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SELECTED ASPECTS OF CONSTRUCTION PROJECTS SELECTION INCLUDING RISK ESTIMATION

WYBRANE ASPEKTY SELEKCJI PRZEDSIĘWZIĘĆ BUDOWLANYCH Z UWZGLĘDNIENIEM OCENY RYZYKA

A b s t r a c t

The complexity and need for a comprehensive approach to construction projects programming helps in researching the different methods of the risk estimation for construction projects. The risk estimation, carried out at the planning stage, not only enables rational investment but also the rational project management during construction. The paper concentrates on the possibility of applying the multi-criteria analysis for the selection of construction projects taking the risks into account.

Keywords: risk assessment, selection of construction project, multi-criteria analysis

S t r e s z c z e n i e

Złożoność i konieczność kompleksowego podejścia do programowania inwestycji budowlanych sprzyja poszukiwaniu różnych metod oceny ryzyka przedsięwzięć budowlanych. Przeprowadzona na etapie planowania ocena ryzyka pozwala nie tylko na racjonalne inwestowanie ale także na racjonalne zarządzanie przedsięwzięciem w trakcie realizacji. W artykule skupiono uwagę na możliwości wykorzystania analizy wielokryterialnej do selekcji przedsięwzięć przy uwzględnieniu ryzyka.

Słowa kluczowe: ocena ryzyka, selekcja projektów, analiza wielokryterialna

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1. Introduction

The assertion of adequate procedures, which facilitate the decision-making process during the construction project planning stage, allows for in depth, multi-criteria analysis of some alternative construction organization methods. The elaborated procedures also provide additional information, which help when choosing a particular solution. The primary goal of construction project selection (or some alternative methods of construction) is their estimation according to the assumed selection criteria and the rank of variants from the best to the worst (the variant with the highest risk level which is associated with its construction). This estimate should be fully comprehensive in character and specify the full scope of construction work. Many of the variables are universal and could be used to analyze any construction project. However, it is important to consider some additional requirements resulting from, among others, the application of modern technologies/construction methods as well as innovative designing solutions. Therefore, this analysis should be based on both the quantitative and qualitative criteria.

The main goal of the authors of this paper is to discuss the problem of variant selection for the project and to present a procedure to facilitate the decision-making process in this field as well as distinguish the factors affecting the final analysis result. The paper does not fully discuss the problem and is simply a contribution to the further consideration.

2. Selection methods of construction projects

Multi-criteria decision-making methods are the most often used for the selection of construction projects. These methods are applied in various kinds of industries and fields of science due to the possibility of examining the problem of multi-aspect selection taking quantitative and qualitative factors, which reflect the requirements of a decision maker into account. The number of references [1–26], concerning solutions to the problem prove their popularity, this being applying a specific tool for project selection combined with risk assessment. These methods accurately reflect the character of the phenomenon (which is their another advantage). There is, however, doubt concerning their poor ability to indicate the correct forecast values. It is therefore due to this fact that there is considerable subjectivity in determining the weights and connecting these with the preferences and variants in the calculation process. The results obtained, however, only provide a rough estimation of the preliminary ranking of the project, due to the individual approach of the decision-maker when solving a problem, which may contain a prediction error. The mentioned defects do not, however, diminish the importance of multi-criteria methods in the optimal variant selection process. Due to the fact that these methods only provide approximate results, the qualitative variables must be used more and more often to describe the reality. The different multi-criteria methods (such as: Promethee, Elektra, AHP, Copras-G, etc. or the fuzzy sets) do, however,allow for qualitative variables to be taken into account during the decision-making process. A review of the available methods and the scopes of their use can be found in the following papers [1–3, 5, 7–11, 14, 15, 17–19, 21–26]. However, it is difficult to estimate the impact degree of error on the final results due to the subjectivity of estimations. It can be assumed that these estimations are acceptable and at the same time they provide some additional evidence in order to make a “rational” decision.

In the case of the factors noted in measurable units, an estimation according to the criterion seems obvious. However, for qualitative factors, the numerical scale of measurement should be assumed. Both selection methods are widely used as well as their modifications [8, 19]. The authors of this paper applied two of them, focusing on characteristic features, basic assumptions as well as the quality of the results obtained.

3. Estimation and sensitivity of selection results

3.1. Selection criteria and procedure of construction projects selection

Construction project variant solutions and the specifying criteria by which they will be estimated ensure their mutual comparison at the primary selection stage. In the case of the selection of construction projects, this is typically emphasized during the financial analysis of the planned construction project [9]. However, in the selection of the final variant it is not only the financial aspect which is important. During the analysis, such factors as: the profit from an investment, internal rate of return, payback period, costs of construction project realization, cost of preparing construction project for realization, cost of building, possibilities of rebuilding and changing the function of building use, possibility of staging of construction and assembling work, degree of building facility complexity, optimization of supplies, legal/law requirements, etc. Building materials and construction methods in the context of the sustainable development (affecting the costs during building facility use) should also be taken into account at the planning stage of a construction project [6]. The authors have focused on multi-criteria methods, because they allow for selection procedures, both the quantitative (i.e. a profit or the rate of return) and qualitative factors (e.g. attractiveness degree of building facility location) to be taken into account. The non-measurable factors have an influence on the decision-making process and allow the problem to be examined in the multi-dimensional way. The assumption of an appropriate scale depends on a decision maker. The scale will enable the further analysis of variants based on the all variables (both the measurable variables and the un-measurable variables).

In the example presented, the authors have focused on the selection of construction projects in terms of the risk estimation, which is connected with realization of a particular construction project. Three separate construction projects have been examined. The construction company, besides the expected benefits (i.e. profit), must also be prepared to incur the costs of production (labor costs, building materials costs, equipment costs) and some additional costs resulting from the occurrence of factors, which can confound the smooth run of the construction.

The primary risks include:

1. **Economic/finance risk**: delay of payments, increase of building materials prices, failures in estimation of production costs;
2. **Contract risk**: not precise notes in a contract, lack of experience of management staff;
3. **Technical risk**: high level of construction project complexity, unknown technology/construction methods (modern solutions that require specialized knowledge), mistakes in project design, a change in the foundation method – the need to replace the soil, collisions of external piping system, replacement of piping);

4. Organizational risk: lack of availability of building materials, limited/small construction site (the problem with the location of social facilities), short construction time due to the investor's requirements, delays in delivery of a project design.

The choice of a proper method of the construction projects selection is not without significance. Each of the applied multi-criteria methods have a different methodology of calculation, some different initial assumptions as well as the information potential of the results obtained. In the article, the authors have applied two approaches to the multi-criteria analysis: AHP and Copras-G. The feature that distinguish these techniques is the method of reaching the final ranking of a construction project in the terms of examined, potential risk.

3.2. Analytical Hierarchy Process

The AHP (Analytical Hierarchy Process) method was developed by T.L. Saaty [15]. The author of the AHP method introduced a 9-point scale (where 1 indicates the equivalence of two variants and 9 indicates the absolute advantage of one variant over the second variant) for the mutual comparison in pairs of the variants examined. For facilitation of the calculation, the examined pairs are listed in the matrix, comparing elements successively from the first column with the elements from the top row. The end result of the analysis is a calculation of the vector of the variants ranking applying the method of the maximum specific value of a matrix. The AHP method is widely used, not only for the selection of projects, but also in the form of the Analytical Network Process (ANP), taking the feedback couplings between the particular groups and the relationship between the criteria, sub-criteria and the examined alternatives into account. The author of the paper [15] also proposed the division of criteria with regard to their character and the regard in the criteria selection procedure, which are opposite to the other criteria. The criteria are ranked in 4 groups: benefits (B), opportunities (O), costs (C) and risk (R). Instead, each of these groups is corresponded a rank according to the AHP idea. There are three methods of aggregation of the obtained results B, O, C, R with the corresponding, normalized weights b, o, c, r, i.e.:

- bB + oO + c(1/C) + r(1/R),
- bB + oO + c(1 – C) + r(1 – R),
- bB + oO – cC – rR.

The fourth possibility – the ratio BO/CR does not include the standardized weights b, o, c, r.

3.3. Copras-G

The procedure of the Copras-G method is based on the elaboration of the decision matrix, where for each pair of comparison of projects are assigned two values – the upper limit and the lower limit. Then, the weight for each attribute should be specified. The next step leads to normalization of the values in the matrix and estimation of the sum of the attributes values depending on their character (i.e. maximization – P_j or minimization – R_j). The final estimation of the analysis determines, for each variant, the relative weight of Q_j and their mutual alignment using the utility degree N_j. It is worth mentioning that this method refers to the so called "Grey System Theory", in a broader sense it has been presented in the references [24–26].

4. Analysis of variants and sensitivity of selection results

Due to the scope of the paper as well as a large number of available methods and techniques, the authors focused on only two methods, taking into account clarity and quality of the results obtained.

Table 1

Summary of data for the risk

	Selection criteria for risk	Weight of criterion	Weight of standardized criterion	Basic matrix: Construction Project A		Basic matrix: Construction Project B		Basic matrix: Construction Project C		Normalized matrix: Construction Project A		Normalized matrix: Construction Project B		Normalized matrix: Construction Project C	
				D	G	D	G	D	G	D	G	D	G	D	G
Technical risk	*R*1 – high level of construction project complexity	0.486	0.162	3	9	3	9	8	9	0.007	0.021	0.007	0.020	0.020	0.022
	*R*2 – unknown technology/construction methods	0.329	0.110	3	9	3	8	8	9	0.005	0.014	0.004	0.012	0.013	0.015
	*R*3 – change in the foundation method	0.102	0.034	8	9	5	6	2	8	0.004	0.004	0.002	0.003	0.001	0.004
	*R*4 – replacement of piping	0.083	0.028	6	7	6	7	3	6	0.002	0.003	0.002	0.003	0.001	0.003
Organizational risk	*R*5 – lack of availability of building materials	0.143	0.048	7	8	8	9	3	8	0.005	0.005	0.005	0.006	0.002	0.006
	*R*6 – limited/small construction site	0.163	0.054	8	9	3	4	1	5	0.006	0.007	0.002	0.003	0.001	0.004
	*R*7 – short construction time due to the investor's requirements	0.273	0.091	1	3	4	8	3	7	0.001	0.004	0.005	0.010	0.004	0.010
	*R*8 – delays in delivery of a project design	0.422	0.141	1	8	6	9	7	9	0.002	0.016	0.011	0.017	0.015	0.019
Other risk	*R*9 – failures in estimation of production costs	0.313	0.104	2	4	6	9	7	9	0.003	0.006	0.008	0.013	0.011	0.014
	*R*10 – delay of payments	0.198	0.066	8	9	6	9	2	5	0.008	0.008	0.005	0.008	0.002	0.005
	*R*11– lack of experience of management staff	0.211	0.070	7	8	3	8	2	3	0.007	0.008	0.003	0.008	0.002	0.003
	*R*12 – increase of building materials prices	0.278	0.093	1	2	2	7	2	4	0.001	0.003	0.003	0.009	0.003	0.006
Arrangement of construction projects									*Qj*	0.0753		0.0840		0.0943	
									Nj	80%		89.14%		100.00%	

Table 2

Summary of data for the benefit

				Construction Project A		Construction Project B		Construction Project C		Construction Project A		Construction Project B		Construction Project C	
	Selection criteria for benefit	Weight of criterion	Weight of standardized criterion	Basic matrix						Normalized matrix					
				D	G	D	G	D	G	D	G	D	G	D	G
Benefits	*K*1 – profit from investment	0.377	0.377	5	7	3	6	4	7	0.051	0.072	0.042	0.084	0.061	0.107
	*K*2 – rate of return	0.321	0.321	3	5	3	5	3	7	0.032	0.054	0.044	0.073	0.048	0.112
	*K*3 – possibility of staging of construction and assembling work	0.132	0.132	5	9	2	4	3	5	0.022	0.040	0.012	0.024	0.020	0.033
	*K*4 – degree of use of construction site area	0.145	0.145	3	9	3	6	1	3	0.015	0.044	0.020	0.040	0.007	0.022
	*K*5 – prestige of investment	0.025	0.025	5	9	5	7	2	5	0.016	0.029	0.022	0.030	0.010	0.024
Arrangement of construction projects								*Qj*		0.186		0.195		0.222	
								Nj		83.78%		87.64%		100%	

Table 3

Summary of data for the results

	Scenario								
	9/1	**7/1**	**5/1**	**3/1**	**1/1**	**1/3**	**1/5**	**1/7**	**1/9**
Benefits	0.900	0.875	0.833	0.750	0.500	0.250	0.167	0.125	0.100
Risk	0.100	0.125	0.167	0.250	0.500	0.750	0.833	0.875	0.900
Construction Project A	0.260	0.278	0.309	0.371	0.555	0.740	0.801	0.832	0.851
Construction Project B	0.267	0.285	0.315	0.375	0.555	0.736	0.796	0.826	0.844
Construction Project C	0.291	0.308	0.336	0.393	0.564	0.735	0.792	0.820	0.837

5. Conclusions

This method is popular for supporting the decision-making process, which is influenced by many factors, among others, the degree of complexity of calculations, the quality of results obtained and the possibility of their implementation. In the scope of selection of construction projects, the authors mainly focused on the multi-criteria, decision, supporting methods. These methods essentially allowed the procedure and character of the two criterion to be taken into account: the qualitative criteria and the quantitative criteria. Despite drawbacks (related to the estimation subjectivity and the given approximate values) the authors (taking the simplicity criterion of the calculation and simplicity of interpretation of the results into account) have not found a better alternative method for the selection of construction projects.

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