EVALUATION OF POSSIBILITIES OF INVESTMENT USING RURAL AREAS WITH MULTICRITERIAL ANALYSIS

Elzbieta Szafranko
University of Warmia and Mazury in Olsztyn, Poland
elasz@uwm.edu.pl

Abstract. Rural areas, which may be used for a variety of investments, are becoming increasingly more attractive to investors. Various characteristics of certain areas define their attractiveness. Features assigned to areas as assessment criteria can be included in preliminary analyses. The paper presents methods of selecting the assessment criteria and performing multicriteria analyses with the aim of evaluating the suitability of land for a specific function. This paper explores the applicability of multicriteria analytic methods to estimating the values of land parcels chosen as alternative locations of an investment project. The study analyzes various aspects of an assessment of a land lot that could be used for development, taking into account the features typical of non-urbanized areas. Two methods of multicriteria analyses are discussed in greater detail and applied to the problem presented in the article.

Keywords: location of an investment, criteria for the location of an investment, multicriteria analysis.

Introduction

Sufficient supply of land for new construction developments is essential for sustaining the urban growth. However, in many areas it is difficult to secure land for new buildings. Most of the land is owned by municipalities or private persons, while many land lots are zoned for public uses. Moreover, prices for land parcels in town centres are usually very high, which encourages a growing number of developers to move outside the town borders. Consequently, suburban land that belongs to rural communes but lies in the vicinity of large towns or cities is becoming extremely attractive. Prices of land parcels outside the town borders are an additional advantage to locating a building investment project in rural surroundings. Rural areas around large cities are more and more often developed for commerce, services and small industrial activities. Rural communes adjacent to urban centres are also chosen for developing new housing estates. Statistical data regarding the land use structure and trends in using farmland near cities confirm that the share of agricultural land is decreasing to the advantage of land used to erect objects for commerce, services or residential purposes. The aim of this paper has been to discuss the possibilities of applying a multicriteria analysis for an estimation of assets of land lots selected while searching for the best location of a new investment project [1; 2].

The problem of choosing the location of an investment, decision-supporting methods

With a multitude of available methods and techniques used for analyzing variant solutions, it is frequently difficult to decide which method would work best in a given case. When selecting a method, one should pay attention to such features as transparency, quality and verifiability of the results as well as the mathematical solutions involved. Also, it is worth considering the question of subjectivity inherent to evaluation because many of the popular methods are based on opinions given by experts and persons involved in an investment project. As a result, their assessments and the final evaluation can be burdened with some error, which should not be overlooked [3; 4].

Two of such methods will be discussed below to illustrate typical procedures. These are the most popular methods that share one characteristic feature, namely the calculations proceed in steps: first, weights are assigned to criteria, then the importance of the criteria is agreed on and finally the degree to which these criteria are satisfied by subsequent variants is assessed. All evaluations are performed according to the knowledge of an investor and architects, in-field interviews as well as surveys distributed among experts and persons involved in the planning of a given investment [5; 6].

Description of the methods

The MCE (Multi-Criteria Evaluation) analytic method can support a decision-making process that involves from a few up to twenty criteria [7; 8]. This method is very often used to help select the best location. The overall objective is to achieve one, shared result. The first step in an MCE analysis is to determine criteria leading to the planned aim. The criteria which appear in the MCE method can be divided into two groups:

- constraints (hard criteria) – barriers, obstacles;
- factors (soft criteria) – parameters.

The second step is to determine the suitability, which is derived from the formula:

$$S = \sum_{i-1}^{n} w_i \cdot x_i \;\; i \in \langle 1, n \rangle , \tag{1}$$

where S – suitability,
w – weight of the criterion,
x – value of the parameter,
i – subsequent criterion,
n – number of the criteria.

The above equation is transformed to the one given underneath if an analysis additionally contains hard criteria, i.e. barriers:

$$S = \sum_{i=1}^{n} w_i \cdot x_i \prod_{j=1}^{n} c_j , \tag{2}$$

where c_j – j^{th} constraint.

The criteria chosen for an analysis serve to determine whether a given location satisfies the pre-defined conditions. When the hard method is applied, criteria are equated with barriers (e.g., no further than 200 m from a water body, the slope angle of the land no more than 3º). Then, the suitability assessment is a zero-one type of evaluation (suitable – 1, unsuitable 0). In other cases, criteria are defined as soft ones (e.g., the further from a road, the better; the flatter the land parcel, the better). The evaluation consists in assigning scores on a previously adopted scale [9; 10].

The other method discussed herein is the analytic hierarchy process (the AHP method), which allows one to include a wide variety of criteria that lead to the attainment of a set goal. The principal assumption is that the ultimate goal can be achieved through a series of partial goals. All analyzed alternative solutions, to a certain extent, meet the expectations. The degree to which the overall aim is achieved by each alternative decision is specified by the degree to which the main criteria as well as sub-criteria arranged in hierarchical structures are fulfilled. The decomposition of the main problem, which is the essence of the AHP method, facilitates evaluation [11; 12]. There are three steps in the analytical process guided by the AHP method. These steps are connected in an integrated and logical sequence:

1. Creating a model of hierarchy (determination of criteria),
2. Evaluating the criteria on a 9-score scale;
3. Assessing and arranging the judgements by establishing priorities (main weights) alongside an analysis of vectors of partial priorities.

For the purpose of assessing variant solutions, a hierarchical model of the structure of a given problem is created. During the process, all criteria at the same level of the hierarchy are compared pairwise, thus identifying their mutual relations and deciding which ones are more important and to what extent they affect the performance of the analyzed project. Pairwise evaluation of criteria and determination of the remaining elements lead to the construction of a preference matrix, which is composed of terms a_{ij} and reverse elements $1/a_{ij}$. Literature [8] provides us with calculation formulas applied at the subsequent steps, which eventually lead to the calculation of the value of a priority index.

The final step in an analysis of alternative solutions according to the AHP method is the identification of the variant that satisfies the predetermined criteria to the highest degree. To this aim, calculations are run in order to answer the question to what degree individual criteria are fulfilled by each of the alternative solutions. Values of the vectors of priorities for each of the superior criteria and individual variants in the context of the analyzed criteria are examined as sums of their products.

$$w_i^A = \sum \overline{w_i^K} w_i^w , \tag{3}$$

where w_j^K – vector of priorities for main criteria
w_i^w – vector of priorities for variants .

Identification of the decision problem

The decision problem such as a choice of a land parcel for a development project will be illustrated by discussing some elements of a possible analysis of the best location when three options are available [13]. For the future building development, the following criteria are said to be dominant:

A. Transport: A1 – connection to the local transportation network, A2 – accessibility, A3 – possibilities of using public transport, A4 – distance to the town centre;
B. Technical infrastructure: B1 – access to an electrical grid, B2 – access to water pipelines, B3 – access to sewerage;
C. Land and groundwater conditions: C1 – bearing capacity of soil, C2 – type of soil, C3 – depth of the bearing layer of soil, C4 – level of the groundwater, C5 – land relief,
D. Urbanistic and planning criteria: D1 – distance to administration offices, D2 – progress in making local management plans, D3 – progress in creating the development strategy for the commune, D4 – need to obtain other permits (environmental protection), D5 – need to obtain expert opinions and consent.

The above problem was solved with the two discussed methods. The analysis was completed for two groups of criteria, which were perceived as crucial for the planned investment. These were the criteria A – transport, and C – land and waterground conditions, sufficient to support the designed construction.

The MCE analysis (Multi-Criteria Evaluation)

In line with the procedure, described earlier in the paper, the first step in an MCE analysis is to identify the criteria, which will lead to reaching the planned goal. In our example, all criteria are expressed as parameters. The method does not limit the number of conditions compared simultaneously. Hence, it is possible to prepare a set of all criteria. From the formula given previously, we can calculate the suitability of each alternative solution. The weights were pre-defined by the investor, who considered conditions ensuring the success of the whole investment. The values of the weights are enclosed in the range of 0-1. Values of the parameters in each variant solution were determined according to the opinions expressed by the experts, architects, designers and the investor. A scale of scores from 0 to 6 was adopted, where 0 stands for failure to satisfy a given criterion while 6 means fulfilling the criterion to the highest degree. The calculations are presented in Table 1.

Table 1

Multi-criteria evaluation for three variants of the investment

No	Analyzed criteria	Weight of a criterion (w)	Value of parameter (x) for variant 1	Fulfilment of criterion by variant 1	Value of parameter (x) for variant 2	Fulfilment of criterion by variant 2	Value of parameter (x) for variant 3	Fulfilment of criterion by variant 3
1	A1	0.05	4	0.20	3	0.15	5	0.25
2	A2	0.02	5	0.10	4	0.08	3	0.06
3	A3	0.10	3	0.30	4	0.40	6	0.60
4	A4	0.03	4	0.12	3	0.09	2	0.06
5	C1	0.40	6	2.40	3	1.20	2	0.80
6	C2	0.10	3	0.30	3	0.30	3	0.30
7	C3	0.05	2	0.10	3	0.15	5	0.25
8	C4	0.20	3	0.60	4	0.80	5	1.00
9	C5	0.05	4	0.20	4	0.20	5	0.25
-	Sum	1.00	-	**4.32**	**-**	**3.37**	**-**	**3.57**

The data comprised in Table 1 show to what extent partial criteria are satisfied and the sum represents the total score that indicates which variant satisfies the analyzed criterion to the highest degree. The analysis suggests that location 1 is the best one.

The AHP analysis (Analytic Hierarchy Process)

The calculations were performed according to the procedure described in literature. The first step consisted in pairwise comparisons of the main criteria.

Table 2

Matrix of comparisons for main criteria

Superior criteria	**A**	**B**	**C**	**D**
A	1.00	0.5	0.14	0.50
B	2.00	1.00	0.33	3.00
C	7.00	3.00	1.00	5.00
D	2.00	0.33	0.20	1.00
Sum a_{ij}	12.00	4.83	1.67	9.50

Table 3

Values of the normalized matrix and priority vector for main criteria

Superior criteria	**A**	**B**	**C**	**D**	**sum wij**	**Vector of priorities W_j**
A	0.0833	0.1034	0.0852	0.0526	0.3246	0.0812
B	0.1667	0.2069	0.1989	0.3158	0.8882	0.2221
C	0.5833	0.6207	0.5966	0.5263	2.3269	0.5817
D	0.1667	0.0690	0.1193	0.1053	0.4602	0.1151

- we determine the matrix maximum eigenvalue:

$$\lambda_{\max} = \frac{1}{w_i}\sum_{i=1}^{n} a_{ij} w_j = 12.00 \text{ x } 0.0812 + 4.83 \text{ x } 0.2221 + 1.67 \text{ x } 0.5817 + 9.50 \text{ x } 0.1150 = 4.11528$$

- value of the consistency index:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} = \frac{4.11528 - 4}{4-1} = 0.0384$$

- consistency ratio:

$$C.R. = \frac{C.I.}{R.I.}$$ where *C.R.* should reach the value < 10 %, *R.I.* = 0.9 [8]

$$C.R. = \frac{0.0384}{0.9} = 0.0427 \text{ x } 100\ \% = 4.27\ \%$$

In many cases, it was also necessary to analyze partial criteria gathered in subgroups subjected to the respective main criteria. A need to analyze subcriteria arises from the limited number of the main criteria brought to direct comparisons and, on the other hand, from the fact that some criteria are difficult to compare directly. In the case discussed here, there are 3 variant locations of the investment. Each variant meets the predefined criteria, *albeit* to a different degree. Because our main interest is to ensure good accessibility of the developed area and proper soil conditions, we will conduct pairwise comparisons for the subcriteria from groups A and C.

Table 4

Matrix of comparisons of the variants in the context of criterion A

Variant	w_1	w_2	w_3
w_1	1.00	0.50	0.33
w_2	2.00	1.00	0.50
w_3	3.00	2.00	1.00
Sum	6.00	3.50	1.83

Table 5

Values of the normalized matrix and priority vector for the variants – c. A

w_{ij}	w_1	w_2	w_3	Sum w_{ij}	Vector of priorities W_i^w
w_1	0.166667	0.142857	0.181818	0.491342	0.1638
w_2	0.333333	0.285714	0.272727	0.891775	0.2973
w_3	0.500000	0.571429	0.545455	1.616883	0.5390

The priority vector values achieved for the analyzed variants show that variant 3 fulfils the best the expectations regarding the ease of access.

Table 6

Matrix of comparisons of the variants in the context of criterion C

Variant	w_1	w_2	w_3
w_1	1.00	3.0	5.00
w_2	0.33	1.0	2.00
w_3	0.20	0.5	1.00
Sum	1.53	4.5	8.00

Table 7

Values of the normalized matrix and priority vector for the variants – c. C

w_{ij}	w_1	w_2	w_3	Sum w_{ij}	Vector of priorities W_i^w
w_1	0.652174	0.666667	0.6250	1.943841	0.6479
w_2	0.217391	0.222222	0.2500	0.689614	0.2299
w_3	0.130435	0.111111	0.1250	0.366546	0.1222

$\lambda_{\max} = 3.005395$; $C.I. = 0.0027$; $C.R. = 0.00465$ x 100 % =0.465 % < 10 % ; $R.I.$ = 0.58 [8].

The analysis of the land and soil conditions proves that the expectations concerning this set of criteria are best fulfilled by variant 1.

It will be interesting to see, which aspect will play a decisive role. To find out, calculations are run to explore to which extent the individual criteria are satisfied by the subsequent variants. Values of priority vectors for each superior and subordinate criterion in individual variants, in respect of the analyzed criteria, are investigated as sums of their products. Our analysis will be limited to some of the criteria.

$$w_i^A = \sum \overline{w_i^K} w_i^w$$

where w_j^k – vector of priorities for main criteria;
w_i^w – vector of priorities for variants.

For the 1st variant W_1 = 0.5817 x 0.6479 + 0.0812 x 0.1638 = 0.3769 + 0.0133 = **0.3902**.
For the 2nd variant W_2 = 0.5817 x 0.2299 + 0.0812 x 0.2973 = 0.1337 + 0.0241 = **0.1578**.
For the 3rd variant W_3 = 0.5817 x 0.1222 + 0.0812 x 0.5390 = 0.0711 + 0.0438 = **0.1149**.

This stage of our analysis, similarly to the previous set of calculations, demonstrates that the first variant best satisfies the previously established criteria.

Results, discussion and conclusions

While planning and preparing a development investment project, it is extremely important to work out and analyze various aspects of the undertaking. Among the most essential questions raised in the early stage is where to locate a building investment. An overview of available development parcels should be aided by decision supporting methods. The two methods discussed above can be successfully used to analyze measurable and non-measurable criteria, which describe specific areas available as building parcels. The MCE method allows us to make a direct comparison of all criteria. The AHP method, by decomposing the main criteria, enables us to understand which parameters contribute to the weight of each main criterion.

Both methods yielded comparable results. Variant 1 scored the highest in our analyses conducted according to the MCE and AHP methods. Diagrams in Fig. 1 demonstrate that the dominant position of variant 1 in either case stemmed from the fact that the land parcel in question offered better land and groundwater conditions (group C criteria). The difference between the assessment results regarding variants 2 and 3 is small. While the MCE analysis placed variant 3 on the second position, the AHP analysis gave it the third place, but this was of no importance. As seen above, the two methods create different analytical opportunities, but the end results coincide with each other. Variant 1 is that alternative solution, which fulfils the set location criteria to the highest degree.

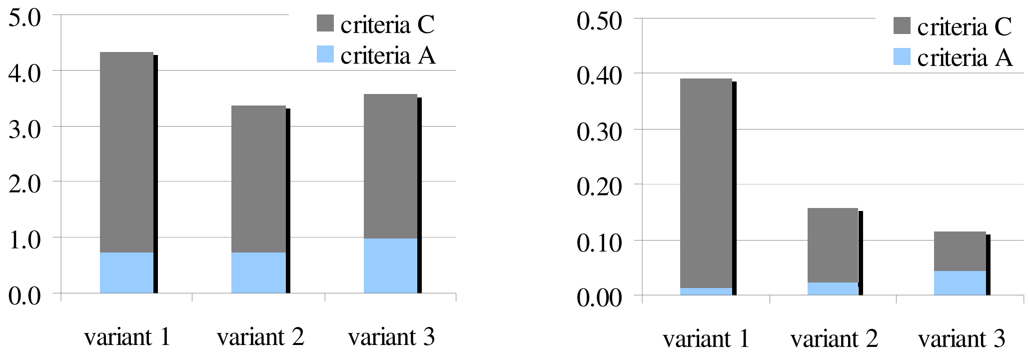

Fig. 1. **Diagram illustrating scores assigned to the analyzed criteria of the three variants by the MCE and AHP method**

The comparative analysis proves that the methods developed in the field of multicriteria analysis are suitable for assessment of different location variants of construction projects. It also emphasizes the usefulness of such analyses in the building practice.

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