ANALIZA INVESTICIJSKEGA POTENCIALA LOKACIJE Z METODO AHP

ANALYSIS OF THE INVESTMENT POTENTIAL OF LOCATION USING THE AHP METHOD

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IZVLEČEK

Študija se nanaša na področje vrednotenja območij med mejo mestnega območja in podeželjem z vidika mogočih prihodnjih investicij. Glavni namen študije je bil razviti postopek za določevanje investicijskega potenciala območja AIP *(angl.* area's investment potential*) za urbana in priurbana območja. Za namene vrednotenja intenzitete investicijskega potenciala lokacije je bil uporabljen analitični hierarhični postopek* AHP *(angl.* analytic hierarhy process*), ki temelji na podatkih planske rabe in infrastrukturne opremljenosti ter na podatkih dejanske rabe prostora. Predlagani pristop je bil preverjen na območju hitro rastočega dela mesta Olsztyn na Poljskem. Obravnavana območja so bila razvrščena na temelju predhodno določene hierarhije obravnavanih značilnosti prostora. Z opredelitvijo mogočih smeri razvoja obravnavanih območij je bil opredeljen investicijski potencial AIP. Predlagani pristop je lahko pomembno orodje za nadzorovanje razvoja območij in vlaganje v zemljišča. Rezultati študije so pokazali, da na investicijski potencial lokacije najbolj vpliva planska raba, pri čemer pa je treba upoštevati tudi prostorske ovire, ki jih je treba preseči na hitro razvijajočih se območjih.*

ABSTRACT

*The presented study deals with the issue of an assessment of an area within the boundary zone between the city and the countryside in terms of predicting future investments. The main aim was to develop a procedure for determining an area's investment potential (*AIP*) for urban and suburban areas. The* Analytic Hierarchy Process *method was applied to assess the intensity of the investment potential location based on its planning and infrastructural features as well as on the features resulting from the current use. The developed procedure was tested using the area of a rapidly developing part of the Polish city of Olsztyn. Based on the prepared graph presenting the hierarchy of features, the final ranking of areas was prepared and the investment potential (*AIP*) was determined by specifying the probable directions of the city development. The proposed procedure may appear to be a useful tool in controlling the process of developing and investing in the land. The study results indicate that for the investment potential of location, the factors defined as planning factors are of key importance, while particular importance should be attached to spatial barriers which are the most difficult to overcome in a rapidly developing area. The features associated with the current land use appeared to be the least important.*

KLJUČNE BESEDE

lokacija, vrednotenje lokacije, prostorski razvoj, razvoj mest, investicijski potencial, analitični hierarhični postopek, AHP

KEY WORDS

location, assessment of location, spatial development, city development, investment potential, Analytic Hierarchy Process, AHP

1 INTRODUCTION

The process of city development refers to transformations taking place within an existing urban system or within the areas closely adjacent to a city. The indication of development opportunities for these areas in relation to their features, and an attempt to determine the pressure of the areas that have already been invested in, pose important challenges to urban planning researchers (Frey and Zimmer, 2001). They found that planning practice is grappling with new treatments of place, based on dynamic, relational constructs, rather than the Euclidean, deterministic, and one-dimensional treatments inherited from the 'scientific' approaches of the 1960s and early 1970s (Graham and Healey, 1999). But such emerging planning practices remain poorly served by planning theory, which has so far failed to produce sufficiently robust and sophisticated conceptual treatments of 'place' in today's globalizing world. The tools that need to be developed should enable the prediction of the directions of the city area development based on increasingly extended bases of information on the area, i.e. geo-information databases (Nowak Da Costa, 2016)

The resources of information on areas, collected using spatial information systems, enable an increasingly wider and more complete imaging of spatial relationships which provide knowledge of the features of the area and the intensity of phenomena occurring within this area (Renigier-Biłozor, 2017). They also enable the identification of areas with features supporting the urbanisation process. On the other hand, methods for the use of this geo-information in order to locate such places more efficiently are still being sought (Kowalczyk, 2015).

The *main problem* in the identification of the investment potential is to determine the weights of location's features so that they can express the actual relationship between this feature's value and the investment potential. The main problem in the identification of the investment potential is to determine the weights of location's features so that they can express the actual relationship between it's value and the investment potential. The *investment potential* of location is defined as a set of advantages of a place, because certain areas have better conditions for investment than others. According to another definition, investment potential is the ability to make investors choose a place and invest in it (Biłozor and Renigier-Biłozor, 2016). This study puts an emphasis on examination of components of area for investment in terms of spatial. Problems of such analyses are apparent from subjectivity in the assessment of the effects of particular features on the investment potential. This subjectivism is a factor which cannot be omitted in spatial studies, although it cannot be ignored either.

This problem results from subjectivity in the assessment of the effects of particular features on the investment potential. This subjectivism is a factor which cannot be omitted in spatial studies.

The *main aim* of the conducted study was to develop a procedure for determining location's investment potential (*AIP*) based on the available GIS databases in such a manner that the highest level of objectivity of the assessments of the criteria regarded as subjective can be achieved and that tools efficiently responding to changes occurring within the area can be provided.

In response to the presented problem and to its complex nature resulting from the complex nature of the area itself, a decision was made to apply multicriteria decision support methods. These methods include the AHP (Analytic Hierarchy Process) method, whose application supports various decision-making processes.

2 THE PRINCIPLES OF OPERATION OF THE ANALYTIC HIERARCHY PROCESS

The AHP method applied in the analysis was developed by an American scientist Saaty (1988). The advantage of the method is the opportunity to compile, within one decision-making process, many various criteria that are described both numerically and verbally. The method is supported with certain automatism of the assessment, which increases the degree of their objectivity, not only on the basis of repeatability of research and the inclusion of a greater group of assessors into it. This automatism involves the construction of a final assessment from the comparison of various features in pairs, which is a process much simpler and objective than the assessment of a set of features at the same time. The AHP, mainly due to the clarity of the methodological argument, has become one of the better-known decision-making methods. Despite (and perhaps due to) its originality, resulting from a different approach in the process of prioritising solutions, the method has found various different applications (Zahedi, 1986; Vargas, 1990; Forman and Gass, 2001; Ramanathan, 2001). This is because it enables the introduction of a relative scale of grades, i.e. priorities for countable and uncountable criteria. The final assessment of the variants is based upon results of scientific and expert opinions, existing measurements and statistical data. To carry out an assessment of descriptive features, it is necessary to present the mutual significance of features in a numerical form, e.g. by using Saaty's fundamental comparison scale, which is described later (Adamus and Gręda, 2005). In order to be able to do it scientifically, the so-called reversible pairwise comparisons need to be performed. They involve a description of the overriding significance, in the decision-making process, of feature i over feature j in such a manner so that where the significance may be defined as p_{ij}, then the relation of j over i will be described as $1/p_{ji}$, while the relation $p_{ii} = 1$ (Saaty, 2001).

The analytical argument providing a basis for the operation of the AHP is a record of relations between the importance of the criteria taken into account in the decision-making process. It is presented as an n-dimensional matrix, where n is the number of criteria taken into account in the analysis and w_n are the weights that these criteria weigh in the assessment (Klutho, 2013).

The unknown in the actual solution of problems is the determination of the relation w_i/w_j. It is close to the significance resulting from the application of Saaty's scale. This relation can be written as follows:

$$A^0 = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \approx \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

The proximity of this relation is determined using the proximity of the maximum eigen value of matrix A^0 λ_{max}. For matrices of such a type, i.e. consistent matrices, in accordance with matrix algebra, λ_{max} is equal to n, and for paired comparison matrix A, λ_{max} should be close to n.

There is a possibility for separating an eigen vector from matrix A, which is a universal scale of values of weights of particular criteria. For the determination of vector W which enables the ranking of possible solutions, matrix A is normalised. In this case, the method of *averaged comparison matrix columns*, also referred to as the Saaty's method, was applied (Michnik, 2009). It involves the transformation of comparison matrix A to normalised matrix $\hat{A}$ by multiplying matrix A by vector S determined from the converse of the sum of columns of the elements of matrix A. In order to simplify the argument, each element of matrix A will be marked as a_{ij}. The product AxS yields a normalised matrix $\hat{A}$. Then, vector $\hat{W}$ is determined, the elements of which are the mean value of the sums of rows of matrices $\hat{A}$:

$$\hat{W} = \begin{bmatrix} \sum_{i=1}^{n} \hat{a}_{i1} \\ \sum_{i=1}^{n} \hat{a}_{i2} \\ \vdots \\ \sum_{i=1}^{n} \hat{a}_{in} \end{bmatrix} = \begin{bmatrix} \hat{w}_1 \\ \hat{w}_2 \\ \vdots \\ \hat{w}_n \end{bmatrix} \tag{2}$$

where: $\widehat{a_{ij}}$ – elements of matrix $\hat{A}$.

The correctness of the determination of the weight vector $\hat{W}$ must be confirmed by an assessment of compatibility (consistency) of matrix A. Saaty (2008) proposed an assessment of consistency using the consistency index CI and consistency ratio CR.

The consistency index is calculated using the following formula:

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

Whereas, if n reflects number of rows of matrices, it should also be borne in mind that it actually reflects the number of comparison alternatives and in order to maintain the consistency of matrices, the condition $n \leq 7+-2$ should be met (Saaty and Ozdemir, 2003). On the other hand, λ_{max} is the maximum eigen value of the comparison matrix, which can be determined as a value being in proximity, with sufficient accuracy, to that calculated from the equation:

$$\lambda_{\max} \approx \sum_{j=1}^{n} \left[\hat{w}_j \sum_{i=1}^{n} a_{ij} \right] \tag{4}$$

Therefore, it is a value close to the sums of products of values of the column sums of comparison matrices A and the normalised values of the weights recorded in vector $\hat{W}$.

It is also to be borne in mind that matrix A should be a consistent matrix, therefore $\lambda_{max} = n$, therefore CI should be equal to 0. However, a certain deviation from this equation is acceptable. It is assumed that the sufficient level of assessment consistency is guaranteed by the matrix for which the consistency ratio CR does not exceed 0.1 (Saaty and Vargas, 2012). Whereas, CR is equal to:

$$CR = \frac{CI}{RI} \tag{5}$$

where RI is the value of a random index, determined by the author of the method as a mean value of CI for a large number of randomly generated comparison matrices. Its values for n degree matrix are presented in Table 1.

Table 1: The value of a random index RI.

n	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	-	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49	1.51	1.54	1.56	1.57	1.58

n – degree of a matrix. Source: Saaty 2001.

If the following condition is met $CR \leq 0.1$ the weighting is considered to be correct and the determined standardized weight for the criteria is correct. If the condition is not fulfilled, the determination of the comparison matrix should be repeated.

In the AHP, the procedure for the assessment of variants possible in the investment process, i.e. the construction of a rating of possible solutions is reduced to a process comprising the following steps:

1. The distribution of a decision-making process into a hierarchically constructed process of criteria assessment.
2. The construction of comparison matrices for criteria and subcriteria at each level of their hierarchy using the universal assessment scale.
3. Determination of weight vectors in relation to particular matrices, depending on the hierarchical level of the criteria, which are referred to as global or local criteria depending on the hierarchical level.
4. An assessment of the consistency of particular comparison matrices. Where the acceptable value of CR is exceeded, the process of assessment through comparison should be repeated.
5. The construction of the ranking of considered variants based on the absolute product of global and local weights as well as normalised assessments of the criteria assigned to a specific variant.

The hierarchical structure of the process of ranking construction in the AHP method can be presented in a simplified form in accordance with Figure 1.

Figure 1: A theoretical hierarchical tree in the AHP. *R1,…Rx* -solutions. Source: own work based on Klutho, 2013.

In the procedure described, an important element is the determination of normalised parameters determined for the assessment of criteria in relation to specific solutions (*R1,…Rx*). In our case, the solutions should be considered equivalent to the basic fields (*r*) with certain features (citeria and subcriteria). Out of these features, criteria for the assessment of the investment potential of location E_{pr} were selected. E_{pr} było podstawą stworzenia ranking pól (*r*) jak na figure 1 (*R1,…Rx*). It was the basis for the creation of ranking the fields (*r*) as shown in Figure 1.

The selected criteria should be subjected to an assessment consistent to their characteristics. Where they are descriptive assessments, they should be subjected to point evaluation (Cieślak and Szuniewicz, 2015). The measurable criteria can be assessed based on their parameters or indicators reflecting their intensity. Eventually, for all obtained measures, the direction of the effect on the level of investment potential Ep should be determined. This should be followed by the normalisation of the considered criteria (Kobryń, 2014). Out of various manners of normalisation, the one being most congruent to the features due to the value span and the purpose of normalisation was selected (Pawlewicz, 2015). This guaranteed an effective operation for a value of the feature equal to 0, and the final span of the normalised features within the range of [0, 1]. Formulas (6) and (7) were used for this purpose:

The stimulants:

$$zn_{rj} = \frac{c_{rj} - \min c_j}{\max c_j - \min c_j} \tag{6}$$

The destimulants:

$$zn_{rj} = \frac{\max c_j - c_{rj}}{\max c_j - \min c_j} \tag{7}$$

where:

c_{rj} – denotes the values of *j*-th criterion for *r*-th field ($r = 1, 2, ..., m, j = 1, 2, ..., n$);

zn_{rj} – normalised value of *j*-th feature (indicator) for *r*-th field. The thus normalised values of the features fall within the numerical range of [0, 1].

The final ranking of the fields (E_r) was constructed by putting in order the sums of the products of normalised assessments of local subcriteria weights (w^l) obtained for these subcriteria multiplied by local weights (w^g) of relevant criteria.

$$E_r = \sum_{i=1}^{n} w_i^g \sum_{j=1}^{n} w_{ij}^l * zn_{rj} \tag{8}$$

3 DESCRIPTION OF THE AREA UNDER STUDY

The study was conducted in fast-growing districts and in a transition zone adjacent to the city of Olsztyn. The total studied area is slightly less than 414 ha. The predominant planning functions include multi-family and single-family residential functions. Furthermore, it should be emphasized that in the period preceding the stocktaking moment (2015), this area showed strong growth dynamics towards areas with high investment potential.

It should be noted that, at the current stage of development of cities with the size and importance comparable to those of Olsztyn, the residential function has the highest demand and is, thus, the best research object. Furthermore, there is a wide availability of public utility facilities and commercial and service facilities, which increase the investment value of the district and expand its development potential. The Jaroty district is one of the fastest-developing areas in Olsztyn.

This study attempted to assess the elements of area with the greatest impact on the potential of urban area development. At each time point, the evaluation of geo-information was performed by means of land quality assessment which yielded the Area Investment Potential. In order to unify and interpret the results, an analysis was carried out by dividing the surface into basic fields. It was decided that the selection of hexagon-shaped geometric fields would be the most optimal since it would create the possibility for more complete analysis and interpretation of results, particularly by means of interpolation. The surface of basic fields is 8,660 m^2. The selection of field size was driven by the size of record parcels that, in general, constitute a basic surface unit in the investment process (Szuniewicz et al., 2015). Due to different sizes of parcels, depending on their function, it was necessary to verify and adjust the surface of fields to the areas identified as individual investments, which were understood as:

- a set of parcels on which there were time-synchronised investments in single-family housings;
- the area on which a multi-family building was constructed, together with management of the surrounding area;
- a similar investment in commercial and service facilities.

Thirteen features which indicated the investments and their quality were analysed. These features were divided into three groups depending on their impact on investments:

Group P: Spatial elements (geo-information) influencing the decision to invest in urban areas. The factors that determine the occurrence of investment on a given area:

P1: Local Area Development Plan (LADP) adopted in a particular area – defined as a ratio of the area under the LADP to the total area of the basic field;
P2: The type and class of usable land – defined as a ratio of the investment-friendly usable land (without technical infrastructure areas, poor quality soils, wasteland and areas with different forms of nature conservation) to the total area of the basic field (%);
P3: Spatial barriers – defined as a ratio of the area of spatial barriers to the total area of the basic field (%);
P4: Topography – determination based on the difference between heights at measuring points in a particular basic field (meter);
P5: The structure of plots – defined as a ratio of the area of plots with an adverse structure to the total area of the basic field (%).

Group I: Geo-information on the availability and location of equipment of technical infrastructure measured using the accessibility defined as a distance between the line of technical infrastructure and the boundaries of the basic field (meter):

I1: Accessibility of water supply and distribution network;
I2: Accessibility of power distribution networks;
I3: Accessibility of sanitary drainage network;
I4: Accessibility of road infrastructure;
I5: Accessibility of central heating network;
I6: Accessibility of gas distribution network.

Group B: Spatial elements (geo-information) determining the quality of investment in urban areas in their functional and aesthetic context. These conditions indicate the correctness of structure on urban areas:

B1: MN – an area designated for development (the value of development indicator for the basic field);
B2: The structure of transportation areas – defined as a ratio of the area of transportation areas including roads, car parks, and pavements to the total area of the basic field (%);
B3: The structure of controlled greenery area – defined as a ratio of the area of controlled greenery land to the total area of the basic field (%);
B4: Investment – defined as a ratio of the area of the invested-into areas to the total area of the basic field (%).

The selection of features was preceded by a review of the literature on assessment and indexation of area, and was supported by a survey study carried out with the experts in spatial management and students from faculties related to spatial management (Strumillo-Rembowska et al., 2014; Cieslak et al., 2016; Przegon et al., 2017). The questionnaires served to create a system for evaluation of individual features and to assign a cumulative value to individual groups. The groups of features were arranged into a hierarchical solution scheme (Figure 2).

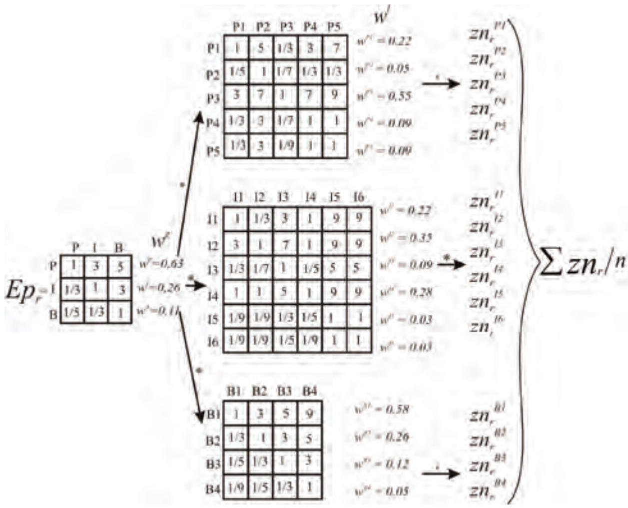

Figure 2: A hierarchical scheme of an assessment of the area. Source: own study.

The comparison matrices presented in Fig. 2 were constructed based on assessments of fifteen land management experts. Each of the experts completed 4 matrices using the Saaty scale. In 8 cases, they were filled out again because the first choice did not give the matrix consistency at the required level. Finally, 60 matrices were obtained for which *CR* =<0.1. Then, 15 values were compared for each of the 36 positions of the matrix (this applied only to the position beyond the transient matrix). Preliminary analysis allowed to conclude that the choices of the experts are consistent and show a clear convergence of decisions (in each case, it was a minimum of 30% of the choice for the same value). The final shape of the matrix was therefore determined based on the dominant (Kassyk-Rokicka, 2011) determined for each position of the matrix. This was followed by a study of the consistency of comparison matrices. The indices *CR* proved to meet the condition <0.1. Their values are presented in Table 2.

Table 2: Results of the assessment of comparison matrices of levels I and II.

Comparison matrices		CR
levels I	-	0.05
levels II	P	0.07
	I	0.07
	B	0.03

Source: own study.

Based on the matrices, local weights of criteria and subcriteria (w^g and w^l) were calculated (Fig. 2). Their product multiplied by the normalised assessment of subcriteria (zn_r), and for each field was a basis for the final ranking (E_r).

4 RESULTS

The first step concerned the inventory of the selected features of the land of the area under study divided into 478 hexagons being the basic fields of the assessment (r). The inventory was carried out based on an analysis of the existing planning documentation and the available cartographic studies detailed with results of field studies.

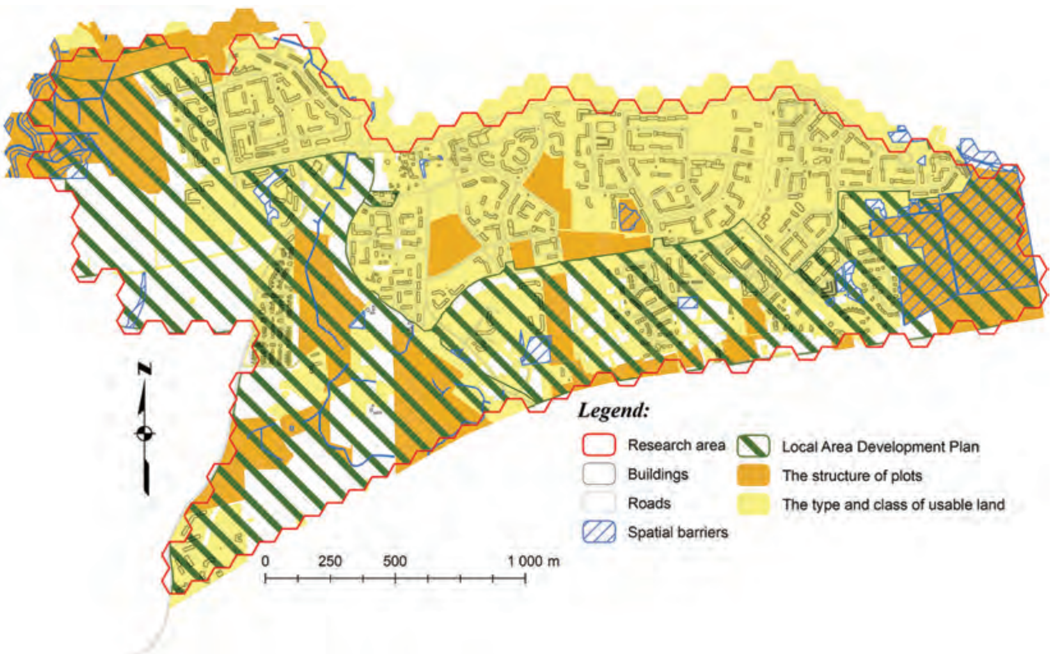

Figure 3: The inventory map of features in group *P* (P1, P2, P3, P5). Source: own study.

The inventory results are presented in maps (Figure 3,4,5,6), on which generalised results of the inventory, segregated in accordance with the groups of features, are found. On the map (Figure 3), features of group P are presented. Separately, in the same group, the feature *P4* – topography was presented (Figure 4). It was necessary for the maintenance of the legibility of drawings.

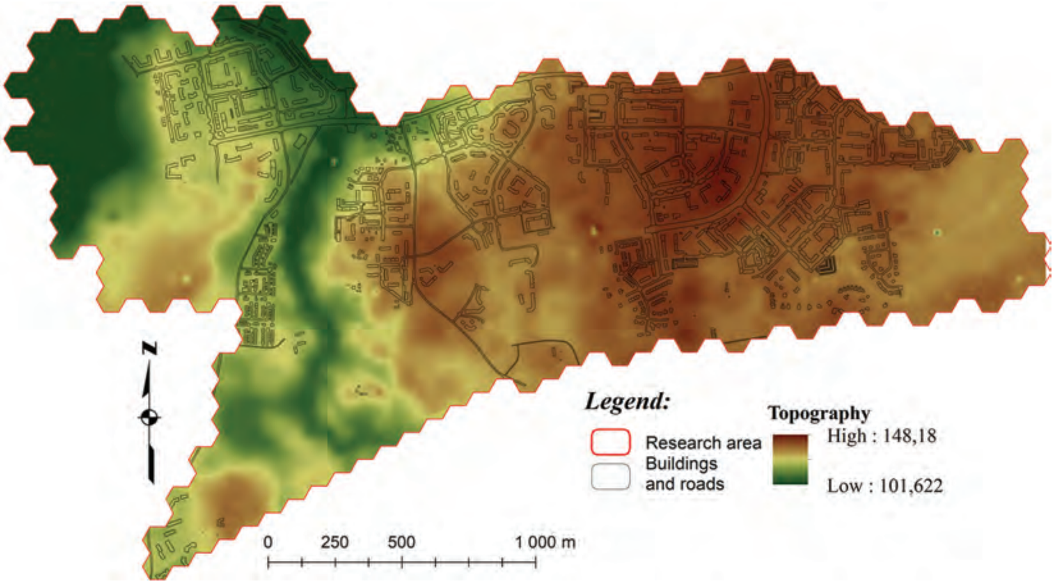

Figure 4: The inventory map of features in group *P* (P4). Source: own study.

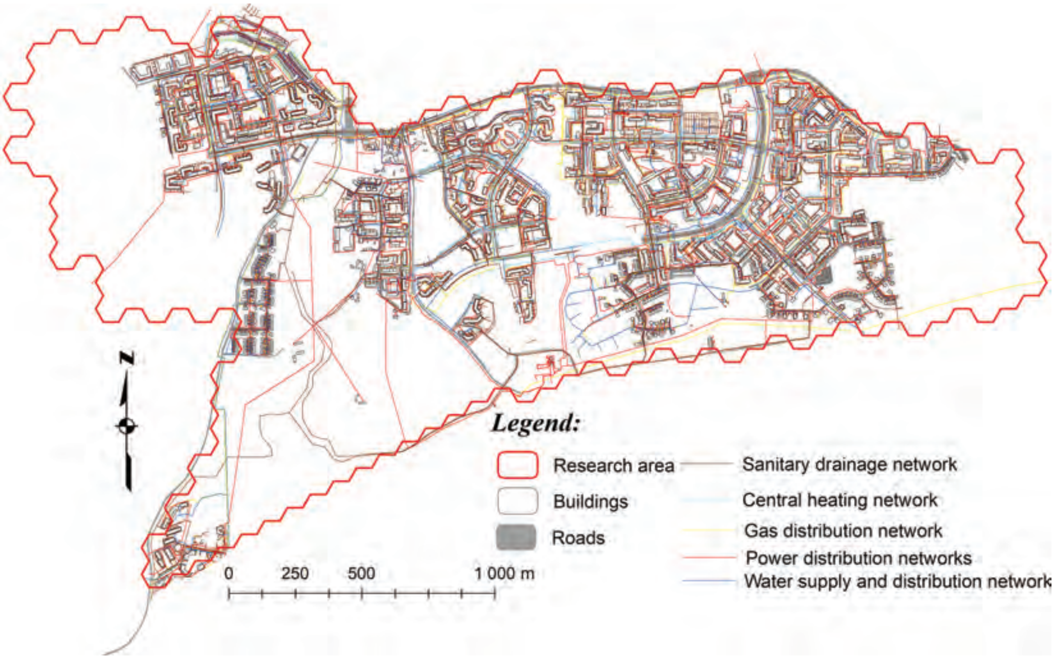

Figure 5: The inventory map of features in group *I*. Source: own study.

Figure 5 presents the results of the inventory of features in group *I*, while Figure 6 shows the results of the inventory of features in group *B*.

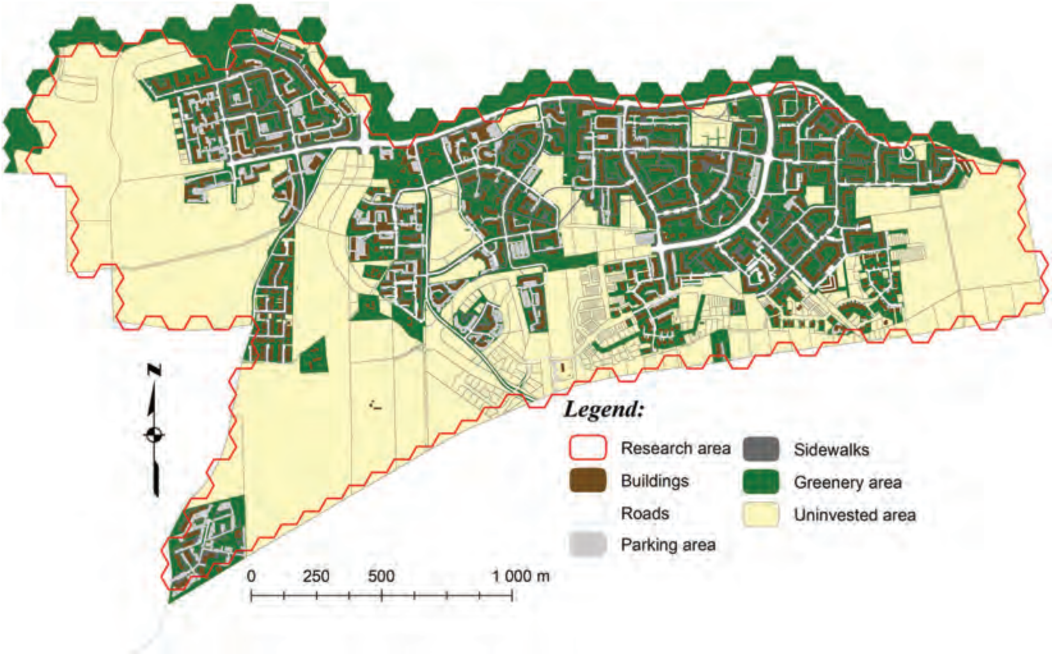

Figure 6: The inventory map of features in group *B*. Source: own study.

The actual assessment of the fields was carried out in two stages. The first step involved an assessment of subcriteria of the second level of the AHP in the previously selected groups (*P, I, B*). The initial assessments of criteria were normalised in accordance with their stimulant or destimulant effect on the value of investment potential of the area. The normalised values were weighed in accordance with the calculations of weights on the second level of the AHP, and summed. In order to graphically present the assessment of subcriteria, classifications of the fields were conducted in three groups. In each group, five classes were separated in accordance with the principle of equal value interval. Their theoretical span is [0.00; 1.00]. Values for each class are presented in table 3.

Table 3: Rules of classification ratings for selected groups of subcriteria (P, I, B).

class	*range of values*	*description potential of location*
I	[0.81; 1.00]	best quality of feature
II	[0.61; 0.80]	good quality of feature
III	[0.41; 0.60]	medium quality of feature
IV	[0.21; 0.40]	low values of features
V	[0.00; 0.20]	very low values of features

Source: own study.

The classification for each group is presented in Figure 7.

The final assessment of the *AIP* was carried out through weighing the assessments determined in groups *P, I, B*. Weights for particular groups were determined on the first level of the AHP. Results of the final assessment of the fields in terms of their investment potential are presented in Figure 8.

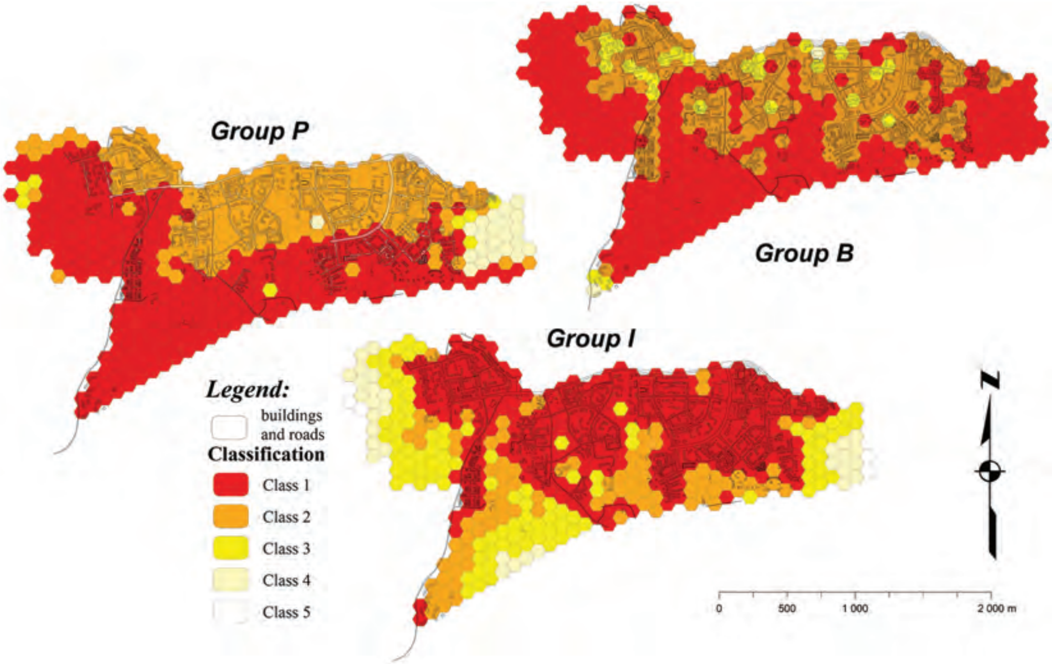

Figure 7: Classification maps for groups *P*, *I* and *B*. Source: own study.

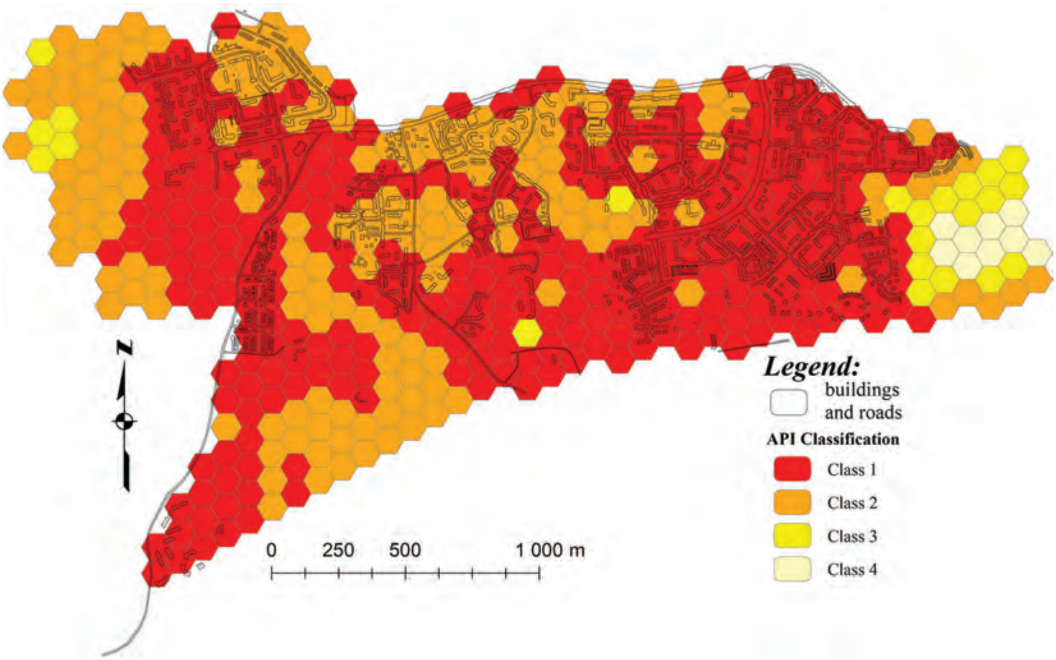

Figure 8: The classification map of results of the final assessment *API*. Source: own study.

5 DISCUSSION AND CONCLUSION

The obtained assessment results indicate the high quality of the investment potential *AIP* in the area under study. For particular groups of criteria, as well as for the final calculation of the *AIP* broken down into classes, most fields were included in high quality classes (Table 4).

Table 4: The number of fields in the assessment classes for the features groups and *API*.

Class	*P*	*I*	*B*	*API*
I	274	252	285	285
II	174	90	166	162
III	8	101	25	22
IV	22	31	2	9
V	0	4	0	0

Source: own study.

More than half of fields for the criteria from the planning group and the planning group related to the current use were included in class I and II. This means that the final assessment of these fields was given a grade of over 0.60. This affected the final assessment of the *AIP*, the results of which were distributed similarly. It can be concluded from an analysis of the map (Figs. 7, 8) that high assessments of the fields within *P* and *B* have similar locations. The situation in the field of an assessment of infrastructure (I) in the area under study is slightly opposite. The highly assessed fields for this group of criteria (classes I and II) are located in the southern part of the area. This can result in investment discomfort in the northern part and in the eastern and western ends of the area.

An analysis of the assessment results indicates that the assessed area has high investment potential *AIP*. The area under study should develop towards the south. It follows from an analysis of Figure 8, that this is the area with the highest *AIP*. The identified direction is consistent with the spatial policy of the city. In order to support the *AIP*, infrastructure needs to be developed within this area as its level may be an investment brake for the area. The analysis of figure 7 shows that relation. For each group of sub-criteria the southern part of the research area obtained lower values.

The study carried out by the authors demonstrate the usefulness of the AHP method for the assessment of investment potential of the areas of the boundary zone between the city and the countryside. The application of the described procedure enables the indication of the directions of development and of the weak elements in the field of land management. In addition, the procedure exhibits considerable flexibility in the selection of criteria, and can be easily adopted to other purposes.

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