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Decisive management in selecting locations for development of construction projects

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Abstract. The location of an investment project is one of the most important decisions in the construction and land development business. The shape of a new building and aspects of its future use depend on making a good choice of a land plot where it will be constructed. There are many characteristics involved descriptions of land available for development. On the one hand, different buildings (with different envisaged use) fit differently to a given location. Residential homes, for example, require a location which will ensure a peaceful lifestyle, with places for walks and recreation, situated in a relatively quite setting. On the other hand, close proximity to schools, shops or a health clinic is another important consideration. Industrial buildings should be localized so as not to be a nuisance to others, and their location should facilitate efficient transport of raw materials and ready products. Yet other requirements are defined for public buildings. It is therefore evident that the characteristics included in an evaluation of the location of a planned building can be highly diverse and their diversity makes the evaluation difficult. Selection of a location can be supported by a variety of methods. For instance, an evaluation can rely on assigning points which indicate the fulfillment of certain criteria. This approach generates a complex evaluation in the form of tables and maps of usefulness. Another possibility is to make an assessment of the criteria that a given land parcels should satisfy in order to develop a specific type of a building. Having combined these two sets of information, we can create a system or a model for the management of land resources, which will easily help to support decision making processes pertaining to the choice of a location. This article shows a model approach for a specific building.

1. Introduction

An investment activity in the field of construction and land development is characterized by the fact that decisions about the shape of future buildings depend on solutions adapted at the stage of planning and designing them. Several problems must be resolved at that stage, primarily the ones which are specific for a given construction project. They include the decision about the location of a building or a structure [1, 2].

Investment projects in the field of construction include objects of various types of use. These are mostly buildings and building structures. Buildings can serve different roles and must therefore satisfy different expectations. Examples are buildings with residential, commercial, services, public and social functions. Irrespective of their use, all buildings share certain features. With respect to building structures, they are distinguished by a greater degree of diversity [3]. They include roads and road facilities, structures serving environmental purposes (wastewater treatment plants, landfills, etc.), transmission installations and lines, water engineering structures (e.g. dams), earthen structures, towers, poles, etc. This highly diverse nature of buildings and building structures generates extremely differentiated decision-making situations. In the majority of cases, the most important decision is the one about the location. Concomitantly, decisions must be made concerning the choice of materials and construction solutions. In most situations, it is also necessary to make decisions that will reduce the negative impact on the natural environment. Some of the decisions are taken at the stage of preparing a technical plan while others must be made earlier, for example the question about the location must be resolved at the stage of planning a new building structure [4, 5].

2. Selection of criteria for evaluation of the location of a project

Preliminary analyses of planned development projects demonstrate the need to include many factors, and a decision regarding the location needs to rely on numerous criteria which will facilitate an evaluation of specific options [6]. The criteria can be grouped, and the most common groups of factors are: technical, economic, social and environmental ones. Several subcriteria can be distinguished within each group, and specific examples depend on the character of a development undertaking. Apart from basic groups of criteria, which repeat in analyses, some projects entail factors specific for given types of buildings and structures. For example, transportation criteria for road investments, technological factors for industrial buildings. Completely different criteria will apply to residential developments, which – beside technical criteria – will encompass such issues as public transport or the possibility to connect a whole housing estate to municipal infrastructure [7]. Quite often, some criteria overlap one another and share certain features. For instance, criteria from the group of functional factors describing the length of roads and maximum traffic volume are frequently connected with the impact on nature, whereas technical criteria remain closely linked to economic ones. With respect to residential development projects, the fulfillment of urbanistic criteria translates into economic and social considerations. Figure 1 shows model criteria for a housing development and their correlations.

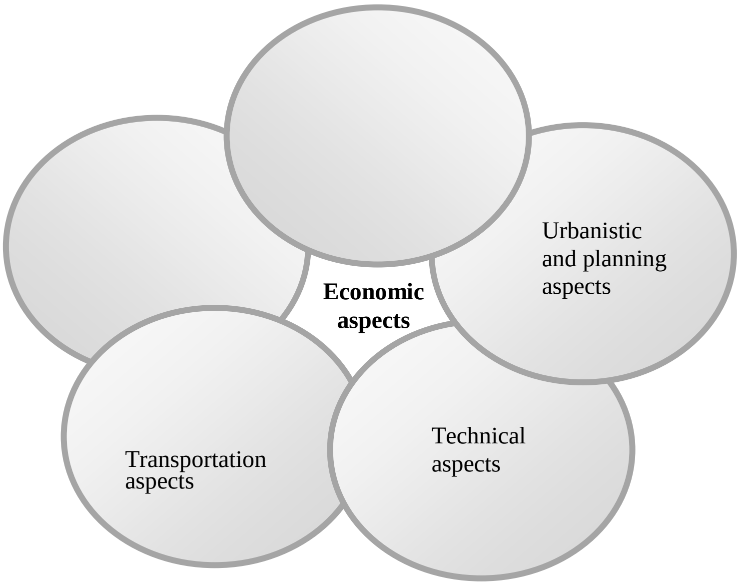

Figure 1. Mutual relationships between criteria applied to assessment of a residential development project.

Irrespective of the type and importance of criteria, they are usually so numerous that simple decisions are difficult to make. It is recommended to apply decision support methods. In such complicated matters as construction and land development projects, multi-criteria methods prove to be helpful. Literature contains many alternatives. The following can be mentioned: Multi Criteria

Evaluation (MCE) [8], Point Method (PM), Weighting Method (WM) [9], Analytic Hierarchy Process (AHP) [10]. Noteworthy is the Indicator Method (IM), developed by the author [11], which takes into account negative aspects of analyzed variants.

3. Methodology of the procedure
All the methods mentioned above share certain features. First of all, the starting point for an analysis is to conduct surveys so as to collect opinions of experts who assign the importance to particular indicators and assess their fulfillment by different alternative solutions. The flowchart in figure 2 illustrates the procedure.

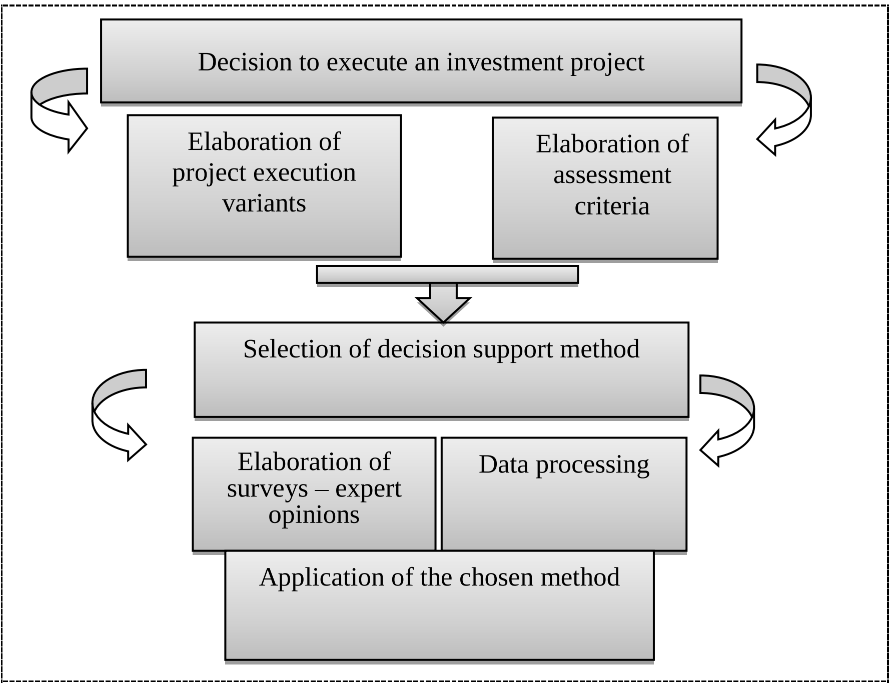

Figure 2. The flow chart of the procedure including the preliminary preparation stage.

The first step which prepares us to conduct the study is to prepare a group of criteria which will serve the analysis. As seen in figure 2, this step is closely correlated with the elaboration of variants submitted to analysis. The simultaneously developed survey serves as an introduction to further analyses and should be correlated with the selected decision support method. A survey prepared to gather data for an analysis with the MCE method looks different from the one needed to supply information for the AHP approach, whereas the Point Method, Weighting Method and Indicator Method all require yet different questionnaires. However, all decision support methods share some properties, also at the stage of preparing surveys. Prior to running an analysis, we must collect information dealing with the importance of individual criteria and the degree to which they are satisfied by the analyzed variant locations. Further steps include the application of a chosen method.
While analyzing variant locations of a planned building project, we can choose one of several available procedures. Depending on their character, it is convenient to apply a different method as well. Some decision management methods are more popular, others are used less often. When selecting a specific method, it is worth paying attention to the data preparation stage and the complexity of mathematical processing. What matters is also the form in which the results are displayed. For illustrating the procedures involved in the application of calculation methods, let us draw examples of calculations performed with the methods known from literature and compare with

an analysis made according to the Indicator Method, developed by the author [11]. Examples of calculations are given in the following section.

4. Examples of analyses of variant locations for a housing development

The problem of selecting a land plot for a housing development project entails analyzing several factors. Some arise from the generally recognized location criteria, while others stem from the specific characteristics of the analyzed location and the development project itself [12]. To some extent, these questions have been discussed in my earlier papers [13]. A review of many similar cases suggests that invariably a great number of factors must be considered. The criteria listed below are the ones whose fulfillment is most important for the development project discussed in this paper. Due to their high number (17), it is recommended to apply a hierarchy approach and rearrange them as groups of main criteria and subcriteria. This method enables the user to evaluate the importance of individual criteria in groups of main criteria, and then in sets of subcriteria. Having taken into account the requirements of the above approach, the predefined criteria were ordered as follows:

A. Accessibility:
   A1 – connections with the local transportation network,
   A2 – solutions regarding access to the site,
   A3 – public transport availability,
   A4 – distance to the city center;
B. Technical infrastructure:
   B1 – access to an electric power network,
   B2 – access to waterworks,
   B3 – access to a sewage system;
C. Land relief, soil and water conditions:
   C1 – load bearing capacity of the subsoil,
   C2 – type of soils,
   C3 – depth of the bearing subsoil level,
   C4 – level of groundwater,
   C5 – land relief,
D. Urbanistic and urban development criteria:
   D1 – distance to offices of architecture and construction supervising authorities,
   D2 – degree to which local plans are developed,
   D3 – degree to which the local commune's strategy and development plans are elaborated,
   D4 – additional consensus (e.g. nature protection) required,
   D5 – expert opinions required.

4.1. Analytical Hierarchy Process

An evaluation of the importance of criteria can be carried out stepwise (hierarchy analysis) or at one level (point method). Slightly different distributions of values are achieved in each case. Because the underlying principle of evaluating criteria and assigning weights to the criteria is that the sum of weights can equal 1 (or 100%), the hierarchy analytical process yields a higher diversity of values. Tables 1 and 2 illustrate the above concept.

The current study dealt with 3 variant locations. The evaluation scale presumes assigning points from 0 to 5. Zero points mean that a given criterion is not satisfied at all, while 5 points suggest that it is fulfilled to the highest degree. The evaluation of the three variants is presented in table 2.

Table 1. Evaluation of weights for main criteria and subcriteria by the hierarchy analytical process.

Main criteria	Subcriteria	Weights of main criteria	Weights of subcriteria	Final weights of subcriteria
	a1	0.28	0.07	0.020
A	a2	0.28	0.18	0.050

	a3	0.28	0.35	0.098
	a4	0.28	0.4	0.112
	b1	0.19	0.22	0.042
B	b2	0.19	0.36	0.068
	b3	0.19	0.42	0.080
	c1	0.35	0.3	0.105
C	c2	0.35	0.24	0.084
	c3	0.35	0.15	0.053
	c4	0.35	0.17	0.060
	c5	0.35	0.14	0.049
	d1	0.18	0.11	0.0198
D	d2	0.18	0.3	0.054
	d3	0.18	0.29	0.0522
	d4	0.18	0.27	0.0486
	d5	0.18	0.03	0.0054

Table 2. Evaluation of the fulfillment of criteria by location variants (analytical hierarchy process).

Criteria			**variant1 (w1)**		**variant2 (w2)**		**variant 3 (w3)**	
	Subcriteria	Weights	fulfilment	rating	fulfilment	rating	fulfilment	rating
	a1	0.0196	2	0.0392	0.5	0.0098	3	0.0588
A	a2	0.0504	2.5	0.1260	0.7	0.0352	3.5	0.1764
	a3	0.0980	3	0.2940	1	0.0980	4	**0.3920**
	a4	0.1120	3	0.3360	2	0.2240	4.5	**0.5040**
	b1	0.0418	1	0.0418	1	0.0418	3	0.1254
B	b2	0.0684	3	0.2052	2	0.1368	4.5	0.3078
	b3	0.0798	4	0.3192	2.5	0.1995	5	**0.3990**
	c1	0.1050	3	**0.3150**	1.5	0.1575	1	0.1050
C	c2	0.0840	3	0.2520	1.5	0.1260	1	0.0840
	c3	0.0525	4	0.2100	2	0.1050	1.5	0.0787
	c4	0.0595	5	0.2975	2.5	0.1487	2	0.1190
	c5	0.0490	5	0.2450	3	0.1470	3	0.1470
	d1	0.0198	2	0.0396	2	0.0396	1.5	0.0297
D	d2	0.0540	3	0.1620	3	0.1620	2.5	0.1350
	d3	0.0522	3	0.1566	4.5	0.2349	3	0.1566
	d4	0.0486	5	0.2430	4.5	0.2187	3	0.1458
	d5	0.0054	1	**0.0054**	2.5	0.0135	4	0.0216
		sum		3.2875		2.0981		2.9858

The table showing the results of the evaluation of variant locations shows large discrepancy of the values –from 0.0054 to 0.504. This is the consequence of conducting the assessment on two levels: criteria and subcriteria. Following multiplication, values of the criteria presumed to be important increase while values of the criteria thought to be less important decrease. It is also noticeable that the data achieved are displayed in a form of quite a complicated table, containing a wealth of information, which makes the interpretation of results more difficult.

4.2. The Point Method evaluation

When the Point Method is applied, surveys are constructed so as to allow the user to evaluate all the analyzed factors directly. Such an evaluation leads to less differentiation of the values, hence it is more difficult to distinguish more important criteria, which means that the final decision is likewise more difficult to make. The results of an assessment of the criteria with the Point Method are given in table 3, while the outcome of an evaluation of the analyzed variants is summarized in table 4.

Table 3. Direct evaluation of criteria.

Criteria	Weights
A1 – connections with the local transportation network,	0.07
A2 – solutions regarding access to the site,	0.05
A3 – public transport availability,	0.07
A4 – distance to the city centre;	0.06
B1 – access to an electric power network,	0.08
B2 – access to waterworks,	0.06
B3 – access to a sewage system;	0.06
C1 – load bearing capacity of the subsoil,	0.08
C2 – type of soils,	0.07
C3 – depth of the bearing subsoil level,	0.05
C4 – level of groundwater,	0.06
C5 – land relief,	0.06
D1 – distance to offices of architecture and construction supervising authorities,	0.04
D2 – degree to which local plans are developed,	0.05
D3 – degree to which the local commune's strategy and development plans are elaborated,	0.06
D4 – additional consensus (e.g. nature protection) required,	0.04
D5 – expert opinions required.	0.04
sum	1.00

Table 4. Evaluation of variants with the Point Method .

Criteria	Weights	w1	w2	w3	rating w1	rating w2	rating w3
a1	0.07	2	0.5	3	0.14	0.035	0.21
a2	0.05	2.5	0.7	3,5	0.125	0.035	0.175
a3	0.07	3	1	4	**0.21**	0.07	**0.28**
a4	0.06	3	2	4.5	0.18	0.12	**0.27**
b1	0.08	1	1	3	0.08	0.08	**0.24**
b2	0.06	3	2	4.5	0.18	0.12	0.27
b3	0.06	4	2.5	5	**0.24**	0.15	0.3
c1	0.08	3	1.5	1	**0.24**	0.12	0.08
c2	0.07	3	1.5	1	0.21	0.105	0.07
c3	0.05	4	2	1.5	0.2	0.1	0.075
c4	0.06	5	2.5	2	0.3	0.15	0.12
c5	0.06	5	3	3	0.3	0.18	0.18
d1	0.04	2	2	1.5	0.08	0.08	0.06
d2	0.05	3	3	2.5	0.15	0.15	0.125
d3	0.06	3	4.5	3	0.18	0.27	0.18
d4	0.04	5	4.5	3	0.2	0.18	0.12
d5	0.04	1	2.5	4	0.04	0.1	0.16
sum	1.00				3.055	2.045	2.915

The presentation of the results is much clearer. Table 3 contains a direct set of criteria and their assessment. The effect of an evaluation of the variants achieved with this method is similar to the one obtained through the hierarchy analytical process, but it is possible to notice less differentiation of the final values. The graphic presentation given in figure 3 manifests one of the disadvantages of using this method, where all criteria are submitted to analysis on the same level. Many similar values are achieved and this makes it difficult to distinguish unambiguously factors contributing to the predominance of one of the variants in further evaluation.

This problem becomes even more evident when we compare this figure to figure 4, where larger differentiation of the results is obtained from an analysis of the main criteria followed by an assessment of the subcriteria. Figure 4 clearly shows that the most important criteria which decide about the choice of a variant solution are A3, A4 and C1.

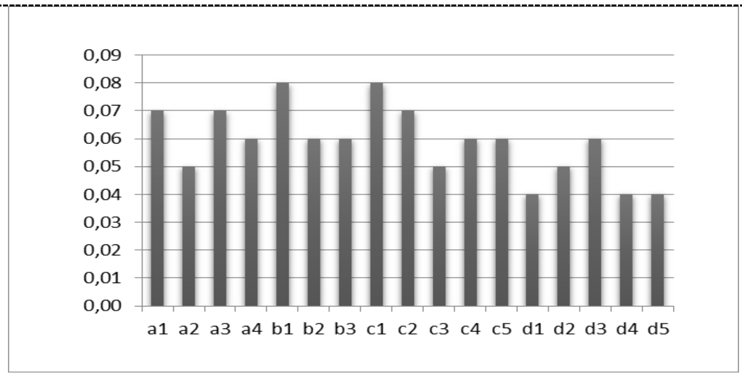

Figure 3. Distribution of values of criteria achieved with the hierarchy analytical method.

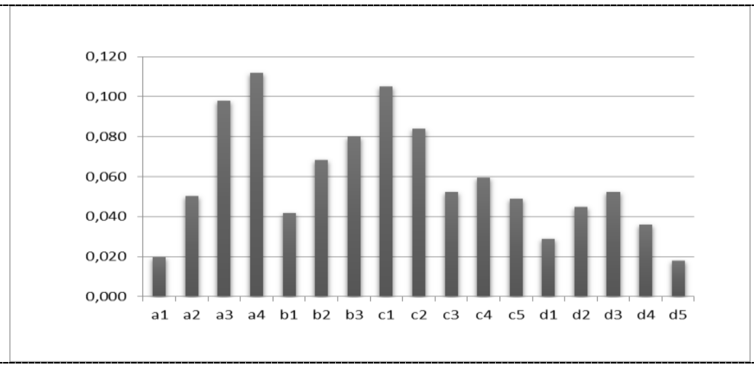

Figure 4. Distribution of values of criteria achieved with the point method.

4.3. The indicator method

For comparison, let us present a solution achieved with the indicator method, developed and discussed in detail by Szafranko [11]. The starting point for this multi-criteria analysis accomplished with the indicator method (similarly to the ones carried out with other multi-crtiteria methods) is to define the criteria which will be applied to evaluate individual variants of an investment project. The assessment to what extent these variant solutions satisfy the set requirements is the most essential stage of the analysis and calls for the participation of many experts [7, 11]. Experts' opinions are collected by an interview carried out in the form of questionnaires. Because the indicator method allows the user to take into account negative effects that the development project might have on the environs, this option should be included in the questionnaire. The survey addressed to experts in the indicator method is different from the other ones mainly in that it lets respondents assign negative scores if expected effects of a project are adverse. Thus, the survey contains questions to which answers are to be given on another scale. When evaluating variants with this method, the criteria chosen for the procedure can be evaluated on a scale, for example, from -5 to +5. Another feature of the indicator method that distinguishes it from other approaches is that it evaluates direct and indirect effects of the analyzed project.

The indicator method uses matrices (constructed in the form of tables), in which individual criteria are described and each subsequent criterion is assigned a weight. The relevant information is set so as to encompass all the analyzed location variants. The number in the left field describes the direct effect while the one in the right field refers to the indirect effect. The sum of effects multiplied by the weight is given in the middle. The sum of individual effects is the partial evaluation of a given variant [11]. Table 5 shows calculations for the case discussed in this article.

Table 5. Matrix of calculations for the indicator method.

Criterial	**subcriteria**	**variant 1 of investment (w1)**			**variant 2 of investment (w2)**			**variant 3 of investment (w3)**			**Weights [W]**
A	A1	1	0.21	2	2	0.28	2	4	0.49	3	0.07
	A2	2	0.25	3	3	0.3	3	3	0.30	3	0.05
	A3	1	0.21	2	4	0.56	4	5	0.70	5	0.07
	A4	1	0.12	1	2	0.24	2	3	0.42	4	0.06
B	B1	1	0.24	2	4	0.64	4	4	0.56	3	0.08
	B2	1	0.12	1	4	0.54	5	3	0.3	2	0.06
	B3	2	0.18	1	3	0.42	4	2	0.24	2	0.06
C	C1	-1	0	1	-1	-0.16	-1	-1	-0.16	-1	0.08
	C2	-1	0.14	3	-1	0.07	2	-1	-0.07	0	0.07
	C3	2	0.05	-1	-1	-0.1	-1	2	0.05	-1	0.05
	C4	-1	0.06	2	-1	-0.12	-1	-1	0.06	2	0.06
	C5	1	0.12	1	1	0.12	1	-1	0	1	0.06
D	D1	0	0.08	2	-1	-0.04	0	-2	-0.04	1	0.04
	D2	0	0.05	1	0	0.05	1	-1	-0.05	0	0.05
	D3	-2	0.06	3	1	0	-1	0	0.06	1	0.06
	D4	-1	0	1	-1	-0.04	0	-1	0.08	3	0.04
	D5	1	0.08	1	0	0.04	1	1	0.08	1	0.04
		sum	1.97		sum	2.8		sum	3.02		

The detailed analysis of indirect and direct effects for all the variants proves that both indirect and direct effects are felt as positive ones in regard of the accessibility and infrastructure criteria. Such a high assessment of the fulfillment of these criteria prevails in assigning variant 3 the highest position. With respect to criteria from groups C and D, their low fulfillment does not alter the final value of the evaluation. Regarding the subcriteria from these groups, direct effects are assessed negatively far more often. The information in the row 'sum' in the final setting of data (tab. 5) points to variant 3 as the most favorable one. The main reason is the positive outcome of the evaluation of group A subcriteria, and particularly the high assessment of the fulfillment of subcriteria A3.

5. Conclusions

The analysis of variant locations of a housing development completed with three methods shows the usefulness of multi-criteria methods in this type of decision making problems. Having several variant locations, we must take into consideration many factors which enable us to evaluate the variants. The methods presented in this article have their specific characteristics, and a choice of one over the others may depend on their advantages and disadvantages. The first method, by evaluating criteria grouped as main ones and subcriteria, yields evident differentiation of the analyzed decision factors. However, it requires complicated calculations and the resulting values set in tables are less readable than the outcome of the point method. In both methods, however, the way questionnaires are prepared and the generated information is processed are similar. The approach followed in the third method, i.e. the Indicator Method, is completely different. This method allows the user to take into account negative impacts as well as direct and indirect effects of the planned development project, and therefore it is different in character from the other two methods. It also generates much more differentiated results of the final assessment of the variants.

Despite the differences in the three approaches, indicated above, the results obtained in all the cases are similar (figure 5). Although the highest score was assigned to variant 3 by the Indicator Method (evaluated as the second best by the other two methods), the differences in the scores are almost negligible. All the proposed decision support methods scored variant 2 the lowest.

The calculations presented in the article have demonstrated the usefulness of multi-criteria methods as a tool supporting the decision making process when the dilemma arises as to where a development project should be located. It should be emphasized that although there are certain different characteristics between the three methods, they all produce similar results and their advantages highlight their versatile applicability in the engineering practice.

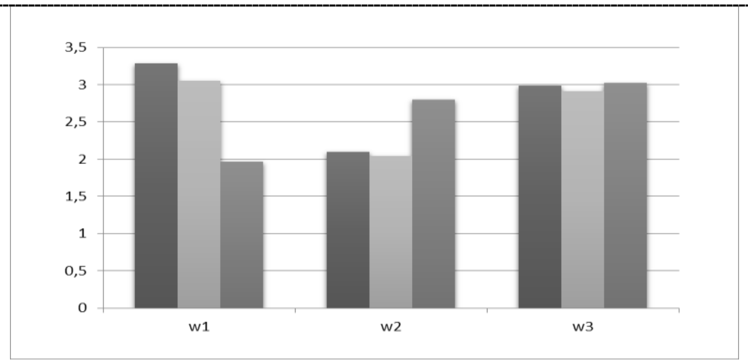

Figure 5. Comparison of results of the evaluation of location variants achieved by the three methods.

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