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MODELING OF CONTRACTOR SELECTION TAKING INTO ACCOUNT DIFFERENT RISK LEVEL

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ABSTRACT

This paper presents contractors' assessment and selection based on the multi-attribute methods in a competitive and risky environment. The model is based on a multi-attributes evaluation of contractors, the determination of their optimality criterion values calculated according to Hodges-Lehman rule. The proposed model could further be applied to construction operations. The attributes of contractor evaluation are selected by taking into consideration the interests and goals of the stakeholders as well as factors that influence the process of construction efficiency. The model is based on metric scores. A background and a description of the proposed model are provided and a few key findings from the data analyses are presented.

KEYWORDS

Attributes, contractor, risk level, Hodges-Lehmann rule

1. INRODUCTION

The efficiency of a construction process is often associated with the successful choice of a contractor. Various procedures for a contractor's selection are applied in practice. A single attribute cannot give a full expression of a goals purposed by various stakeholders. Choice of a contractor was analysed by following authors: Skitmore, Olson and other [1-5]. The importance of non-price factors is well recognised in the literature. Various scientists offer different models for a contractor's evaluation. Multiple attributes decision aid provides several powerful and effective tools [6-17] for confronting sorting problems.

In Turkey, a two-stage procedure is used, but at the end, the lowest price determines the selection [18]. In Lithuania, the ''lowest bidder'' is selected as in Canada and the USA. Hence, it may be concluded that price attribute is decisive in contractor selection. Lately the ''lowest bid'' selection practice has been criticized because it involves high-risk exposure of the client. The selection based on the low price basis can be one of the reasons for project completion delays, poor quality and/or financial losses, etc. [4]. Topcu [18] states, that in seeking to minimize risk, the pre-qualification procedure is often chosen. Topcu [18] proposed a multi-attributes decision model based on time, price and quality attributes evaluation for eligible contractor selection. To set the proper contractor evaluation attributes, Hatush and Skitmore [4] suggested determining the client's needs and aims of a particular project. The proposed attributes involve price, time, quality parameters, uncertainty level, flexibility to make changes, the allocation of risks and the ability of a contractor to cope with the level of complexity that are involved. Hatush and Skitmore [19] proposed the application of the multi-attributes utility theory for contractor selection. By applying an additive model, they compared four contractors against different attributes.

2. METHODOLOGY

The problems of selection of rational construction variants are solved under various conditions, which are characterised by efficiency attributes [16, 17, 20, 21]. The attributes for each of the variants being compared (projects, strategies, alternatives) are calculated or set by means of experiments, upon assessing environmental conditions, these attributes are characterised by the information available. Decisions may be made under totally definite conditions (for a determined problem), upon evaluating one or several efficiency attributes.

Every problem to be solved is represented by a matrix, which contains variants (rows) and attributes (columns). The variants represent a set of situations for a problem that really exists. All variants considered are evaluated using the same attributes. The evaluation results are put in a matrix x_{ij}, $i=\overline{1,m}$, $j=\overline{1,n}$. Usually the attributes have different dimensions. That is why their effectiveness cannot be compared directly. An exception is the application of evaluation numbers without any dimensions according to a points system. This, however, involves subjective influences to a great extent. Hence, it should only be used in exceptional cases. In order to avoid the difficulties due to different dimensions of the attributes, the ratio of the optimal value is used. In this way the discrepancy between different dimensions of optimal values is also eliminated. There are various theories about the ratio of the optimal value. Note that the decision for a theory may affect the solution. However, the values are mapped either on the interval [0; 1] or on the interval [0, infinity) by the transformation. Only those well-known theories of transformation are used that are appropriate for both problems of maximisation and minimisation.

The linear normalization uses a scale of the existing values [22]. The calculated values are dependent on the size of the interval and thus change if the interval is altered.

$$\overline{x_{ij}} = \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}, \text{ when } \max x_j \text{ is optimal} \quad (1)$$

$$\overline{x_{ij}} = \frac{\max_j x_{ij} - x_{ij}}{\max_j x_{ij} - \min_j x_{ij}}, \text{ when } \min x_j \text{ is optimal} \quad (2)$$

The calculation of the relative deviation is a well performing linear transformation. Hodges-Lehmann rule. With this rule [23] confidence in the knowledge of the probabilities of the strategies of the opponent can be expressed by the parameter λ:

$$K_i = \lambda \sum_{j=1}^{n} q_i x_{ij} + (1-\lambda) \min_j \overline{x_{ij}} \quad (3)$$

K_i – optimality criterion. λ – the factor assess risk; q_i – attribute weight.

$$K_{opt} = \max_i K_i \quad (4)$$

K_{opt} – optimal alternative. $\lambda = 0$ (no confidence) gives the solution according to Wald's rule. $\lambda = 1$

(great confidence) gives the solution according to Bayes's rule.

3. MODEL OFF THE CONTRACTOR SELECTION

The model is described by discrete values of construction: construction time, quality of performed projects, bid estimates, communication level with stakeholders, and capacity influence based on the risks and uncertainties of different stakeholder sector. The model is presented in the Fig.1. The subject of investigation is 9 floor administration and business complex building in Vilnius city. Each contractor is described by 8 attributes. Attributes and their weights were determined on the basis of performed questionnaires (see Table 1). The attributes of contractor selection are as follows: x_1 - ***bid estimates [million €].*** For the contractor, a bid estimate submitted to the stakeholder either for competitive bidding or negotiation consists of direct construction cost including field supervision, plus a mark-up to cover general overhead and profits. The direct cost of construction for bid estimates is usually derived from a combination of the following approaches.

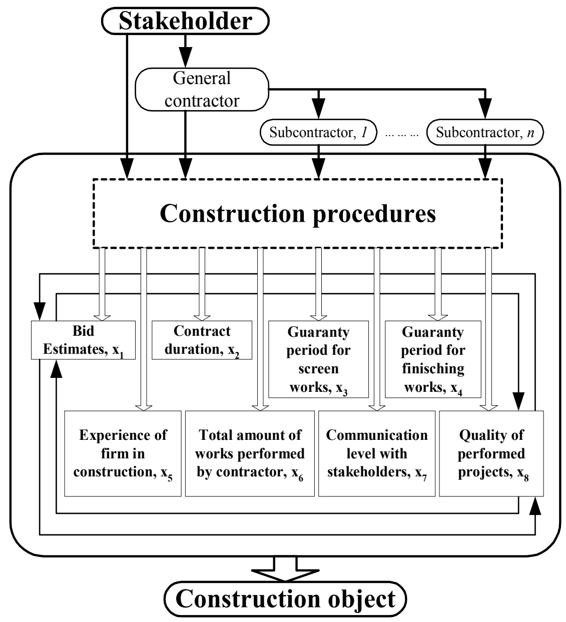

Figure 1. The model of the selection of contractors in construction

Subcontractor quotations

Quantity takeoffs

Construction procedures

x_2 - ***construction duration [months].*** Most contracts are quite specific regarding the amount of construction time allowed to complete the work, and many provide for the payment of "liquidated damages" by the contractor to the owner for failure to complete on time or, in some cases, to complete portions of the work that interface with other contract schedules where multiple prime contracts have been executed.

The work covered in a construction contract includes a stated guarantee period. The contractors according to valid regulations and rules must to give construction works guaranty: x_3 - ***guaranty period for screen works [year],*** must be not less than 10 years, x_4 - ***guaranty period for finishing works [year]-*** must be not less than 5 years. The contractor is responsible for the quality workmanship, the quality of the materials used, and for performance of the contract only. x_5 - ***experience of firm in construction [year].*** This attribute assess contractors activity in construction sector. x_6 - ***total amount of works performed by contractor [rate],*** the contractor must at the few, like the fifty percent work fill theirs intensity. x_7 - ***communication level with stakeholders [point],*** is very important all construction period and after finishing construction work. x_8 - ***quality of performed projects [point].*** The algorithm for the ranking of alternatives using Hodges-Lehman rule is presented in the Fig. 2.

In order to establish the importance indicators, a survey has been carried out and 20 experts have been questioned. These experts, basing their answers on their knowledge, experience and intuition, had to rate indicators 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 importance of indicators was established according to the rating methods [7] of these experts and also demonstrated the priorities of the user (stakeholder).

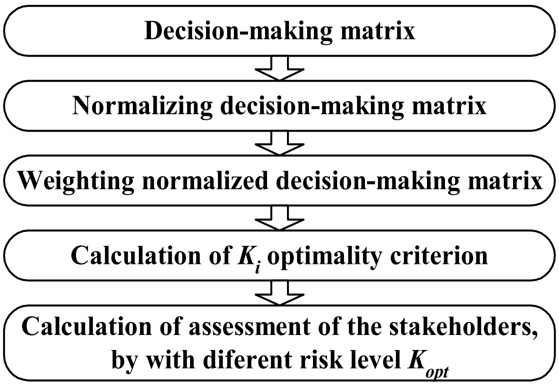

Figure 2. Ranking of alternatives using Hodges-Lehman rule

If scrutinize initial decision-making matrix we can found that no one alternative have all optimal attributes values. The best price is in alternative 6, the shortest construction duration is in alternative 9, and so on.

The results of the calculation are presented in the Table 2 and Fig 3. According to the solution results it is clear, that according all risk level the best alternative is 10th alternative. Exception is risk level 0.333. In this case the best alternative is 9th alternative. The second alternative almost in all cases of risk is 9th alternative. There are two exceptions. The second alternative is 4th alternative at risk levels 0.000 and 0.333.

The best 10th alternative were selected according to the calculated optimality criterion values at different risk level.

Table 1. Initial decision-making matrix with values

Alternative	Attributes							
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8
	min	*min*	*max*	*max*	*max*	*max*	*max*	*max*
Attribute weight – q_j	0.18	0.14	0.12	0.09	0.14	0.09	0.10	0.14
A_1	5.00	26	10	5	13	0.74	8.00	9.01
A_2	5.54	23	10	10	13	0.61	7.21	9.24
A_3	4.63	30	10	2	13	0.55	8.51	8.38
A_4	5.56	22	15	10	18	0.71	9.22	8.15
A_5	5.14	24	15	2	57	0.77	7.32	8.08
A_6	4.99	28	10	5	48	0.79	8.48	7.51
A_7	4.57	29	10	2	15	0.65	7.21	7.84
A_8	5.15	27	15	5	13	0.72	7.72	7.35
A_9	5.25	19	10	5	50	0.85	8.50	8.61
A_{10}	5.31	25	10	10	56	0.72	7.36	8.45

Table 2. Optimality attributes values of optimality criterion K_i at different risk level

Alternative	λ							
	0.000	0.167	0.333	0.500	0.667	0.833	1.000	
A_1	5.753	4.913	4.087	3.239	2.400	4.913	5.753	
A_2	6.045	5.161	4.257	3.397	2.513	5.161	6.045	
A_3	5.192	4.438	3.737	2.933	2.178	4.438	5.192	
A_4	6.719	5.734	4.758	3.770	2.785	5.734	6.719	
A_5	6.455	5.516	4.569	3.644	2.705	5.516	6.455	

Alternative	λ							
	0.000	0.167	0.333	0.500	0.667	0.833	1.000	
A_6	6.265	5.351	4.403	3.529	2.615	5.351	6.265	
A_7	5.180	4.427	3.697	2.926	2.173	4.427	5.180	
A_8	5.799	4.952	4.153	3.263	2.416	4.952	5.799	
A_9	6.768	5.781	4.798	3.813	2.825	5.781	6.768	
A_{10}	6.830	5.831	4.555	3.841	2.843	5.831	6.830	

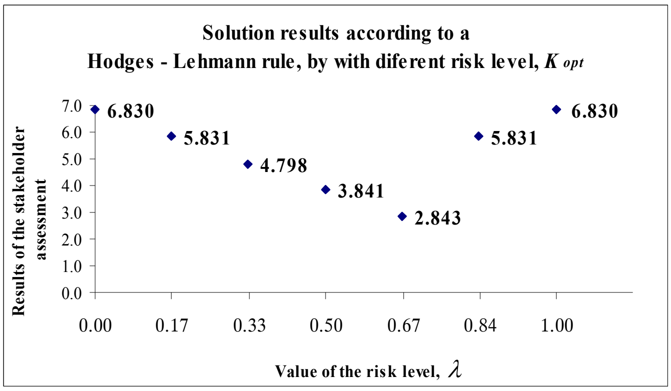

Figure 3. Solution results to a Hodges-Lehman rule, by different risk level

4. CONCLUSION

A contractors' assessment and selection always deals with risk and single attribute- price can be used in certain cases only.

In competitive and risky environment contractors selection must be performed according to multiple attributes.

The selection of contractor can be in different risk level. Hodges-Lehman rule allows stakeholders to select contractor taking into account different risk level.

Knowing risk level stakeholders can effectively to mange risk.

This model can be applied to select alternatives in construction under risky environment.

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