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FUZZY MULTI–CRITERIA MODEL FOR CONSTRUCTION PROJECT SELECTION IN CONDITIONS OF UNCERTAINTY

Abstract. The article examines the task of construction project selection. The existing methods of selecting construction projects are studied and a list of criteria that can influence the choice of a construction project is given. The experience has shown that the more reliable the methods of construction project evaluation are the greater the reliability of technological, organizational, managerial and economic solutions. A review of relevant literature shows that there is a limited number of studies to select projects in the construction industry. The article demonstrates a systematic procedure of preliminary evaluation based on fuzzy sets theory.

Keywords: construction project selection, uncertainty, multi-criteria optimization, pre-investment phase, construction industry, criteria analysis.

Introduction

Construction works are a complex, long and labor-intensive process that requires the interaction of construction participants, the use of significant financial, material and other resources. Complexity, dynamic character and uncertainty in the construction industry complicate the ways of achieving the goals of construction participants. This business is very exposed to various risks and adverse conditions of the construction industry, which determines its the final result. Under conditions of external environment variability, construction projects do not always achieve expected results in terms of time, cost and quality. One of the main reasons for such inefficiency is that a significant number of risk

factors are not taken into account in the planning process [1].

The construction projects practice shows that the influence of uncertainty factors leads to unpredictable situations, which in its turn leads to unexpected costs. Therefore, the analysis of construction projects in conditions of uncertainty is relevant.

Preliminary analysis of projects is an important part of construction work. For project managers who are going to manage construction projects in the future, and for investors who are investing, it is important to know how to select a construction project in order to achieve success and profit. Project selection based on the analysis conducted during the pre-investment phase of the construction is a process

of evaluating individual projects in order to select the best project [2] and is extremely important for the successful achievement of the goals of the construction participants [3]. Consequently, making the right decisions in accordance with various criteria is one of the main conditions for achieving the planned objectives and qualitative completion of the construction project within the specified time frame.

Models for selection construction projects

Correct project selection analysis is one of the first and most important factors leading to successful achievement of the goal of any significant project. Selecting a project among a multitude of possible alternatives, taking into account a multitude of conflicting factors in the construction industry, is a complex task faced by a decision-maker [4]. The complexity of the decision-making process is due to the existence of many uncertain, inaccurate and incomplete information, which is influenced by many critical factors.

Uncertainty can be defined as the occurrence of events that cannot be controlled [5]. Williamson [6] believes that uncertainty is one of the main root causes of conflict between construction participants. When evaluating, it is important to take into account unfavorable and often uncertain preferences of various parties involved. Since conflicts are common in almost all construction projects and incorrect resolution of such conflicts can lead to overspending of funds and delays [7]. Uncertainty about construction projects is therefore an important factor to be properly managed as it can have a significant impact on overall construction results.

Zavadskas et al. (2010) [8] applied TOPSIS gray and COPRAG-S methods to assess the risks of construction projects. Risk assessment attributes are chosen taking into account the interests and goals of the parties involved, as well as factors affecting the efficiency of the construction process and real estate value.

Taylan et al. (2014) [9] proposed an integrated methodology of fuzzy analytical hierarchy process (AHP) and fuzzy technique to prefer an order of simi-

larity to the ideal solution (TOPSIS) for construction project evaluation. Fuzzy AHP was used to determine weights for fuzzy linguistic variables in the overall risk of a construction project, while fuzzy TOPSIS was used to make the final selection decision.

Dikmen et al. (2007) [10] presented a decision making model based on ANP to show how the project selection process can be carried out taking into account both quantitative and qualitative criteria as well as their interrelationship instead of classical B/C analysis.

In order to overcome inaccuracy and uncertainty in the selection of a construction project, Ebrahimnejad et al. [11] presented a two-phase group decision making (GDM) approach. This approach combines a modified analytic network process (ANP) and an improved compromise ranking method, known as VIKOR. ANP is introduced to solve the problem of dependence as well as feedback between conflicting criteria and determine their relative importance, and VIKOR expands the potential project ranking based on their overall performance.

Ravanshadian et al. [12] proposed a construction project selection model that took into account the impact of the company's current projects and used a multi-step method of fuzzy Multiple Attribute Decision Making (MADM).

Mohanty [13] developed a Multiple Attribute Decision Making (MCDM) to evaluate project proposals. The model is a structured sequential heuristics for evaluation of acceptability indices, which includes identifying project selection options, identifying internal and external criteria, analyzing and accepting these criteria, and pairwise comparison of these criteria with reference to project selection.

A review of relevant literature shows that the choice of projects in the construction industry has not received sufficient attention from researchers.

Criteria for construction project selection

Project evaluation and selection include solutions that are critical to the profitability, growth and survival of project management organizations in an increasingly competitive global environment. Such

solutions are often complex because they require identification, examination and analysis of many criteria [14]. Knowledge of these criteria can provide a suitable foundation for customers, contractors, managers and decision-makers to achieve their construction project goals.

Many criteria have been suggested for the analysis of construction projects and are considered during the selection of construction projects in the pre-investment phase of construction activity [12; 15–21]. The most important factor in construction projects is the completion of the project in accordance with the scope of work to the satisfaction of the customer within the budget and the execution of works in a reasonable time to achieve a certain goal of the customer.

On the basis of many sources, the authors of this article has analyzed the criteria for evaluation of construction projects compiled by different researchers and selected the following basic criteria for construction project selection:

1. Technical capacity;
2. Stakeholders-related factors;
3. External environment;
4. Socio-economic situation;
5. Political situation;
6. Organizational capability;
7. Management ability;
8. Technological factors.

Each criterion for more effective assessment should be broken down into sub-criteria. Since this article was not intended to provide sub-criteria, this list is not provided.

Research Methodology

Evaluation of construction projects can be considered as a multi-criteria problem of decision-making, since alternative projects are evaluated according to a common set of criteria.

Selection of a rational construction project in conditions of uncertainty with a variety of criteria should be based on a multi-component method of preliminary assessment, which can take into account

each of the significant factors, their interaction, process uncertainty and environmental variability.

According to Fetz et al. [22], fuzzy sets theory provides the basis for solving this problem. The strength of fuzzy sets theory lies in the fact that it allows to formalize fuzzy data, to present their fuzziness, which can be included in calculations, and theoretical interpretation. A tool based on fuzzy sets theory allows to take into account uncertain phenomena, allowing to qualify inaccurate information, to reason and to make decisions based on uncertain and incomplete data [23].

This article presents a model for solving the choice of construction projects based on fuzzy sets theory.

First, a set of criteria for evaluation of alternative construction projects is established taking into account the set goals of the participants of construction activity and all factors that affect the adequate performance of the project. The decision making criteria are broken down into sub-criteria to achieve effective selection of a construction project, after which a hierarchical structure of criteria is created. The criteria do not have the same importance, so each criterion is given a weight reflecting its importance. To calculate the weight of each criterion, decision-makers must present their comparative judgment on the relative importance of one criterion in relation to another. In paired comparison, there is a lot of inaccurate, incomplete and uncertain information that is difficult to determine by the decision makers' judgments. Therefore, assessments are subjectively described by linguistic terms such as "important", "average", "unimportant", etc. This set of linguistic terms is designed to help decision makers assess the relative importance of criteria.

The next step is to evaluate several alternative construction projects by selected criteria based on the TOPSIS (The Technique for Order Preference by Similarity to the Ideal Solution). The application of TOPSIS allows to calculate the most preferred alternative that takes into account the relative importance of each criterion compared to other criteria,

as well as the correspondence of each criterion with the closest proximity to the ideal solution and to be further from the unacceptable solution [24].

Each of these criteria has its own dimension and distribution, and they are difficult to compare or operate directly. As a result, the initial data of criteria evaluation should be dimensionless method of normalization.

Step 1. the normalized fuzzy solution matrix can be presented as [25]:

$$\tilde{S} = [\tilde{S}_{ij}]_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n, \quad (1)$$

where matrix entry $[\tilde{S}_{ij}]$ are calculated as follows:

$$\tilde{S}_{ij} = \frac{S_{ij}}{S_j^+} = \left(\frac{s_{ij}^a}{s_j^+}, \frac{s_{ij}^b}{s_j^+}, \frac{s_{ij}^d}{s_j^+} \right) \left\{ \begin{array}{l} S_j^+ = \max s_{ij} \end{array} \right\} \quad (2)$$

when S_j is the benefit criteria;

$$\tilde{S}_{ij} = \frac{S_j^-}{S_{ij}^-} = \left(\frac{s_j^-}{s_{ij}^-}, \frac{s_j^-}{s_{ij}^-}, \frac{s_j^-}{s_{ij}^-} \right) \left\{ \begin{array}{l} S_j^- = \min s_{ij} \end{array} \right\} \quad (3)$$

when S_j is the cost criteria.

Step 2: the weighted normalized decision matrix is determined by multiplying the normalized decision matrix by the weights associated with it [26]:

$$v_{ij} = w_j \oplus \tilde{S}_{ij} \quad (4)$$

where w_j is the weight of j -th criterion, $\tilde{S}_{ij}$ is the elements of the normalized decision matrix.

TOPSIS approach favors an alternative that is closest to the fuzzy positive ideal solution (FPIS) and the farthest to the fuzzy negative ideal solution (FNIS). FPIS consists of the best performance values for each alternative, while FNIS consists of the worst performance values [25].

Step 3: calculate the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) using the following formulas [24]:

$$FPIS = (V_1^+, V_2^+, \dots, V_n^+), \quad (5)$$

$$\text{where } V_j^+ = \left(\max_m V_{ij}, j \in J_1; \min_m V_{ij}, j \in J_2 \right)$$

$$NPIS = (V_1^-, V_2^-, \dots, V_n^-), \quad (6)$$

$$\text{where } V_j^- = \left(\min_m V_{ij}, j \in J_1; \max_m V_{ij}, j \in J_2 \right)$$

where J_1 and J_2 are sets of benefit criteria and cost criteria.

Step 4: determine the distances of each alternative project from PIS and NIS [25]:

$$d_j^+ = \sum_{i=1}^n d_v(V_{ij}, V_j^+), i = 1, 2, \dots, m \quad (7)$$

$$d_j^- = \sum_{i=1}^n d_v(V_{ij}, V_j^-), i = 1, 2, \dots, m \quad (8)$$

Step 5: the proximity coefficient is calculated to determine the order of ranking of all alternative projects after calculation of d_j^+ and d_j^- for each alternative:

$$CC_j = \frac{d_j^-}{d_j^+ + d_j^-} \quad (9)$$

Consequently, the order of ranking of all alternative projects can be determined according to the proximity coefficient and the best of alternative can be selected.

Conclusion

Construction is an activity with an increased level of risk caused by the uncertainty of a large number of factors. Therefore, the tasks to be solved at the pre-investment phase of construction and forming the basis for analysis of construction projects are quite diverse and complex. To solve such tasks, the article suggested a methodological approach to preliminary selection of construction projects based on fuzzy approach with the use of linguistic assessment and project evaluation by selected criteria based on TOPSIS. Complex consideration of the influence of these factors at the stage of selection of construction projects will contribute to improving the efficiency of the process of implementation of the construction project and the successful achievement of the goals of construction participants.

References:

1. Odimabo O. O., Oduoza C. F. Risk Assessment Framework for Building Construction Projects' in Developing Countries. *International Journal of Construction Engineering and Management*, 2(5). 2013.– P. 143–154.
2. Powers G., Ruwanpura J., Dolhan G., & Chu M. Simulation based project selection decision analysis tool. *Proceedings of the Winter Simulation Conference*, 2,– Vol. 2. 2002.– P. 1778–1785.
3. Boskers N. D., Abou Rizk S. M. Modeling Scheduling Uncertainty in Capital Construction Projects. *Proceedings of the 2005 Winter Simulation Conference*. Association for Computing Machinery,– New York, 2005.– P. 1500–1507.
4. PMBOK Guide. A guide to the project management body of know, Sixth Edition, 2017.– P. 5–8.
5. Mays W. L. and Tung Y. K. *Hydro Systems Engineering and Management*. McGraw-Hill,– New York, 1992.– 530 p.
6. Williamson O. Transaction cost economics: The governance of contractual relations. *The Journal of Law and Economics*, 22, 1979.– P. 233–261.
7. Kassab M., Hipel K., & Hegazy T. Uncertainty analysis in construction conflict resolution using Information-Gap theory. *2007 IEEE International Conference on Systems, Man and Cybernetics*, 2007.– P. 1842–1847.
8. Zavadskas E. K., Turskis Z., & Tamošaitiene J. Risk assessment of construction projects. *Journal of Civil Engineering and Management*, 16(1). 2010.– P. 33–46.
9. Taylan O., Bafail A. O., Abdulaal R. M., & Kabli M. R. Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. *Applied Soft Computing*, 17, 2014.– P. 105–116.
10. Dikmen I., Birgonul M. T., & Ozorhon B. Project appraisal and selection using the analytic network process. *Canadian Journal of Civil Engineering*, 34(7). 2007.– P. 786–792.
11. Ebrahimnejad S., Mousavi S. M., Tavakkoli-Moghaddam R., Hashemi H., & Vahdani B. A novel two-phase group decision making approach for construction project selection in a fuzzy environment. *Applied Mathematical Modelling*, 36(9), 2012.– P. 4197–4217.
12. Ravanshadnia M., Rajaie H., & Abbasian H. R. Hybrid fuzzy MADM project-selection model for diversified construction companies. *Canadian Journal of Civil Engineering*, 37(8). 2010.– P. 1082–1093.
13. Mohanty R. Project selection by a multiple-criteria decision-making method: an example from a developing country. *International Journal of Project Management*, 10(1). 1992.– P. 31–38.
14. Dodangeh J. and Mojahed M. Best project selection by using of Group TOPSIS method, *International Association of Computer Science and Information Technology-Spring Conference 2009. IACSITSC'09*. April, 2009.– 5053 p.
15. Vahdani B., Mousavi S. M., Hashemi H., Mousakhani M., & Ebrahimnejad S. A New Hybrid Model Based on Least Squares Support Vector Machine for Project Selection Problem in Construction Industry. *Arabian Journal for Science and Engineering*, 39. 2014.– P. 4301–4314.
16. Prascevic N., Prascevic Z. Application of FUZZY AHP for ranking and selection of alternatives in construction project management. *Journal of Civil Engineering and Management*, 23(8). 2017.– P. 1123–1135.
17. Shokri-Ghasabeh M., Chileshe N., & Zillante G. From construction project success to integrated construction project selection. In *Construction Research Congress*, Alberta,– Canada, 2010.– P. 1020–1029.

18. Mojahed M., Yusuff R. M., & Reyhani M. Determining and ranking essential criteria of Construction Project Selection in Telecommunication of North Khorasan-Iran. *International Journal of Environmental Science and Development*, 1(1). 2010.– P. 79–84.
19. Chan A. P.C., Scott D., & Chan A. P.L. Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management*, 130(1). 2004.– P. 153–155.
20. Baldwin J.R.; Manthei J.M., Causes of delays in the construction industry. *ASCE Journal of the Construction Division*, 97(2). 1971.– P. 177–187.
21. Ali Z., Zhu F., & Hussain S. Identification and Assessment of Uncertainty Factors that Influence the Transaction Cost in Public Sector Construction Projects in Pakistan. *Buildings*, 8 (11). 2018.– 157 p.
22. Fetz T., Oberguggenberger M., Jager J., Koll D., Krenn G., Lessmann H., & Stark R. F. Fuzzy Models in Geotechnical Engineering and Construction Management. *Computer-aided Civil and Infrastructure Engineering*, 14. 1999.– P. 93–106.
23. Zadeh L. A. The concept of a linguistic variable and its application to approximate reasoning, *Information Sciences* 8(3). 1975.– P. 199–249.
24. Tan Y., Shen L., Langston C., & Liu Y. Construction project selection using fuzzy TOPSIS approach. *Journal of Modelling in Management*, 5(3). 2010.– P. 302–315.
25. Sodhi B., and Prabhakar T. V. (2012). A Simplified Description of Fuzzy TOPSIS. [pdf] Available at: URL: <http://arxiv.org/pdf/1205.5098v1.pdf>// (Accessed: 11 August, 2020).
26. Mahmoodzadeh S., Shahrabi J., Pariazar M., & Zaeri M. Project selection by using FUZZY AHP and TOPSIS technique. *World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 1, 2007.– P. 270–275.