DOI 10.4467/21995923GP.22.009.17087 GEOINFORMATICA POLONICA
21: 2022

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APPLICATION OF GIS TO ASSESS THE QUALITY OF LIFE OF INHABITANTS IN URBANIZED AREAS

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Abstract

In a democratic country, every citizen has the right to information about the environment in which he or she lives – therefore, there should be some procedure of conventional, formal evaluation of an urbanized area with reference to its local fragments. Such kind of the procedure has been proposed in this article.

The procedure is based on the conventional scoring of local areas, which can be assigned weights representing positive and negative features. The procedure provides for variants of preconditions and continuation of considerations for source data variables.

The method of assessing the quality of life in the local area should serve the broad local community, therefore the intermediate and final results of the considerations are presented not only in the form of maps, but also in an illustrative way – in the form of three-dimensional (3D) images, with colors easily associated with positive or negative features.

A wide range of tools from the professional GIS package – ArcGIS version 10 was used to perform the task. These tools allow to solve complex spatial problems as well as to visualize the results in an effective way.

Keywords: quality of life assessment, urban area, geographical information system (GIS), visualization of GIS data

ZASTOSOWANIE GIS DO OCENY JAKOŚCI ŻYCIA MIESZKAŃCÓW NA TERENACH ZURBANIZOWANYCH

Abstrakt

W kraju demokratycznym obywatel ma prawo do informacji o środowisku, w którym żyje – dlatego powinna istnieć procedura umownej, formalnej oceny terenu zurbanizowanego z wyróżnieniem jego lokalnych fragmentów. Przykładowy algorytm postępowania został zaproponowany w niniejszym artykule.

Propozycja bazuje na umownej punktacji lokalnych obszarów, którym można przyporządkowywać wagi reprezentujące cechy pozytywne i negatywne. Algorytm przewiduje wariantowanie warunków wstępnych i kontynuację rozważań dla zmiennych danych źródłowych.

Metoda oceny jakości życia w lokalnym obszarze powinna służyć szerokiej społeczności lokalnej, dlatego wyniki pośrednie i końcowe rozważań przedstawiono nie tylko w postaci map, lecz także w sposób poglądowy – jako obrazy trójwymiarowe (3D), z barwami łatwo kojarzonymi z cechami pozytywnymi lub negatywnymi warunków lokalnych.

Do realizacji zadania wykorzystano szeroką gamę narzędzi profesjonalnego pakietu GIS – systemu ArcGIS. Zastosowane narzędzia pozwalają na realizację skomplikowanych zadań przestrzennych, jak również umożliwiają efektowną wizualizację wyników analiz.

Słowa kluczowe: ocena jakości życia, teren zurbanizowany, system informacji geograficznej (GIS), wizualizacja danych GIS

1. INTRODUCTION

One of citizens' rights in a democratic country is the right to have the access to information on the human environment. In the urbanized area the density of population and infrastructure is high, which consequently affects the quality (degree of comfort) of life. The comfort of life includes factors connected with basic existential needs, such as: the state of the local environment, transport connection with the working place, shopping centres, leisure centres and health services. The environment of a big city also generates nuisance and even threat. The most common nuisance includes air pollution and noise from traffic and airborne transport. In some cases, the threat of flood and environmental disasters also occurs.

Let us try to create the procedure of formalized assessment of the residents' life quality for any local urban areas. Such assessment can help, inter alia, in making decisions on the location of the place of residence or can make basis for civil interventions aimed at the improvement of life comfort of the local community [1].

Two basic factors make the problem more complicated. First is the relationship of subsequent features to specific areas of the city. The second factor is the character of individual features – positive (desired) and negative, diminishing the quality of life or even posing threat. We can assume that different local areas, in the relation do the city area, have positive and negative features of different intensity. Thus, formalized procedure of the life quality assessment should consider the weight of the features, both those with sign plus and minus. The weight of negative value contradicts the idea of weighting information in engineering-related issues, which expresses the degree of confidence to a given value. However, in this case, we deal with the assessment of certain state, which make different real factors in the relation to their neutral (zero) impact. Thus, weights can be treated as conventional scoring in the relation to geographic space of the city. Certain universalism of the procedure should be provided by the possibility of shaping the parameters of this scoring – depending on local conditions. Various proposals to define weights of the features of the objects in the real estate market are the subject of analyses in many publications in literature, inter alia: [2-7]. In this paper the examples of weights were proposed, without concentrating on their justification, which is a separate issue. The proposed algorithm will work equally well in another set of weights for the features in the analysed areas. Thus, they should be treated as a set of start parameters obtained from separate analyses.

2. AN EXAMPLE OF THE STUDY AREA AND THE APPLICATION OF THE ANALYSIS TOOL

Figure 1 presents a scheme of the analysed city area. The selected fragment, situated around the centre, is 5.0 km × 3.5 km, and is area is 17.5 km^2. Traffic is car-

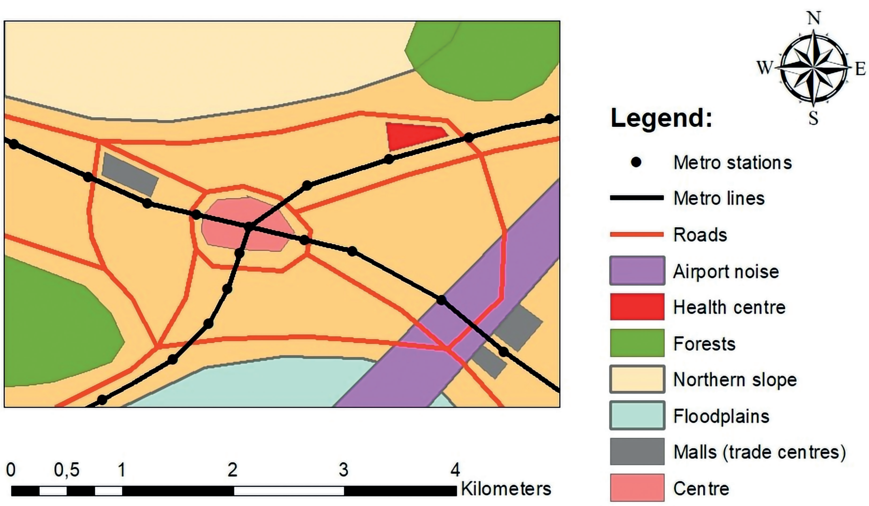

Fig. 1. The analysed city area with selected linear and areal objects
Ryc. 1. Obszar miasta podlegający analizie z wybranymi obiektami liniowymi i powierzchniowymi

Table 1. Analysed features of the fragment of the city
Tabela 1. Rozpatrywane cechy fragmentu miasta

Description and parameters of the feature	Number of points (weight of the feature)
Positive feature – city centre and not further than 1000 m from the city	+5
Positive feature – not further than 1000 m from forest recreational areas	+4
Positive feature – not further than 1000 m from large trade centres	+3
Positive feature – not further than 1000 m from the health centre	+8
Positive feature – not further than 300 m from the closest metro station	+6
Negative feature – areas threatened by floods (floodplains)	–10
Negative feature – zone of noise from landing aeroplanes	–5
Negative feature – areas located on the northern slope	–3
Negative feature – areas located alongside the transit roads, up to 100 m from the road	–2

ried out in two ring roads, one around the centre of the old city, the second running in the distance of one to two kilometres from the central bypass road. The connection with the peripheral areas is provided by transit roads in a star-like pattern. Good personal transport in the city is given by two metro (underground) lines crossing in the centre. In case of the analysis for other cities – metro can be replaced by fast urban railway.

The margins of the city are overgrown with natural forests. There is no anti-flood canal for the river and the southern fragment of the city is situated on a vast terrace is threatened by the flood. In the upper part of the map there is a broad slope in the northern direction. In the south-eastern part of the city there is a corridor for the aeroplanes, connected with the direction of the runway in the airport of the agglomeration.

For the analysis nine typical features, deciding about positive or negative qualification of the city fragment were selected (table 1). There were 5 positive and 4 negative features. Each feature received weight – an arbitrary-given number of positive or negative points. In case of positive features, the favourable areas should

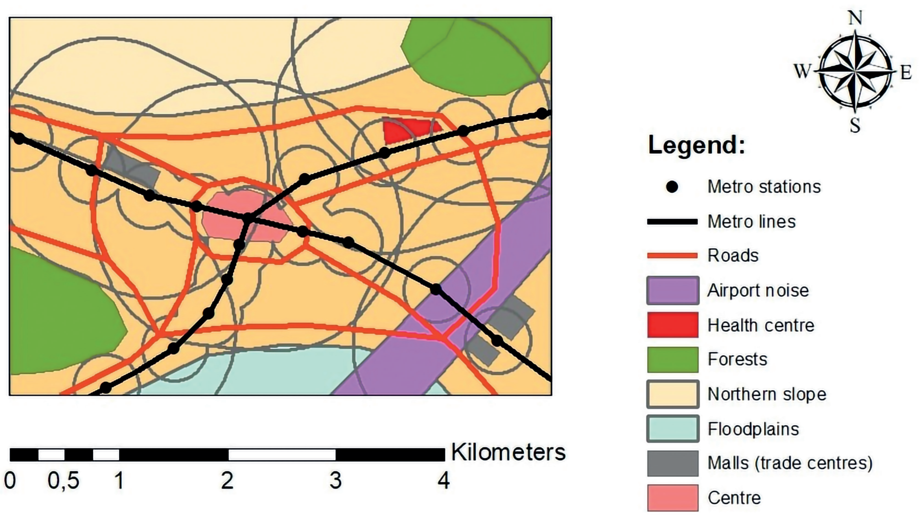

Fig. 2. Borders of buffer zones of point and areal objects – borders of the buffers of metro stations and areas of positive features – city centre, forests, trade centres and the health centre
Ryc. 2. Granice stref buforowych obiektów punktowych i powierzchniowych – granice buforów stacji metra i obszarów o cechach pozytywnych – śródmieścia, lasów, marketów i ośrodka zdrowia

be not further then the width of the conventional chosen zone (buffer) around the desirable objects, addressing vital needs of the residents. The following objects were considered: city centre, recreational areas, trade centres, health centres and metro stations. Negative features, in three cases, refer to core areas that do not require buffering (floodplains, flight corridor and the areas on the northern slope), in one case, as an unfavourable area the buffer of transit was considered.

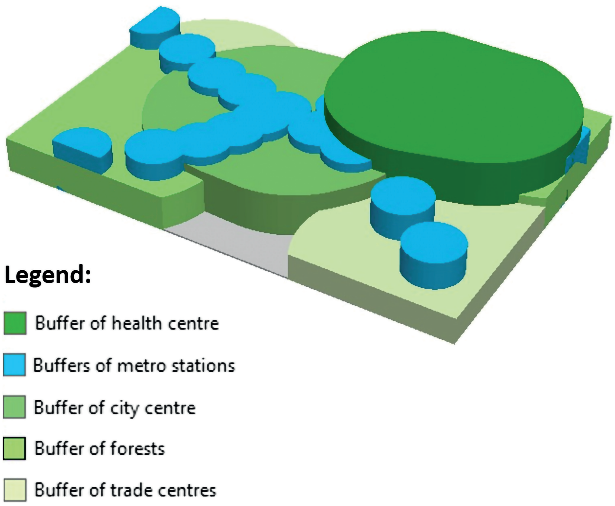

Fig. 3. Visualization of favourable features of the terrain
Ryc. 3. Wizualizacja korzystnych cech terenu

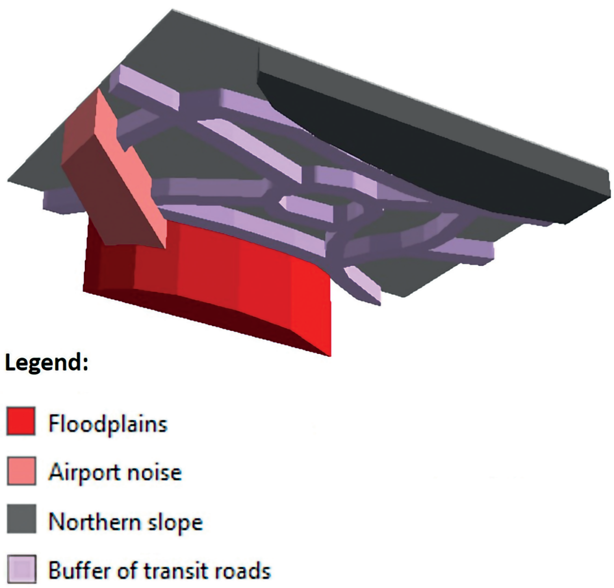

Fig. 4. Visualization of negative features of the area
Ryc. 4. Wizualizacja negatywnych cech terenu

To carry-out the task a wide range of the professional tools of GIS package – system ArcGIS was applied [8]. Many authors use the wide possibilities of this package, among others [9].

Figure 2 presents the borders between the areas of positive features (contours of buffers) and core areas of negative features. The figure does not show road buffers in order not to overload the map with details.

Since this analysis should serve wide citizens' consultation – its subsequent stages should be presented in a visual way, understood to everyone [1]. Thus, the pattern of favourable and unfavourable zones was presented in the form of a three-dimensional (3D) image, in figures 3 and 4, respectively. The heights of zones correspond to the number of conventional points listed in table 1.

While the visualization of 3D areas with positive features, regarding the number of positive points (fig. 3) should not be controversial – 3D visualization of the areas of negative features (fig. 4) requires explanation. In this case the attributed points (weights) have negative signs, thus the observation point was given below the border zero plain, representing the neutral situation. This is due to the necessity of visualising unfavourable zones. The floodplain – marked red is particularly visible and was given the highest negative weight – minus 10 points.

3. STAGE I AND II OF THE ANALYSIS-AGREGATION OF ZONES AND SUMMING THE AREAS OF IDENTICAL NUMBERS OF POINTS

One of the most powerful tools of GIS is overlapping of the areas of different spatial reference and various features. In this case, the aggregation of source zones was done. As a result, 72 elementary areas (fields), labelled with a summary number of points were obtained. In the map, 3 very small areas situated beyond the graded zones can be seen. The criteria contained in table 1 did not apply to them. This results from accepting the most important positive and negative features affecting daily needs and nuisance of the residents in urbanized areas. Figure 5 presents the diagram of the size of elementary areas in the first-degree analysis, regarding 72 fragments of the city made from the overlapping of features. The horizontal scale of the diagram differentiates 72 areas, vertical scale presents the size of the areas.

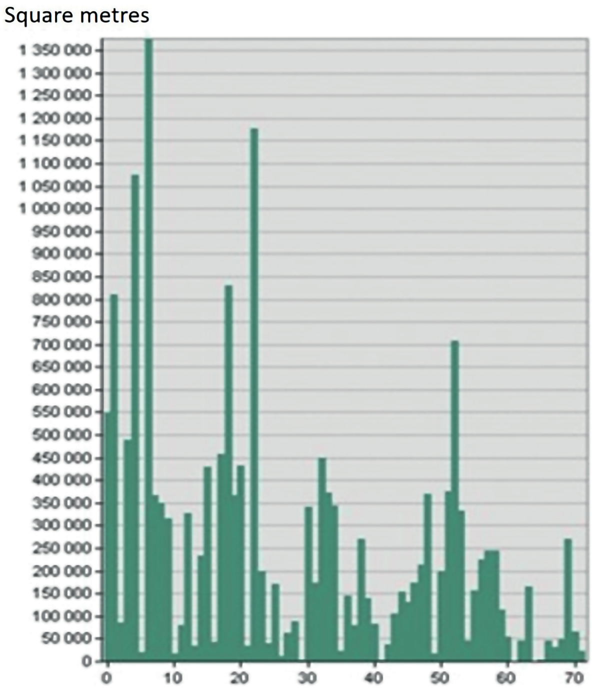

Fig. 5. Areas of 72 elementary fields
Ryc. 5. Powierzchnie 72 obszarów elementarnych

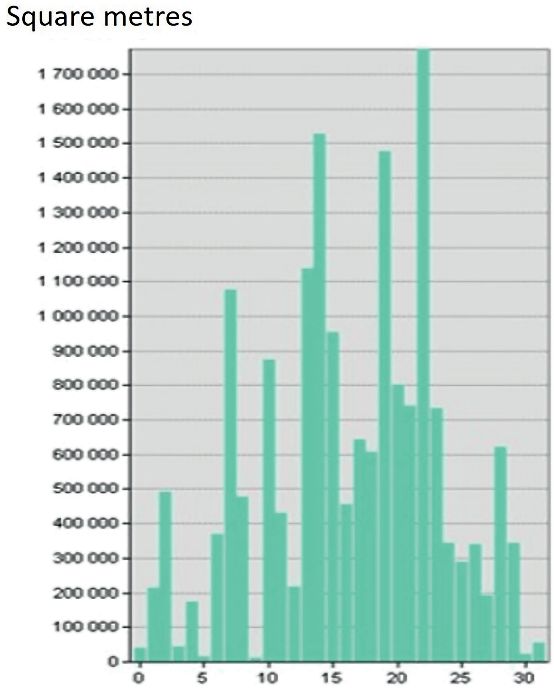

Fig. 6. Areas of 32 aggregated sections
Ryc. 6. Powierzchnie 32 obszarów zagregowanych

During the analysis it turned out that many elementary fields have the sum of weights of identical values. Sums of points consist of features of differentiated origin. But, if we decided that the problem is formalized and local city areas were represented by conventional points, consequently, we should treat the areas of equal number of points as equal. Thus, it would be reasonable to reduce number of 72 elementary fields – this number was reduced by qualifying the areas of identical number of points – to one class of weight. After the operation of summing such fragments – the number of source areas was reduced to 32. Obtained in such a way situation can be treated as the 2nd degree of analysis.

Figure 6 presents the diagram of the elementary areas in the analysis 2nd stage, regarding the city fragments made from the overlapped features. The horizontal scale of the diagram contains 32 areas, the vertical scale presents the size of the areas.

The result of 2nd stage analysis can also be presented in another way – exposing the relation between weights and the area. Such relationship was shown in a graphic form in figure 7. The horizontal scale contains the sums of points in the interval –15 to +23. Rectangles of the diagram mean the size of the areas in square metres corresponding these areas.

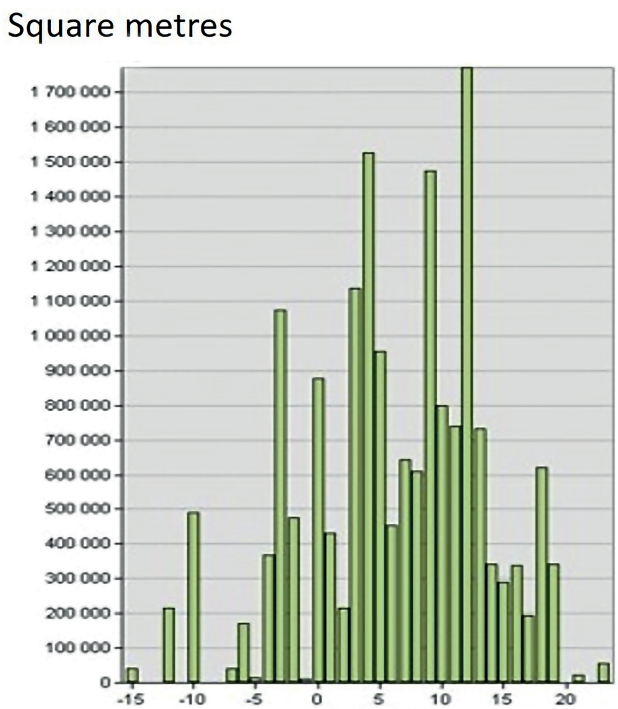

Fig. 7. Areas of the aggregated section – in the relation of the weights' values – interval –15 to +23
Ryc. 7. Powierzchnie obszarów zagregowanych – w relacji do wartości wag – w przedziale od –15 do +23

4. STAGES III AND IV OF THE ANALYSIS – REDUCTION OF ZONES IN A GRAPHICAL WAY

Attributed to subsequent zones summary number of points ranges from –15 to +23. To make the visualisation more transparent, the elementary areas were grouped in seven-point intervals. The formed point classes were established, regarding maximal point range (39 points), which, according to the statistical rules should be grouped in about 6–7 classes (square root of the population [10]). The width of subsequent classes results from the obvious fact that in selected for habitation localizations more features have positive than negative character. Thus, positive features (of point values above zero) can be considered with more details to capture the differentiation. This is 3rd stage of the analysis. The border values of point intervals were presented in table 2.

After grouping the areas of the number of points corresponding subsequent intervals a map was obtained, presented in figure 8. Subsequent fragments of the city have their core labels, however their colours correspond 7 conventional intervals (Fig. 8). The scale of colours in this case corresponds the transition from intensive red to intensive green, which, for every user should be correctly associated with the intensification of unfavourable or favourable characteristics of a local fragment of the city.

Table 2. Grade classes attributed to subsequent zones
Tabela 2. Klasy punktacji przyporządkowanej poszczególnym strefom

Zone number	Interval of points (weights) in the zone
1	+21 ... +23
2	+16 ... +20
3	+11 ... +15
4	+5 ... +10
5	+1 ... +4
6	–6 ... 0
7	–15 ... –7

For better visualization the same features, grouped in seven zones, were presented in figure 9 in the form of a 3D image. Heights of subsequent zones correspond seven established score intervals, regarding negative and positive features.

In 4th stage of the analysis the number of intervals was reduced to two – zones of negative and positive weights. The map with the differentiation of such zones was presented in figure 10. The colours of the areas are compliant with the accepted convention. Binary (zero-one) classification of the areas is a great simplification and can only serve approximate interpretation

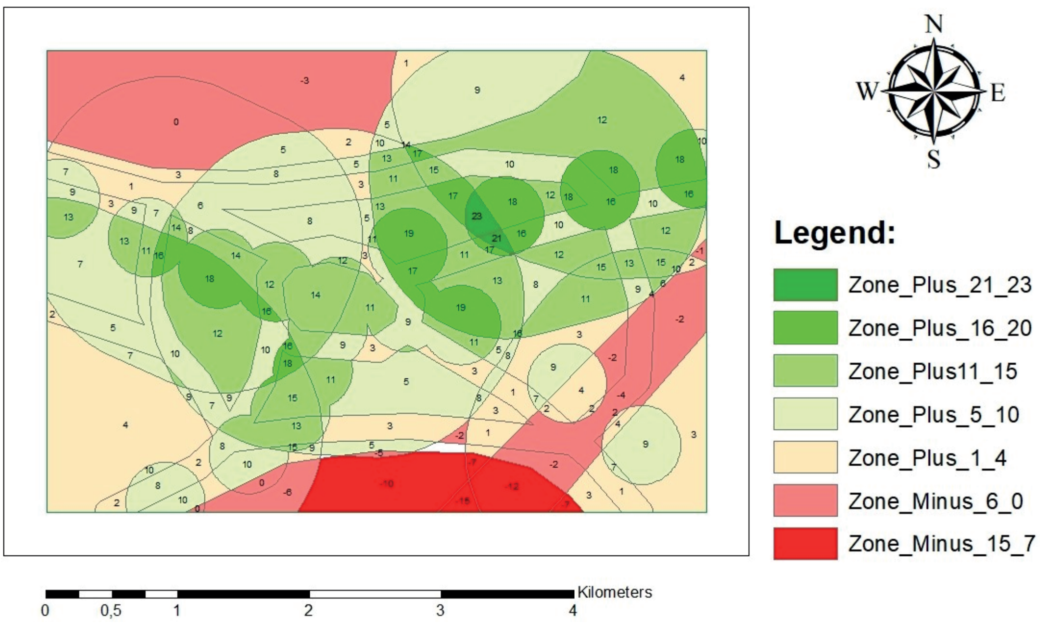

Fig. 8. Borders of the areas of positive features and negative features in 7-degree scale
Ryc. 8. Granice obszarów o cechach pozytywnych i negatywnych w skali 7-stopniowej

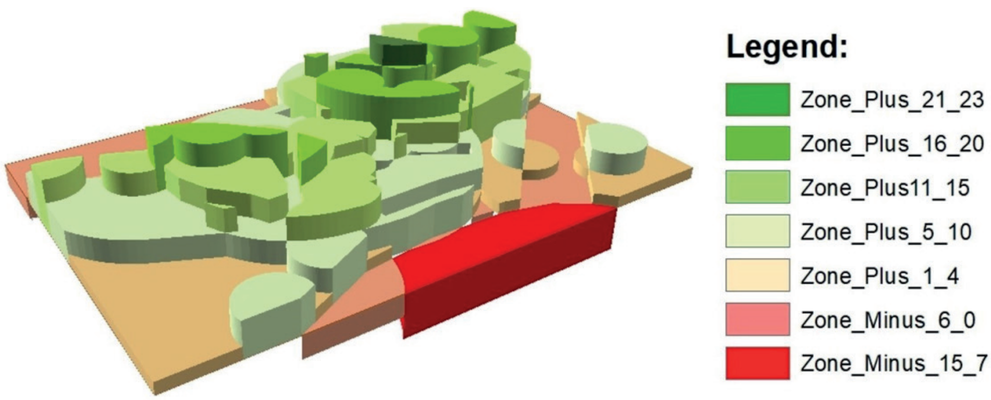

Fig. 9. Visualization of favourable and unfavourable features of the area in 7-degree scale
Ryc. 9. Wizualizacja korzystnych i niekorzystnych cech terenu w skali 7-stopniowej

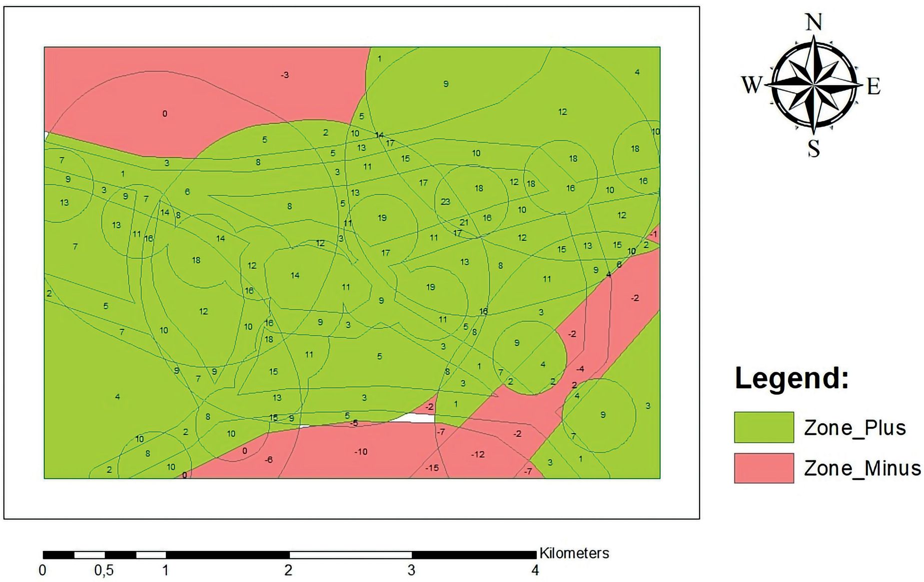

Fig. 10. Areas of positive and negative features in a 2-degree scale
Ryc. 10. Obszary o cechach pozytywnych i negatywnych w skali 2-stopniowej

in the macro scale. Such interpretation of the urbanized area can be helpful while establishing conventional scoring, visualising the results of the life quality analysis in a given city.

5. DISCUSSION OF THE RESULTS

The described example of the classification of a selected urbanized area illustrates possibilities given by graphical analysis in the process of ranking the fragments of the area in terms of features influencing the life quality in a specific city. The possibility of the generalization of data, their aggregation – given by such a tool as ArcGIS – undoubtedly facilitates legibility and interpretation of results, and consequently, averaged individual assessment of the life of the given area.

6. CLOSING REMARKS

This article makes one more presentation of the possibilities of a system tool for the analysis of GIS data. Many authors present in their publications examples of the applications of this type of tools (inter alia: [11–13]), which forms a wide range of possibilities, which will become wider and wider in the future. Independently from the descriptive assessment, system tools (such as ArcGIS, [8]), facilitating parametrization of the formal assessment of the urbanized area, differentiating its local fragments. The procedure of such parametrization was presented in this article.

The proposed algorithm of proceeding is based on the conventional scoring of local areas, with attributed weights representing the intensity of positive and negative features of the analysed area. The algorithm predicts varianting initial conditions and further taking into account various sets of source data. The method of the assessment of life quality in a local area should be legible for the local community, which definitely makes easier graphical presentation of the analysis in every stage, in the form of 3D images.

REFERENCES

1. Eckes, K. Nauczanie GIS z wykorzystaniem naturalnych procesów poznawczych. Annals of Geomatics 2016. Tom XIV, vol. 2 (72), pp. 183–191.
2. Geoforum: pomiar i opis cech nieruchomości. Available online: https://geoforum.pl/news/24738/pomiar-i-opis-cech-nieruchomosci (accessed on 29.01.2018).
3. Barańska, A. Correlation analysis in the process of weighting real property attributes. Real Estate Management and Valuation 2019, vol. 27, no. 4, pp. 74–84.
4. Barańska, A. Linear and nonlinear weighing of property features. Real Estate Management and Valuation 2019, vol. 27, no. 1, pp. 59–68.
5. Barańska, A. Optimization of the weighting of real estate features. In Proceedings of the Innowacje w geodezji i kartografii, gospodarce nieruchomościami oraz ochronie wód powierzchniowych, IV konferencja naukowo-techniczna, Janów Lubelski, Poland (5–7.06.2019).
6. Krajewska, M.; Gaca, R. Preferencje nabywców nieruchomości na wybranych rynkach rodzajowych. Studia i Materiały Towarzystwa Naukowego Nieruchomości 2007, vol. 15(3–4), pp. 35–42.
7. Mohd Sairi, N. A.; Burhan, B.; Mohd Safian, E.E. Identifying housing submarkets in Johor Bahru and Kulai, Malaysia: a data-driven method. Real Estate Management and Valuation 2022, vol. 30(2), pp. 01–11.
8. Dokumentacja systemu ArcGIS ver. 10 – Users guide, Environmental Systems Research Institute (ESRI), Redlans CA, USA.
9. Malczewski, J.; Jaroszewicz, J. 2018: Podstawy analiz wielokryterialnych w systemach informacji geograficznej. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa.
10. Krysicki, W.; Bartos, J.; Dyczka, W.; Królikowska, K.; Wasilewski, M. Rachunek prawdopodobieństwa i statystyka matematyczna w zadaniach część 2, 9th ed.; Wydawnictwo Naukowe PWN: Warszawa, Poland, 2004.
11. Cichociński, P. A Study on the Usability of Open Spatial Data for Road Network-Based Analysis – Using Openstreetmap as an Example. Geoinformatica Polonica 2021, vol. 20, pp. 89–96.
12. Pirowski, T.; Timek, M. Analysis of land use and land cover maps suitability for modeling population density of urban areas – redistribution to new spatial units based on CLC and UA databases. Geoinformatica Polonica 2018, vol. 17, pp. 53–64.
13. Walenciak, K.; Kozieł, M.; Antolak, M. Methodical and technological assumptions for using of the participatory GIS method in planning and revitalization of urban green space (part 1). Geoinformatica Polonica 2017, vol. 16, pp. 19–33.