbursement, poor competency of labourers, not buying insurance for major equipments and employees, inadequate safety measures or unsafe operations, lack of readily available utilities on site, prosecution due to unlawful disposal of construction waste and serious air and water pollution due to construction activities, suppliers' incompetency to deliver materials on time.

Many construction contracts are awarded to the lowest bidder. An offered bid price is undoubtedly an important factor in choosing a contractor, but there are many other important ones playing a vital role in project implementation that have to be incorporated in the contractor's evaluation process.

2. Multi-attribute contractor selection models

Many researchers (Zavadskas and Kaklauskas 1996, 2007; Zavadskas and Vilutiene 2006; Vilutiene and Zavadskas 2003) have pointed out that in construction it is essential to be able to take into account the impacts of cultural, social, moral, legislative, demographic, economic, environmental, governmental and technological change, as well as changes in the business world on international, national, regional and local real estate markets. Evaluation of contractors based on multi-attributes is becoming more popular and is, in essence, largely dependent on the uncertainty inherent in the nature of construction projects and subjective judgment of decision-makers.

Multi-attribute decision-making is defined by processes that involve designing the best alternative or selecting the best one from a set of alternatives, that has the most attractive overall attributes, and that involves the selection of the optimal alternative, handled via preference models (Sage 1977; Bui 1987; Chankong and Haimes 1983; French *et al*. 1998; Hwang and Lin 1987; and Hwang and Yoon 1981). Multi-attribute decision-making can be classified as follows:

a) Multi-attribute decision-making (MADM) for the sorting or the ranking of alternatives according to several attributes, and
b) Multi-objective decision-making (MODM), for driving a vector optimization-based design process to a solution (Colson and Bruyn 1989).

Train (2002) certifies that in the eighties of the 20th century main models of qualitative selection analysis methods, defined statistic and economic properties of such methods were delivered. The methods were successfully applied in many fields; including transport, energy, civil engineering and market (enumerated a few only). Multi-attribute decision-making methods have different characteristics (Triantaphyllou 2000). There are different ways to classify them. Multi-attribute methods can be classified by the type of initial information (deterministic, stochastic, fuzzy set theory methods) or by the number of decision-makers (one or a group). Scientists classify deterministic MADM methods differently. Lin and Wu (2007) presented classification of the methodology which can be used for qualitative and quantitative methods aimed at technology management. The classification of MADM methods according to the type of information proposed by Larichev (Ларичев 2000) is given below:

1) Methods based on quantitative measurements. The methods based on multi-attribute utility theory may be referred to this group (TOPSIS – Technique for Order Preference by Similarity to Ideal Solution (Hwang and Yoon 1981; Arditi and Günaydın 1998), SAW – Simple Additive Weighting (Mac Crimon, 1968; Zavadskas *et al.* 2007b), LINMAP – Linear Programming Techniques for Multidimensional Analysis of Preference (Srinivasan and Shocker 1973; COPRAS – COmplex PRoportional ASsessment (Zavadskas and Kaklauskas 1996; Zavadskas *et al.* 2007a) and other new methods.
2) Methods based on qualitative initial measurements. These include two widely known groups of methods, i.e. analytic hierarchy methods (AHP) (Saaty 1994) and fuzzy set theory methods (Zimmermann 2000).
3) Comparative preference methods based on pairwise comparison of alternatives. This group comprises the modifications of the ELECTRE (Roy 1996), PROMETHEE I and II (Brans *et al.* 1984), and other methods.
4) Methods based on qualitative measurements not converted to quantitative variables. This group includes methods of verbal decision-making analysis (Berkeley *et al.* 1991; Andre'eva *et al.* 1995; Larichev *et al.* 1995; Larichev and Moshkovich 1996; Flanders *et al.* 1998) and uses qualitative data for decision environments involving high levels of uncertainty.

All these procedures are aimed at selecting a qualified contractor on a competitive basis, but in reality a decision is usually based on a single criterion (Hatush and Skitmore 1998). Siskos *et al.* (2000) described their methodological approach based on the principles of multi-attribute modelling and the application of the original preference disaggregation method as used in MUSA (Multi-criteria Satisfaction Analysis) for data analysis and interpretation.

The contractor pre-qualification process involves the establishment of a standard for measuring and assessing the capabilities of potential contractors (Ng *et al.* 1999). According to Hatush and Skitmore (1997) and Holt (1996), the information used for the assessment of parameters for pre-qualification falls into the following groups:

- General information that is used mainly for administrative purposes;
- Financial information;
- Technical information;
- Managerial information;

- Experience attributes;
- Performance attributes;
- Safety information;
- Environmental concerns.

Jaselskis and Russel (1992), Crowley and Hancher (1995), Russel (1996), Kumaraswamy (1996) have identified commonly used attributes for prequalification and bid evaluation and have proposed methodologies for contractor selection.

Zavadskas and Kaklauskas (1996) selected 25 attributes of contractor selection and applied COPRAS method to contractor selection. Hatush and Skitmore (1998) have initiated the use of systematic multi-attribute decision analysis techniques for contractor selection and bid evaluation based on additive multi-attribute utility function model. Banaitiene and Banaitis (2006) performed an analysis of criteria for contractors' evaluation. Dikmen *et al.* (2007) after conducting a thorough research, 44 candidate factors affecting the bid mark-up decisions selected as factors having a potential impact on bid mark-up size for a project. The factors are divided into 4 groups, namely: general features about company and project, risk factors, opportunity factors, and competition factors.

An extensive literature review by the researchers revealed that the most acceptable contractor's pre-qualification attributes are financial stability, management and technical ability, contractor's experience, contractor's performance, resources, quality management and health and safety concerns. Therefore, the contractor's attributes corresponding to these attributes should be evaluated.

Ustinovichius *et al.* (2006) presented a systematic procedure based on fuzzy set theory to evaluate the capability of a contractor to deliver the project as per the owner's requirements. The notion of Shapley value is used to determine the global value or relative importance of each criterion in accomplishing the overall objective of the decision-making process. One major advantage of the proposed method is that it makes the selection process more systematic and realistic, as the use of fuzzy set theory allows the decision makers to express their assessment of contractors' performance on decision attributes in linguistic terms rather than as crisp values.

Another approach suggested by Al-Harbi (2001), Mahdi *et al.* (2002) and Topcu (2004) used Analytical Hierarchy Process methods to select contractors. Shiau *et al.* (2002) developed an sub-contractor selection management aid system. They acquired the evaluation attributes and calculated their weights by conducting surveys and using Analytical Hierarchy Process and integrated them into the system. Topcu (2004) proposed a multi-attribute decision model based on time, price and quality attributes evaluation for eligible contractor selection. Pongpeng and Liston (2003) addressed the use of a combination of utility function and social welfare function to evaluate the contractor ability when assessing tenders. Wong *et al.* (2003) explored the use of a multivariate discernment technique for developing a contractor classification model for the project specific attributes.

Mitkus and Trinkuniene (2006) analyzed three models of multi-attribute attributes systems of construction contraction agreements. They in 2007 (Mitkus and Trinkuniene 2007) proposed to use analytic hierarchical model for structural evaluation of construction contracts.

El-Sawalhi *et al.* (2007) presented a hybrid model, combining the merits of Analytical

Hierarchy Process, Neural Network and Genetic Algorithm in one consolidated unit which is able to overcome the published models limitations.

Murtoaro and Kujala (2007) pointed that the client and contractor face significant difficulties in negotiating major projects, project negotiations have not attracted much attention in the academia. The basic idea is to embrace both the buyer and seller perspectives in a single continuum of recurring negotiations, oriented around the zone of possible agreement. Kersuliene (2007) proposed an analysis model of construction process parties during dispute settlement. She stated that with the use of optimism and asymmetric information models it is possible to determine the most economically advantageous behavioral pattern for both parties.

Selection of contractor is an important issue in the field of construction management (Zagorskas and Turskis 2006; Turskis *et al.* 2006; Zavadskas and Vilutiene 2006) for the success or failure of a project is usually influenced by the quality of contractor.

Researches listed above had significantly improved the contractor selection process in the construction industry. However, some of the proposed methods and approaches could be complex and difficult to apply in practice. The construction industry needs simple but effective methods in contractor selection process due to the limited time intervals of the bidding periods. For these and many other reasons, selection of a construction contractor requires the contractor selection model that should be able to meet the critical characteristics of the pre-qualification:

- a multi-attribute problem;
- risks inherited from different decision-maker's opinion;

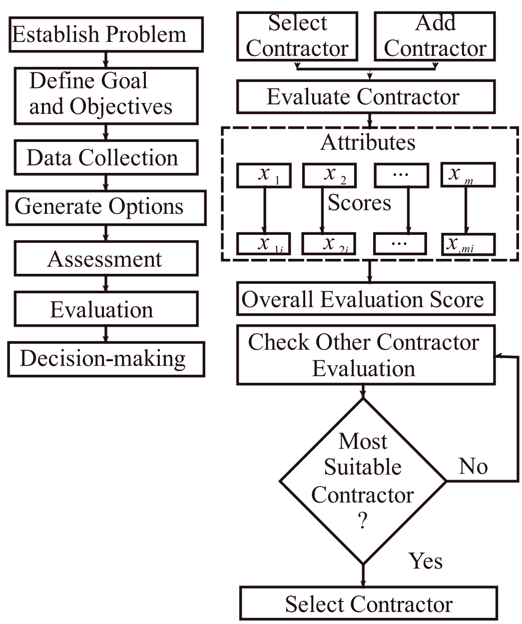

Fig. 1. Contractor's evaluating and selecting process

- noisy and uncertain date given by different contractors;
- subjective judgement made by decision-makers;
- non-linear relationships between contractor's attributes and their corresponding pre-qualification decisions;
- to deal with qualitative as well as quantitative data.

The multi-attribute contractors selection model is shown in Fig. 1.

It should be noted that the stakeholders must adjust the attributes depending on the demand of each project. The critical point is that the selected attributes should have a direct effect on performance. In addition, the selected evaluation attributes should also based on the measurement culture of the stakeholder.

3. Ordering feasible alternatives of solutions in terms of preferability

The permutation method uses Jaquet-Lagreze‘s successive permutations of all possible rankings and alternatives (Hwang and Yoon 1981). When applying this MADM method, all permutations of alternatives according to their preferability are checked and compared among themselves. This method allows dealing with qualitative and quantitative data as well as with data expressed in words (verbal defined data) and enables us to define the most appropriate ordering of alternatives. The method was developed by Paelnick (1976) and for contractor`s evaluation not used yet. With m alternatives, $m!$ Permutations are available. The algorithm of this method is given in Fig. 1 (Zavadskas *et al.* 1994).

Suppose a number of alternatives (a_i, $i = 1, 2, ..., m$) have to be evaluated according to attributes (X_j, $j = 1, 2, ..., n$). The decision-making matrix is a set up according to the form:

$$P = \begin{matrix} a_1 \\ \vdots \\ a_m \end{matrix} \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix}. \quad (1)$$

Assume that a set of attributes weights is given to the set of corresponding attributes:

$$w_j = 1, 2, \ldots, n, \ \sum_{j=1}^{n} w_j = 1. \quad (2)$$

From these m alternatives we must assign the ranks of alternatives and choose the best alternative. If we have $m = 4$ alternatives, then there exist $m! = 4\cdot3\cdot2\cdot1 = 24$ permutations:

$$\pi_{01} = a_1 \succ a_2 \succ a_3 \succ a_4;\ \pi_{02} = a_1 \succ a_2 \succ a_4 \succ a_3;\ \pi_{01} = a_1 \succ a_3 \succ a_2 \succ a_4;$$

$$\pi_{04} = a_1 \succ a_3 \succ a_4 \succ a_2;\ \pi_{05} = a_1 \succ a_4 \succ a_2 \succ a_3;\ \pi_{06} = a_1 \succ a_4 \succ a_3 \succ a_2;$$

$$\pi_{07} = a_2 \succ a_1 \succ a_3 \succ a_4;\ \pi_{08} = a_2 \succ a_1 \succ a_4 \succ a_3;\ \pi_{09} = a_2 \succ a_3 \succ a_1 \succ a_4;$$

$$\pi_{10} = a_2 \succ a_3 \succ a_4 \succ a_1;\ \pi_{11} = a_2 \succ a_4 \succ a_1 \succ a_3;\ \pi_{12} = a_2 \succ a_4 \succ a_3 \succ a_1;$$

$$\pi_{13} = a_3 \succ a_1 \succ a_2 \succ a_4;\ \pi_{14} = a_3 \succ a_1 \succ a_4 \succ a_2;\ \pi_{15} = a_3 \succ a_2 \succ a_1 \succ a_4;$$

$$\pi_{16} = a_3 \succ a_2 \succ a_4 \succ a_1;\ \pi_{17} = a_3 \succ a_4 \succ a_1 \succ a_2;\ \pi_{18} = a_3 \succ a_4 \succ a_2 \succ a_1;$$

$$\pi_{19} = a_4 \succ a_1 \succ a_2 \succ a_3;\ \pi_{20} = a_4 \succ a_1 \succ a_3 \succ a_2;\ \pi_{21} = a_4 \succ a_2 \succ a_1 \succ a_3;$$

$$\pi_{22} = a_4 \succ a_2 \succ a_3 \succ a_1;\ \pi_{23} = a_4 \succ a_3 \succ a_1 \succ a_2;\ \pi_{24} = a_4 \succ a_3 \succ a_2 \succ a_1;$$

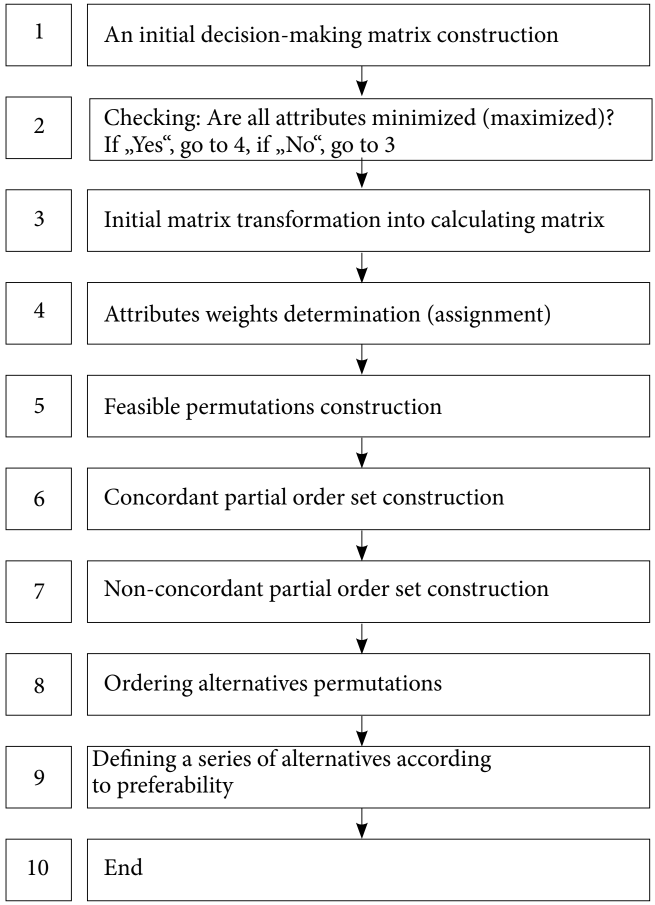

Fig. 2. Block-diagram of ordering feasible alternative solutions according to their preferability

Assume that testing order of alternatives is a

$$\pi_{14} = \{a_3, a_4, a_1, a_2\}.$$

Then we can say that the set of concordance partial order is:

$$\{a_3 \geq a_4; a_3 \geq a_1; a_3 \geq a_2; a_4 \geq a_1; a_4 \geq a_2; a_1 \geq a_2\}.$$

The set of discordance partial order is:

$$\{a_3 \leq a_4; a_3 \leq a_1; a_3 \leq a_2; a_4 \leq a_1; a_4 \leq a_2; a_1 \leq a_2\}.$$

If in ranking (permutation) of alternatives the partial ranking $a_k \succ a_l$ appears, it means that $x_{kj} \geq x_{lj}$ will be rated w_j and $x_{kh} \leq x_{lh}$ will be rated $(-w_h)$.
The ranking of alternatives $\beta_g\ (g = 1, 2, \cdots, m!)$ is carried out as described above.

Let us suppose that there is g^{th} permutation: $\pi_g = \{\cdots, a_k, \cdots, a_l, \cdots\}; g = 1, 2, \cdots, m!,$

where a_k is preferable to a_l. Then to this permutation there is given the following evaluation criterion β_g :

$$\beta_g = \sum_{k,l=1}^{m} \sum_{j \in C_{kl}} w_j - \sum_{k,l=1,k \neq l}^{m} \sum_{j \in C_{kl}} w_j; \quad (g = 1, 2, \cdots, m!), \tag{3}$$

where

$$C_{kl} = \left\{ j \mid x_{kj} \geq x_{lj} \right\}, \; k, \; l = 1, 2, \ldots, m; \; k \neq l; \; H_{kl} = \left\{ j \mid x_{kj} \prec x_{ej} \right\}, \; k, \; l = 1, 2, \ldots, m; \; k \neq l.$$

The best concordant ordering is the one, which value β_g is the largest.

Some examples illustrating the use of this method are presented in Zavadskas book (Завадскас 1991).

4. Case study

Stakeholders wishes to emphasize that construction work is open to any firm that desires construction work, provided it meets qualifying standards, actively participates in the bid process, and demonstrates high measures of performance on the job. The Informal Contracts process is designed by stakeholders to ensure that the best-qualified contractors perform construction work. This means that the contractors who have worked for many years with stakeholders will enjoy preferred bidding status so long as an active degree of bid participation and high quality of work continues. This also means that new contractors can quickly establish the same consideration for bid work as a contractor who has worked with stakeholders for many years. Conversely, the process also ensures that both "old" and "new" contractors must continue to perform well and offer reasonably priced construction services in order to maintain their invitational status. Contractors are invited to bid on individual projects, based upon parameters that include but are not limited to:

1. A history of reasonable bid price submissions.
2. A work history that indicates specialization and quality of workmanship in a particular construction skill, including the extent to which the Contractor follows project specifications and drawings provided by stakeholders.
3. Degree of participation in the stkeholders bid process, i.e. demonstrating a high degree of attendance at pre-bid meetings and submitting competitive bids when invited to bid.
4. Contractor's degree of quality control, i.e. identification and correction of deficient work or plan conflicts in a timely manner.
5. Decorum, conduct, and non-disruptiveness of contractor staff and subcontractors.
6. Cooperation with other contractors on the project and in the vicinity.
7. Degree to which Contractor is considerate of building occupants and the construction management project manager with regard to notification, scheduling, and coordination of operations that will cause noise, vibrations, dust, odours, safety concerns, and other activities that can potentially interrupt the normal conduct of business.

8. Responsiveness to warranty issues.
9. Safety consciousness on the job site.
10. Job site cleanliness during projects and upon leaving job sites.
11. Flexibility and cooperation when resolving delays
12. Ability to meet project schedule, given size of full-time staff and the ability to sub-contract quickly.
13. Work load at the time of a project solicitation.

Contractor ratings play a direct role in determining whether a contractor will be invited for construction work. Contractors rating is performed according to the following proposed attributes (Table 1): x_1 – price [mln. \$]; x_2 – time [months]; x_3 – quaranty period [years]; x_4 – qualification (experience time in construction); x_5 – relations with client; x_6 – risk (amount of works per year own), if less than f less than $x_1 \cdot 1.0$ per year – risk is very high, if is in interval $x_1 \cdot (1.0 \div 1.5)$ – risk is high, if is in interval $x_1 \cdot (1.5 \div 2.0)$ risk is above average, if is in interval $x_1 \cdot (2.0 \div 3.0)$ risk is average; if $x_1 \cdot (3.0 \div 4.0)$ risk is below average and if it is more than $x_1 \cdot 4.0$ – small risk.

Stakeholders rated contractors for performance on a project by applying permutation method.

The initial decision-making matrix have been formed according to these attributes values.

Table 1. Initial decision-making matrix

Alternatives	↔		**Attributes**	↔		
↓	x_1	x_2	x_3	x_4	x_5	x_6
Weights w →	0.29	0.23	0.19	0.1	0.05	0.14
Optimum →	*min*	*min*	*max*	*max*	*max*	*min*
a_1	1	7.5	11	11	Average	Very high
a_2	1.25	10.5	10	13	Below average	Below average
a_3	0.9	10	12	9	Above average	Average
a_4	1.1	9	11	10	Average	Below average

Table 2. Permutations and calculation process of evaluation criterion

	$\pi_1 = a_1 > a_2 > a_3 > a_4$			
	a_1	a_2	a_3	a_4
a_1	0	0.2 9+ 0.23+0.19 + 0.05 = 0.76	0.23+0.1=0.33	0.29 + 0.23 + 0.1 + 0.05 + 0.14 = 0.81
a_2	0.1+0.14=0.24	0	0.1=0.10	0.1 + 0.14 = 0.24
a_3	0.29 + 0.19 + 0.05 + 0.14 = 0.67	0.29 + 0.23 + 0.19+ 0.05 + 0.14 = 0.90	0	0.29 + 0.05 + 0.14 = 0.48
a_4	0.19 = 0.19	0.29 + 0.23 + 0.19 + 0.05 = 0.76	0.23+0.19+0.1=0.52	0
Evaluation criterion β_1		0.76 + 0.33 + 0.81 + 0.10 + 0.24 + 0.48	0.24 + 0.67 + 0.90 + 0.19+0.76+0.52	2.72 – 3.28 = –0.56

Continuation of Table 2

	$\pi_2 = a_1 > a_2 > a_4 > a_3$			
	a_1	a_2	a_4	a_3
a_1	0	0.29+0.23+0.19+ 0.05=0.76	0.29+0.23 + 0.1 + 0.05+0.14 = 0.81	0.23 + 0.1 = 0.33
a_2	0.1+0.14=0.24	0	0.1 + 0.14 = 0.24	0.1 = 0.10
a_4	0.19 = 0.19	0.29 + 0.23 + 0.19 + 0.05 + 0.14 = 0.76	0	0.23 + 0.19+ 0.1 = 0.52
a_3	0.29 + 0.19 + 0.05 + 0.14 = 0.67	0.29 + 0.23 + 0.19+ 0.05 = 0.90	0.29 + 0.05 + 0.14 = 0.48	0
Evaluation criterion β_2		0.76 + 0.33 + 0.81 + 0.33 + 0.24 + 0.10	0.24 + 0.19 + 0.76 + 0.67 + 0.90 + 0.48	2.57 – 3.24= – 0.67
...				
	$\pi_{14} = a_3 > a_1 > a_4 > a_2$			
	a_3	a_1	a_4	a_2
a_3	0	0.29 + 0.19 + 0.05 + 0.14 = 0.67	0.29 + 0.05 + 0.14 = 0.48	0.29 + 0.23 + 0.19 + 0.05 + 0.14 = 0.90
a_1	0.23+0.10=0.33	0	0.29 + 0.23 + 0.10 + 0.05 = 0.67	0.29 + 0.23 + 0.19+ 0.05 = 0.76
a_4	0.23+0.19+0.10=0.52	0.19 + 0.14 = 0.33	0	0.29 + 0.23 + 0.19+ 0.05 = 0.76
a_2	0.10=0.10	0.10 + 0.14 = 0.24	0.10 + 0.14 = 0.24	0
Evaluation criterion β_{14}		0.67 + 0.48 + 0.90+ 0.67 + 0.76 + 0.76	0.33 + 0.52 + 0.33 + 0.10 + 0.24 + 0.24	4.24 – 1.76= 2.48
...				
Italic font - concordance values			Regular font - non-concordance values	
...				
	$\pi_{24} = a_4 > a_3 > a_2 > a_1$			
	a_4	a_3	a_2	a_1
a_4	0	0.23 + 0.19 + 0.10=0.52	0.29 + 0.23 + 0.19 + 0.05 = 0.76	0.19 + 0.14 = 0.33
a_3	0.29+0.05+0.14=0.48	0	0.29 + 0.23 + 0.19 + 0.05 + 0.14 = 0.90	0.29 + 0.19 + 0.05+ 0.14 = 0.67
a_2	0.10+0.14=0.24	0.10=0.10	0	0.10+0.14=0.24
a1	0.29 + 0.23 + 0.10 + 0.05 = 0.67	0.23 + 0.10 = 0.33	0.29 + 0.23 + 0.19 + 0.05 = 0.76	0
Evaluation criterion β_{24}		0.52 + 0.76 +0.33+ 0.90 + 0.67 + 0.24	0.48 + 0.24 + 0.10 + 0.67 + 0.33 + 0.76	3.42 – 2.58 = 0.84
Italic font – concordance values			Regular font – non-concordance values	

Table 3. Summary of calculation results

	Permutation	Concordance	Non-concordance	βg	βg
1	$\pi_{01} = a_1 \succ a_2 \succ a_3 \succ a_4$;	0.76+0.33+0.81+ 0.10+0.24+0.48=2.72	0.24+0.67+0.90+ 0.19+0.76+0.52=3.28	2.72 – 3.28 = –0.56	15
2	$\pi_{02} = a_1 \succ a_2 \succ a_4 \succ a_3$;	0.76+0.33+0.81+ 0.33+0.24+0.10=2.57	0.24+0.19+0.76+ 0.67+0.90+0.48=3.24	2.57 – 3.24 = –0.67	16
3	$\pi_{01} = a_1 \succ a_2 \succ a_3 \succ a_4$;	0.33+0.76+0.67+ 0.90+0.48+0.24=3.38	0.67+0.24+0.10+ 0.33+0.52+0.76=2.62	3.38 – 2.62 = 0.76	8
4	$\pi_{04} = a_1 \succ a_3 \succ a_4 \succ a_2$;	0.33+0.76+0.67+ 0.90+0.48+0.24=3.38	0.67+0.24+0.10+ 0.33+0.52+0.76=2.62	3.38 – 2.62 = 0.76	9
5	$\pi_{05} = a_1 \succ a_4 \succ a_2 \succ a_3$;	0.67+0.76+0.33+ 0.76+0.52+0.10=3.14	0.33+0.24+0.24+ 0.67+0.48+0.90=2.86	3.14 – 2.86 = 0.28	12
6	$\pi_{06} = a_1 \succ a_4 \succ a_3 \succ a_2$;	0.67+0.33+0.76+ 0.52+0.90+0.90=4.08	0.33+0.67+0.48+ 0.24+0.10+0.10=1.92	4.08 – 1.92 = 2.16	3
7	$\pi_{07} = a_2 \succ a_1 \succ a_3 \succ a_4$;	0.24+0.10+0.24+ 0.33+0.67+0.48=2.06	0.76+0.90+0.67+ 0.76+0.33+0.52=3.94	2.06 – 3.94 = –1.88	21
8	$\pi_{08} = a_2 \succ a_1 \succ a_4 \succ a_3$;	0.24+0.24+0.10+ 0.67+0.33+0.52	0.86+0.86+0.33+ 0.90+0.67+0.48	2.10 – 4.10 = –2.00	23
9	$\pi_{09} = a_2 \succ a_3 \succ a_1 \succ a_4$;	0.10+0.24+0.24+ 0.67+0.48+0.67=2.40	0.90+0.76+0.33+ 0.76+0.52+0.33=3.60	2.40 – 3.60 = –1.20	18
10	$\pi_{10} = a_2 \succ a_3 \succ a_4 \succ a_1$;	0.10+0.24+0.24+ 0.48+0.67+0.33=2.06	0.90+0.76+0.52+ 0.76+0.33+0.67=3.94	2.06 – 3.94 = –1.88	22
11	$\pi_{11} = a_2 \succ a_4 \succ a_1 \succ a_3$;	0.24+0.24+0.10+ 0.33+0.52+0.33=1.76	0.76+0.76+0.67+ 0.90+0.48+0.67=4.24	1.76 – 4.24 = –2.48	24
12	$\pi_{12} = a_2 \succ a_4 \succ a_3 \succ a_1$;	0.24+0.10+0.24+ 0.52+0.33+0.67=2.10	0.76+0.90+0.48+ 0.76+0.67+0.33=3.90	2.10 – 3.90 = –1.80	20
13	$\pi_{13} = a_3 \succ a_1 \succ a_2 \succ a_4$;	0.67+0.90+0.48+ 0.76+0.67+0.24=3.72	0.33+0.10+0.24+ 0.52+0.33+0.76=2.28	3.72 – 2.28 = 1.44	5
14	$\pi_{14} = a_3 \succ a_1 \succ a_4 \succ a_2$;	0.67+0.48+0.90+ 0.67+0.76+0.76=4.24	0.33+0.52+0.33+ 0.10+0.24+0.24=1.76	4.24 – 1.76 = 2.48	1
15	$\pi_{15} = a_3 \succ a_2 \succ a_1 \succ a_4$;	0.90+0.67+0.48+ 0.24+0.24+0.67=3.20	0.10+0.33+0.76+ 0.52+0.76+0.33=2.80	3.20 – 2.80 = 0.40	11
16	$\pi_{16} = a_3 \succ a_2 \succ a_4 \succ a_1$;	0.90+0.48+0.67+ 0.24+0.24+0.33=2.86	0.10+0.52+0.76+ 0.33+0.76+0.67=3.14	2.86 – 3.14 = –0.28	13
17	$\pi_{17} = a_3 \succ a_4 \succ a_1 \succ a_2$;	0.48+0.67+0.90+ 0.62+0.76+0.76=4.19	0.52+0.33+0.38+ 0.10+0.24+0.24=1.81	4.19 – 1.81 = 2.38	2
18	$\pi_{18} = a_3 \succ a_4 \succ a_2 \succ a_1$;	0.48+0.90+0.67+ 0.76+0.33+0.24=3.38	0.52+0.10+0.24+ 0.33+0.67+0.76=2.62	3.38 – 2.62 = 0.76	10
19	$\pi_{19} = a_4 \succ a_1 \succ a_2 \succ a_3$;	0.33+0.76+0.52+ 0.76+0.33+0.10=2.80	0.67+0.24+0.24+ 0.48+0.67+0.90=3.20	2.80 – 3.20 = –0.40	14
20	$\pi_{20} = a_4 \succ a_1 \succ a_3 \succ a_2$;	0.33+0.52+0.76+ 0.33+0.76+0.90=3.60	0.67+0.48+0.67+ 0.24+0.24+0.10=2.40	3.60 – 2.40 = 1.20	6
21	$\pi_{21} = a_4 \succ a_2 \succ a_1 \succ a_3$;	0.76+0.33+0.52+ 0.24+0.10+0.33=2.28	0.24+0.67+0.76+ 0.48+0.90+0.67=3.72	2.28 – 3.72 = –1.44	19
22	$\pi_{22} = a_4 \succ a_2 \succ a_3 \succ a_1$;	0.76+0.52+0.33+ 0.10+0.24+0.67=2.62	0.24+0.48+0.90+ 0.67+0.76+0.33=3.38	2.62 – 3.38 = –0.76	17
23	$\pi_{23} = a_4 \succ a_3 \succ a_1 \succ a_2$;	0.52+0.33+0.76+ 0.67+0.90+0.76=3.94	0.48+0.67+0.33+ 0.24+0.10+0.24=2.06	3.94 – 2.06 = 1.88	4
24	$\pi_{24} = a_4 \succ a_3 \succ a_2 \succ a_1$;	0.52+0.76+0.33+ 0.90+0.67+0.24=3.42	0.48+0.24+0.10+ 0.67+0.33+0.76=2.58	3.42 – 2.58 = 0.84	7

The weights $\boldsymbol{w_i}$ of attributes, presented in Table 1, were determined by application of the expert judgment method proposed by Kendall (Kendall 1970; Turskis *et al.* 2006).

The calculation process shortly is presented in Table 2.

According to the results of Table 3, we can find the priority of considered alternatives $a_3 \succ a_1 \succ a_4 \succ a_2$ (permutation π_{14}). The best alternative (third contractor) was selected.

5. Conclusions

Making decisions play an important role in the construction management, such as investment, contractor or subcontractor selection, construction technique alternative evaluation and human resource arrangement.

The overall benefit of selecting the most suitable contractor can be an improvement of the stakeholders overall performance. Choosing the right contractor for the right job influences the work quality as well as the construction progress. Especially during the bidding process optimum selection of contractors is vital for an accurate and realistic bid proposal.

Traditional selection of contractors, such as choosing those with whom the stakeholder had already done business, can lead to inefficiencies in projects and poor project performance.

The proposed model is based on multi-attribute evaluation of potential contractors, the determination of their ranks by taking into account the results obtained in the applied multi-attribute analysis. Following the suggested model, the evaluation attributes are selected by taking into consideration the objectives and interests of the stakeholders.

As construction projects and contract works become more complex, a combined assessment of various attributes should be considered by the stakeholders in order to select the most suitable one.

The model presented in this research is a feasible tool to aid in decision-making for contractor pre-qualification. This model can help improve the selection process and obtain the best decision on selecting a contractor.

The application of the model offered in this paper may reduce the risk involved in the selection of a contractor and can lead to the elimination of unqualified contractors during the bidding process.

It should be noted that the stakeholders must adjust the attributes depending on the demand of each project. The critical point is that the selected attributes should have a direct effect on performance.

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DAUGIATIKSLIS RANGOVŲ PARINKIMO METODAS TAIKANT ĮMANOMŲ SPRENDINIŲ ALTERNATYVŲ RANGAVIMO PRIORITETO POŽIŪRIU BŪDĄ

Z. Turskis

Santrauka

Rangovų vertinimas – gyvybiškai svarbi projekto vadybos ciklo dalis, susijusi su rizika ir rizikos valdymu. Viena svarbiausių projekto įgyvendinimo dalių – kainos nustatymas konkurso tvarka. Investuotojai siekia pasirinkti geriausiai jų tikslus atitinkantį rangovą, realiausią ir tiksliausią kainos pasiūlymą. Tam reikia turėti išsamios informacijos apie finansinę rangovo būklę, techninį pasirengimą ir kvalifikaciją. Straipsnyje aprašomas daugiatikslis rangovų parinkimas taikant įmanomų sprendinių alternatyvų rangavimo prioriteto požiūriu metodą. Šio būdo sprendimų priėmimo matricos informacija gali būti aprašoma kokybiniais, kiekybiniais ir verbaliniais (žodžiais reiškiamais) duomenimis. Pateiktas straipsnio pabaigoje rangovų parinkimo pavyzdys parodo šio modelio taikymo tikslingumą ir praktiškumą.

Reikšminiai žodžiai: statyba, rangovas, daugiatikslis vertinimas, išankstinis kvalifikacijos nustatymas, sprendimų priėmimas, perstatymų metodas.

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