

# Methodology in the Assessment of Construction and Development Investment Projects, Including the Graphic Multi-Criteria Analysis – a Systemic Approach

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**Abstract.** Assessment of variant solutions developed for a building investment project needs to be made at the stage of planning. While considering alternative solutions, the investor defines various criteria, but a direct evaluation of the degree of their fulfilment by developed variant solutions can be very difficult. In practice, there are different methods which enable the user to include a large number of parameters into an analysis, but their implementation can be challenging. Some methods require advanced mathematical computations, preceded by complicating input data processing, and the generated results may not lend themselves easily to interpretation. Hence, during her research, the author has developed a systemic approach, which involves several methods and whose goal is to compare their outcome. The final stage of the proposed method consists of graphic interpretation of results. The method has been tested on a variety of building and development projects.

## 1. Introduction

Investment and construction activities are characterized by the fact that even in the planning and design stage there are made decisions about the future shape of objects. The decisions deal with numerous problems, which are strictly connected with the nature of a planned building or development project. When planning to build an edifice or another structure, we face the task of making choices among many different technologies and materials. In order to select an economically viable variant that meets all other requirements set for building constructions, we need to perform comprehensive analyses. It is vital that a building or a building construction should be reliable as well as durable and needing as few maintenance repairs as possible during its service life [3].

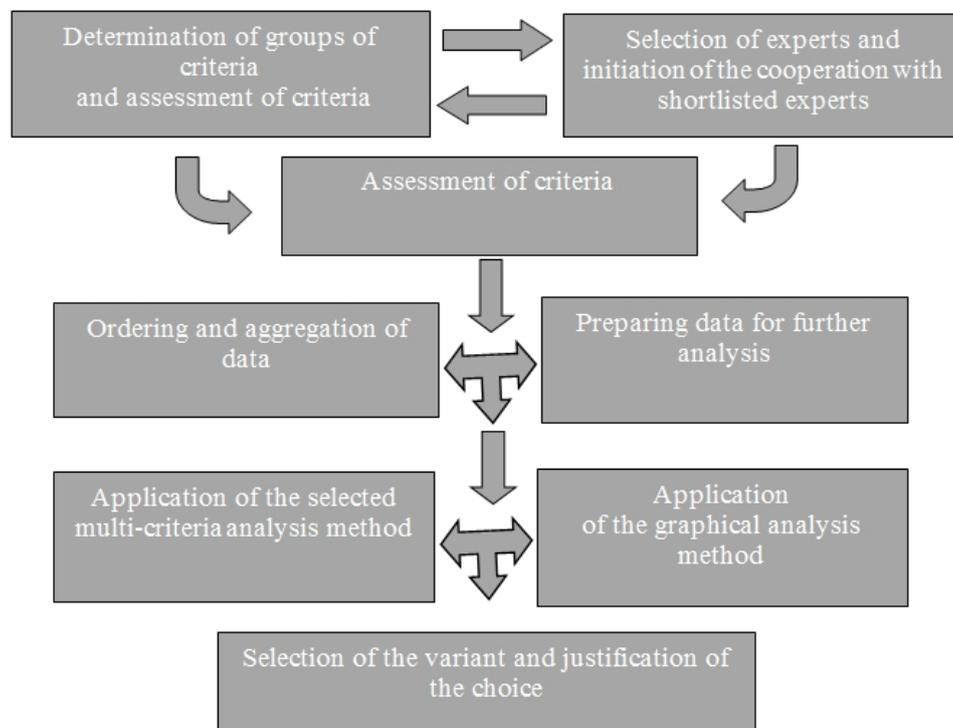
While analysing variants of an investment it is also necessary to take into consideration alternative locations of the investment and environmental conditions [9]. Quite often, a larger part of the analysis is dedicated to the issue of limiting the negative impact of a planned building or structure on the natural and social environment. With respect to some investments (e.g. roads, because of their linear character), this is the most important part of the analysis [6]. Moreover, the investor and future users are interested in a relatively short construction process. In brief, when analysing a future investment, it is essential to identify its specific character, determine appropriate assessment criteria and then optimise these criteria [2].



## 2. Methods

There are many multi-criteria analysis methods. The literature provides numerous examples of how these methods are applied [5, 10, 11, 12]. However, our experience in drawing up and analysing variants of building investments proves that all the methods have certain advantages and disadvantages, which make some of them more suitable in specific cases. Our decision which method will support the decision-making process in a given instance should be guided by such features as readability, quality and verifiability of results as well as the applied mathematical apparatus. It is also important to check how data must be prepared for analysis [1, 4, 13].

In all cases, our analysis begins with a procedure whose aim is to assign weights to criteria and to identify to what degree the criteria are satisfied by the analysed variants. This is the stage when a group of experts is engaged, and their opinions expressed in a questionnaire form the basis for further analyses [7, 8 14]. The schematic presentation of the proposed procedure is illustrated in figure 1.



**Figure 1.** The scheme of procedure and systematic approach

Fragments of a broader analysis, encompassing variants of a road building investment project, will serve to illustrate the above process.

## 3. Case study, analytic method

In the project discussed in this paper, the following criteria and sub-criteria were applied:

### A. transportation and communication sub-criteria:

A1 - transport performance (number of vehicles x kilometres per hour)

A2 – costs due to the time it takes to transport loads, including the time wasted due to traffic jams or extension of the route,

A3 – length of the road in km,

A4 – costs due to maintenance of vehicles (repairs, fuel).

### B – economic sub-criteria

B1 – costs of constructing the road

- B2 – costs of purchasing the land  
 B3 – costs of compensation paid  
C – environmental sub-criteria  
 C1 – incursion into protected areas  
 C2 – length of routes running through forested areas  
 C3 – number of trees to be felled  
 C4 – cutting across routes travelled by wild animals  
 C5 - cutting across watercourses  
D – social and planning sub-criteria  
 D1 – number of buildings to be demolished  
 D2 – number of buildings 0-50 m away from the planned road  
 D3 – number of buildings 50-100 m from the planned road  
 D4 – acreage of the land to be repossessed  
 D5 – collisions with the planned spatial management

Weights assigned to particular criteria take into account the specific character of the said investment and the conditions in which the new road will be used. Weights of main criteria and sub-criteria are considered. Their value lies within an interval of 0-1. When analysing the degree to which criteria are satisfied by analysed variants, a 0-6 scale is used, where 0 means failure to meet a given criterion, while 6 stands for the maximum satisfaction of this parameter. The calculations are set in Table 1.

**Table 1.** Specification of weights of main criteria and sub-criteria

Criterion	Sub-criterion	Weights for criterion	Weights for sub-criterion	Global weights
<b>A</b>	a1	0.12	0.07	0.008
	a2	0.12	0.18	0.022
	a3	0.12	0.35	0.042
	a4	0.12	0.4	0.048
<b>B</b>	b1	0.14	0.22	0.031
	b2	0.14	0.36	0.050
	b3	0.14	0.42	0.059
<b>C</b>	c1	0.29	0.14	0.041
	c2	0.29	0.15	0.044
	c3	0.29	0.17	0.049
	c4	0.29	0.24	0.07
	c5	0.29	0.30	0.087
<b>D</b>	d1	0.40	0.11	0.044
	d2	0.40	0.27	<b>0.108</b>
	d3	0.40	0.29	<b>0.116</b>
	d4	0.40	0.33	<b>0.132</b>
<b>E</b>	e1	0.05	0.26	0.013
	e2	0.05	0.32	0.016
	e3	0.05	0.42	0.021

Because of the character of the investment project, i.e. building a road, much importance was ascribed to environmental criteria, which would be affected strongly by the future road, while the cost-related criteria achieved high weights due to the large size of the investment.

The calculations suggest that the most important sub-criteria, which can be decisive for the final choice of a variant solution, are: incursion into protected areas and the length of routes crossing forest areas (C1, C2). Because of the size of the investment, construction costs and costs of due compensation are equally important, as they can weigh heavily on the budget (B1, B3). An assessment of the degree to which the analysed variants satisfy the above criteria is presented in Table 2.

**Table 2.** Assessment of analysed variants

Sub-criterion	Assessment of varian1		Assessment of varian2		Assessment of varian1		
	Weights	V1	V2	V2	V3		
<b>a1</b>	0.008	2	0.016	0.5	0.004	3	0.024
<b>a2</b>	0.022	2.5	0.055	0.7	0.0154	3.5	0.077
<b>a3</b>	0.042	3	0.126	1	0.042	4	0.168
<b>a4</b>	0.048	3	0.144	2	0.096	4.5	0.216
<b>b1</b>	0.031	1	0.031	1	0.031	3	0.093
<b>b2</b>	0.050	3	0.150	2	0.100	4.5	0.225
<b>b3</b>	0.059	4	0.236	2.5	0.1475	5	0.295
<b>c1</b>	0.041	3	0.123	1.5	0.0615	1	0.041
<b>c2</b>	0.044	3	0.132	1.5	0.066	1	0.044
<b>c3</b>	0.049	4	0.196	2	0.098	1.5	0.073
<b>c4</b>	0.07	5	0.350	2.5	0.175	2	0.140
<b>c5</b>	0.087	5	<b>0.435</b>	3	0.261	3	0.261
<b>d1</b>	0.044	2	0.088	2	0.088	1.5	0.066
<b>d2</b>	0.108	3	<b>0.324</b>	3	<b>0.324</b>	2.5	0.270
<b>d3</b>	0.116	3	<b>0.348</b>	4.5	<b>0.522</b>	3	<b>0.348</b>
<b>d4</b>	0.132	5	0.660	4.5	0.594	3	<b>0.396</b>
<b>e1</b>	0.013	1	0.013	0.5	0.0065	1	0.013
<b>e2</b>	0.016	2	0.032	1	0.016	1.5	0.024
<b>e3</b>	0.021	3	0.063	1.5	0.0315	1.5	0.031
			3.522		2.6794		2.806

Our analysis shows that the highest total score was achieved by variant 1. However, this result may not necessarily agree with the investor's expectations, because the total score is composed of points scored for meeting other, less significant criteria. Moreover, an analysis of the results can be a laborious process, made even harder by the abundance of generated data. An alternative solution proposed in this paper is an approach developed by the author, which relies on graphic evaluation supported by profiles.

#### 4. Method of graphic analysis

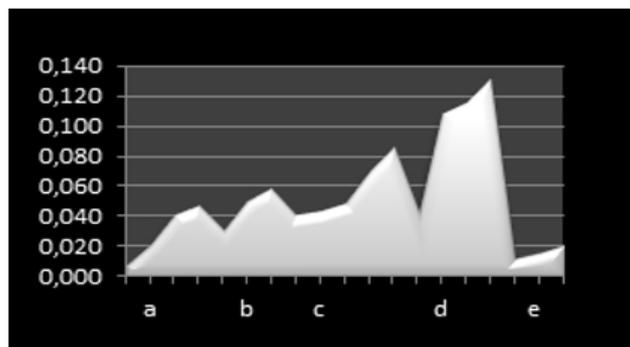
Multi-criterial analysis methods are mathematical methods. Whichever one is chosen, a more or less complicated mathematical apparatus must be applied. Time-consuming and laborious calculations frequently discourage those who are interested in decision support solutions. In addition, the fact that calculation results must be analysed in the form of series of numbers impedes the implementation of these methods in practice. Hence, while exploring variants of different solutions created for the execution of various building investment projects, I developed methodology based on comparisons of the shape of graphic profiles of variant solutions with a template of criteria identified for a given solution.

In order to obtain a template of criteria, main criteria are put in the increasing order of the values of weights. Sub-criteria within the groups of main criteria are ordered in the same manner. The sequence has been established based on the assigned weights: 0.12; 0.14; 0.29; 0.4. Table 5 shows sub-criteria arranged according to the above-mentioned principle.

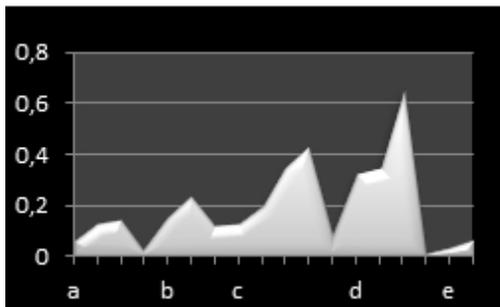
The subsequent step consists of an assessment of the variant solutions and development of profiles for each analysed variant. Data must be arranged according to the same order as has been adopted for developing the template. In the analysed case, our task is to make an assessment of three alternative plans for an investment into the road infrastructure. The results of this evaluation are summarized in Tables 3 and 4 and profiles are shown in figures 2, 3, 4 and 5.

**Table 3.** Data for the preparation of a template of criteria

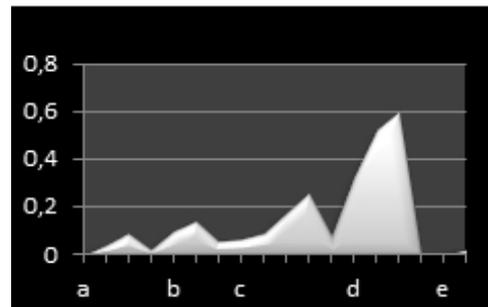
Criterion	Sub-criterion	Weights	Criterion	Sub-criterion	Weights
<b>a</b>	a1	0,008	<b>d</b>	d1	0,044
	a2	0,022		d2	0,108
	a3	0,042		d3	0,116
	a4	0,048		d4	0,132
<b>b</b>	b1	0,031	<b>e</b>	e1	0,013
	b2	0,050		e2	0,016
	b3	0,059		e3	0,021
<b>c</b>	c1	0,041			
	c2	0,044			
	c3	0,049			
	c4	0,07			
	c5	0,087			

**Figure 2.** Template of criteria**Table 4.** Data for graphic analysis.

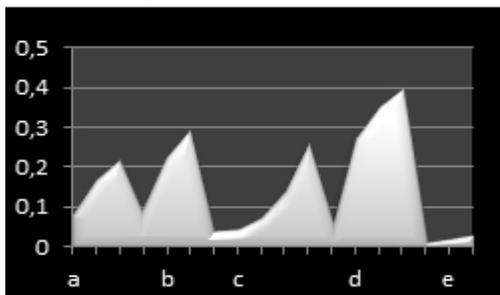
	V1	V2	V3
<b>a1</b>	0,016	0,004	0,024
<b>a2</b>	0,055	0,0154	0,077
<b>a3</b>	0,126	0,042	0,168
<b>a4</b>	0,144	0,096	0,216
<b>b1</b>	0,031	0,031	0,093
<b>b2</b>	0,15	0,1	0,225
<b>b3</b>	0,236	0,1475	0,295
<b>c1</b>	0,123	0,0615	0,041
<b>c2</b>	0,132	0,066	0,044
<b>c3</b>	0,196	0,098	0,0735
<b>c4</b>	0,35	0,175	0,14
<b>c5</b>	0,435	0,261	0,261
<b>d1</b>	0,088	0,088	0,066
<b>d2</b>	0,324	0,324	0,27
<b>d3</b>	0,348	0,522	0,348
<b>d4</b>	0,66	0,594	0,396
<b>e1</b>	0,013	0,0065	0,013
<b>e2</b>	0,032	0,016	0,024
<b>e3</b>	0,063	0,0315	0,0315



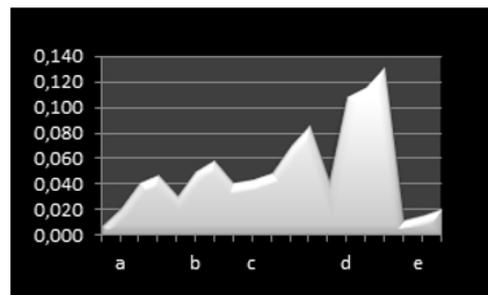
**Figure 3.** Profile of V1



**Figure 4.** Profile of V2



**Figure 5.** Profile of V3



**Figure 6.** Template of criteria

Having compared the shape of diagrams, we can conclude that the profile of variant 2 is in the best agreement with the template. This comparison reveals that variant 2 satisfies the most important criteria to the highest degree, while the other variants are less satisfying in this regard. The reason why variant 1 was evaluated the highest in the course of the above calculations was that it scored higher for the fulfilment of the remaining criteria. The graphic analysis method enables us to take into account the specific character of solutions and, having made all comparisons required, it allows us to evaluate the desirable properties of available variants.

## 5. Summary and discussion of results

In the process of preparing a building investment project, it is extremely important to analyse various variant solutions. One of the problems that a designer must solve, having reached an agreement with the investor, is to choose the location for a building structure. Analysis of available variants should be carried out with the help of decision support methods.

The case presented in this article demonstrates how the graphic method, developed by the author, can be applied to an assessment of variant solutions. The paper presents results obtained with a mathematical method (AHP), which were then compared with an assessment consisting of a comparison of profiles of the variants with a template of the assessment of criteria. It has been revealed that sometimes an interpretation of results achieved with the graphic method does not confirm the data generated by calculations involved in a mathematical approach. This may happen when one of the analysed variants highly satisfies most of the criteria but does not fulfil to the highest degree the criterion that we find most important. Such situations are illustrated in table 4 and figure 4. When we compare the results generated by these methods, we can take into account the specific character of an investment project submitted to analysis, and the eventual choice of a variant will be in the hands of the decision maker. We can decide whether we wish the most important criterion to be fulfilled or whether the best solution is the one which has scored the highest total number of points.

The application of graphic interpretation of solutions, consisting of the comparison of variants with a template of criteria, is the most easily performed method for interpretation among multi-criteria methods of analysis. The profiles prepared previously can be used by planners and designers as well as investors in the civil engineering business, and they have already received a friendly welcome in the world of civil engineers.

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