Selected Aspects of Multi-Criteria Analyses Supporting Assessment of Construction and Material Solutions in Buildings and Building Structures

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Abstract. Decisions concerning planned buildings and building structures are made as early as the stage of planning development investments. Different variants of construction solutions and materials are evaluated, which entails reviewing numerous physical, chemical or maintenance factors. The more factors are involved, the more difficult it is to make a decision. While analysing alternative solutions, the decision-making process can be supported with a variety of methods. A possible approach is to employ a multi-criteria decision analysis method. Such methods will differ from one another in the way data are processed for analyses, in the methodology of analyses and in the form of an output. Moreover, every method may be burdened with errors. This article presents various problems connected with an analysis of data accomplished according to the MCE, AHP and Indicator Method, and arising during the interpretation of results.

1. Introduction
Many decisions must be made at the stage of preparing and planning development investments. Among numerous considerable problems to be solved there are the ones regarding construction details as well as functional, technological and material solutions [1]. The contemporary building materials industry, advances in technical concepts and technological progress all provide a wide range of choices. In every case, when reviewing different variants of materials and defining the assessment criteria, it is possible to include the physical, chemical and resistance characteristics of materials.

Equally important is the durability of materials and the technology needed for their incorporation into a building. When making an assessment of construction solutions, their durability and future exploitation are considered. In order to take into account all aspects of the final solutions, it is necessary to employ efficient decision-making support tools. Due to a large number of factors to be considered, multi-criteria methods are helpful [2,3].

2. Characteristics of the analysed methods
When selecting a particular approach to an evaluation of construction and building material solutions, attention should be paid to whether the selected method will allow us to take into account specific features of the development project. Other characteristics to be considered are: the legibility and quality of the results obtained, the mathematical apparatus used, the ease of applying the method and verifying the outcome. The input data processing procedure is also worth considering, as well as the...
subjectivity of assessments because most of the methods rely on expert opinions. Out of the numerous possibilities, this article discusses the following multi-criteria methods: Multi Criterial Evaluation (MCE), Analytic Hierarchy Process (AHP) and Indicator Method (IM).

An assessment supported by the MCE method starts by the determination of weights and importance of the criteria, and subsequently proceeds to the verification to what extent these criteria are fulfilled by the variant solutions. This method can support a decision-making process when there are several criteria at hand and no restriction regarding their number. The first step in the analytical process is to identify the conditions that will help to ensure the achievement of the planned goal. Criteria which appear in MCE analyses can be divided into hard ones: barriers or restrictions, and soft ones: parameters or factors. By having these two groups of criteria, at the first stage we are able to exclude the variants that do not satisfy the basic requirements from further proceedings [4, 5, 6].

The AHP method allows the user to include various criteria which are decisive for the achievement of the set goal [7, 8]. The degree to which the main aim is met by each of the analysed variants depends on the degree to which main criteria as well as subcriteria grouped in appropriate categories are satisfied. By decomposing a problem, it is easier to evaluate it, and this is the essence of the AHP method. Three integrated stages (steps) lead to a solution of a problem. The literature provides formulas for the calculations to be made at each consecutive step so as to compute the value of the priority parameter, and it recommends to verify the cohesion of the vectors of priorities, which is another essential element of this method.

The starting point for a multi-criteria analysis supported by the Indicator Method (similarly to other multi-criteria decision making methods) is to define the criteria that will be applied to an assessment of all investment variants. An estimate of the extent to which the analysed options meet certain requirements is the crucial stage of the analysis. The Indicator Method allows the user to take into account negative effects of the planned solution, denoted as negative values of some evaluated criteria. In order to build a computational model, questionnaires addressed to experts must enable them to assign negative values to the evaluated criteria whenever they deem it necessary. Calculations are made in the form of matrices, which include direct and indirect effects of planned development solutions [9].

3. Analysis of some problems arising from an application of the multi-criteria methods
The first problem we encounter when running analyses supported by multi-criteria methods is the fact that we must gather data on different aspects of the analysed problem. Supporting a decision-making process with multi-criteria methods entails the participation of many experts who evaluate the importance of criteria. The selection of criteria decides about the effectiveness of the subsequent analysis. Expert opinions may vary, which is because of the different roles that experts perform in the investment process, and the final result is sometimes laden with an error that ought to be taken into consideration. Diverse opinions can appear mostly when quality factors are estimated. When so-called measurable factors are analysed, an assessment made against a certain benchmark is obvious. There are two types of procedure implemented in order to obtain an objective evaluation of quality parameters. One is a descriptive evaluation of the importance of a criterion, and the other one demands the inclusion of a numerical scale of evaluation. However, it is difficult to estimate the error that affects the final outcome of an analysis of qualitative parameters. The problem of assigning the weight to analysed parameters occurs in all the methods discussed herein, but each method has some specific characteristics and the problems emerging in the subsequent procedures will be different as well.

The MCE method does not restrict the number of compared parameters. However, research observations show that if too many factors, e.g. over a dozen, are taken into account, the weights are too dispersed and consequently the results are flattened. It is not easy to identify the criteria that clearly prevail over the others and decide which solution should be accepted. To illustrate this problem, fragments of a larger set of calculations are contained in Table 1 and plotted in Figure 1.
Table 1. Evaluation of assessment criteria with MCE method

| No | Subcriteria | Weights | No | Subcriteria | Weights |
|----|-------------|---------|----|-------------|---------|
| 1. | a1          | 0.089   | 6. | b2          | 0.108   |
| 2. | a2          | 0.082   | 7. | b3          | 0.097   |
| 3. | a3          | 0.079   | 8. | b4          | 0.091   |
| 4. | a4          | 0.054   | 9. | c1          | 0.091   |
| 5. | b1          | 0.109   | 10. | c2         | 0.095   |
|    |             |         | 11. | c3         | 0.105   |

Figure 1. The graphical illustration of the results obtained by the MCE method

The AHP method eliminates the above inconvenience by first grouping all criteria and then assessing the criteria and associated sub-criteria. However, the method brings about its own problems due to a much larger dose of subjectivity in making ranking lists, and the results are scored on a scale adopted by convention. Also, the procedures needed to aggregate assessments and to analyse the cohesion of preferential vectors can be cumbersome (Table 2 and Figure 2).

Table 2. Evaluation of assessment criteria with AHP method

| Criteria | Subcriteria | Main weights | Indirect weights | Weights |
|----------|-------------|--------------|------------------|---------|
| a        | a1          | 0.0740       | 0.46             | 0.0340  |
|          | a2          | 0.0740       | 0.20             | 0.0148  |
|          | a3          | 0.0740       | 0.26             | 0.0192  |
|          | a4          | 0.0740       | 0.08             | 0.0059  |
| b        | b1          | 0.6400       | 0.41             | 0.2624  |
|          | b2          | 0.6400       | 0.29             | 0.1856  |
|          | b3          | 0.6400       | 0.17             | 0.1088  |
|          | b4          | 0.6400       | 0.13             | 0.0832  |
| c        | c1          | 0.2800       | 0.11             | 0.0308  |
|          | c2          | 0.2800       | 0.26             | 0.0728  |
|          | c3          | 0.2800       | 0.63             | 0.1764  |
The Indicator Method (IM) proposed as an alternative is less known and not used as often. This is mainly because it requires making a comprehensive and labour-consuming description of the criteria applied during the research. However, an analysis carried out according to this method can include many aspects that determine the shape of the planned investment, which are reviewed in the context of their direct and indirect effects. The assessments supported by this method differ from the previous ones in that it is based on an average of the minimum and maximum values that the criteria scored in the surveys. Because the extreme values must be included in an analysis supported by the IM approach, the final results are more diverse, which can be seen in Table 3 and the graph illustrating the distribution of assessments (Figure 3).

Figure 2. The graphical illustration of the results obtained by the AHP method

Table 3. Evaluation of assessment criteria with IM method

| No | Analysed criteria | Evaluation |  |  |  |
|----|-------------------|------------|---|---|---|
|    |                   | Min.       | Med. | Max. |
| 1  | A1                | 0.001      | 0.0115 | 0.022 |
| 2  | A2                | 0.001      | 0.006  | 0.011 |
| 3  | A3                | 0.001      | 0.014  | 0.027 |
| 4  | A4                | 0.005      | 0.008  | 0.011 |
| 5  | B1                | 0.787      | 0.894  | 1.001 |
| 6  | B2                | 0.576      | 0.784  | 0.992 |
| 7  | B3                | 0.401      | 0.5515 | 0.702 |
| 8  | B4                | 0.117      | 0.1975 | 0.278 |
| 9  | C1                | 0.018      | 0.0925 | 0.167 |
| 10 | C2                | 0.021      | 0.1295 | 0.238 |
| 11 | C3                | 0.156      | 0.3575 | 0.559 |
Figure 3. The graphical illustration of the results obtained by the IM method

Because the Indicator Method assumes that negative impacts of a planned development are also considered, this option should be foreseen in surveys. A questionnaire addressed to experts will be different from ones suggested previously by presenting questions about negative effects of the evaluated investment. Thus, the questionnaire is more complicated and the purposefulness of some of the points it comprises may need clarification.

4. Results and conclusions
When approaching to an assessment of material and construction solutions planned in a development project, it is worth considering the usefulness of well-known and popular decision supporting methods. Among them, there are methods based on descriptive evaluations and the ones where a scoring scale must be adopted and the analysed factors are assigned concrete values. Some methods will involve advanced computational techniques. The users’ experience suggests that:
- most often two or three methods are used simultaneously, as this allows the user to show some phenomena in a different light;
- much caution is needed when applying methods which require the use of weights because the determination of weights is based on opinions requested from experts;
- it is recommendable to apply methods which will present results of an analysis in a variety of ways;
- for an easier interpretation of the results, mathematical calculations should be supplements with graphic illustrations or descriptions.

References
[1] E. Szafranko, “Multi-criteria methods in an analysis of variants of a construction project”, International Scientific Publication, Materials, Methods & Technologies, Volume 9/2015, pp.155-168.
[2] P. W. G. Morris, “Lessons in managing major projects successfully in a European context”, Technology in Society, 10(1)1998, pp. 71-98.
[3] E.K. Zavadskas, P. Vainiūnas, Z. Turskis, & J. Tamošaitienė, “Multiple criteria decision support system for assessment of projects managers in construction”, International Journal Of Information Technology & Decision Making, 11(02)2012, pp. 501-520.
[4] C. Zopounidis, M. Doumpos, “Multi-criteria decision aid in financial decision making: methodologies and literature review”. Journal of Multi-Criteria Decision Analysis, 11(4-
5)2002, pp. 167-186.

[5] G. Marques, D. Gourc, M. Lauras, “Multi-criteria performance analysis for decision making 1057-1069. In Project management”, International Journal of Project Management, 29(8)2011, pp. 1057-1069.

[6] J. Šelih, A. Kne, A. Srdić, M. Žura, “Multiple-criteria decision support system in highway infrastructure management”, Transport, 2008(23)/4, pp. 299-305.

[7] T.L. Saaty, “Decision making with the analytic hierarchy process”, International journal of services sciences, 1(1)2008, pp. 83-98.

[8] R.W. Saaty, “Decision making in complex environments: the analytic network process (ANP) for dependence and feedback; a manual for the ANP software super decisions”, Creative decisions foundation, Pittsburgh, PA 2002.

[9] E. Szafranko, “Applicability of the indicator method to evaluation of road building projects”, News in Engineering, 1/2015, pp. 1-8.