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Weronika Dąbrowska[1], Andrzej Biłozor[2]

MULTI-CRITERIA GIS ANALYSIS IN URBAN AREA REVITALIZATION

Abstract: This study presents a procedure for identifying problem areas that could be considered in the urban revitalization program. The research was conducted in ESRI's ArcGIS Pro software using Geoprocessing tools. The aim of this study is to utilize multi-criteria GIS analysis in the process of urban area revitalization. In selecting the study area, in this case, the city of Wrocław, both its characteristics and the availability of geospatial information were taken into account. Four main indicators, described by 11 negative factors, were adopted for the GIS analysis of urban revitalization: social phenomena (personal and public safety, the number of individuals subject to "blue card" procedures per 1,000 inhabitants, the number of crimes per 1,000 inhabitants, the number of individuals receiving social assistance due to poverty per 1,000 inhabitants), economic factors (deficit of bridging capital, overall unemployment rate, level of economic wealth), environmental factors (noise in decibels), and functional-spatial factors (spatial distribution of public transport stops, spatial distribution of green areas, spatial distribution of access to services). As a result of the analysis conducted in the urban area, neighborhoods were identified that should be included in the revitalization process.

Keywords: spatial management, spatial planning, GIS, universal connection, revitalization

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[1] University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Spatial Management and Geography, Department of Socio-Economic Geography, Olsztyn, Poland, ORCID ID: https://orcid.org/0000-0003-0471-7722, email: weronikadabrowska63@gmail.com

[2] University of Warmia and Mazury in Olsztyn, Faculty of Geoengineering, Institute of Spatial Management and Geography, Department of Socio-Economic Geography, Olsztyn, Poland, ORCID ID: https://orcid.org/0000-0002-4716-1069, email: abilozor@uwm.edu.pl

Introduction

Geographical Information System (GIS) refers to an integrated system of knowledge, personnel, hardware, and software used for acquiring, storing, transmitting, analyzing, and visualizing spatial data. Spatial information is understood as any data that can be assigned to a specific location (Longley et al. 2008; Urbański, 2008). GIS can be perceived by researchers as a framework for developing and validating spatial data. It serves to address scientific issues comprehensively, starting from formulating a research hypothesis, collecting a database, processing it, conducting spatial analysis, verifying the hypothesis, and concluding with results (Jażdżewska, Urbański, 2013).

GIS finds increasingly widespread applications across various fields, providing solutions with a spatial dimension. In contemporary times, GIS is utilized in the following industries:

- telecommunications: marketing, network planning, design, and maintenance,
- retail: market analysis, competitiveness studies, selection of store locations, etc.,
- real estate: location selection and pricing, land and building registry, presenting locations and their surroundings,
- mining: management of mine infrastructure, environmental impact monitoring, design and supervision of land reclamation,
- transportation: passenger and freight traffic analysis, logistics operation planning, real-time vehicle tracking, route planning for public transport,
- healthcare: distribution of facilities, disease occurrence mapping, epidemic spread analysis,
- crime prevention: spatial analysis of crime occurrences, locating police stations, and municipal security units,
- agriculture and forestry: pest control, selection of appropriate crops, prevention of water erosion, fire protection,
- archaeology: documentation of findings, dissemination of information about archaeological sites,
- emergency and crisis management: coordination of rescue operations, risk assessment for people and assets, loss estimation (Urbański, 2008; Bielecka, 2006; Gotlib et al., 2007).

GIS thus plays a pivotal role in solving problems with spatial dimensions across an array of disciplines.

GIS is not merely a computer system, software, program, or a collection of tools. It also encompasses people who, with the right data, skills, and experience, leverage its applications (Drzewiecki, 2004).

The tools of GIS are increasingly utilized in spatial management, particularly in spatial analyses aimed at planning, developing, and optimizing various solutions and projects (Renigier-Biłozor & Biłozor, 2014). Spatial management is a broad research field, resulting in definitions that are both imprecise and complex. It constitutes both a domain of knowledge and a practical activity, which are closely interconnected. As a scientific discipline, spatial management arises from the needs expressed by practitioners. At the

same time, by addressing practical requirements, it provides the necessary tools and knowledge for making spatial decisions (Parysek, 2006; Biłozor & Cieślak, 2021).

According to the three-tier definition of spatial management proposed by Dębski (2001), it should be understood as:

1. practical activity aimed at creating spatial order in the existing development, considering (in an idealistic sense) the well-being of individuals and society over the longest possible time horizon;
2. reality encompassing the totality of phenomena occurring in space, ranging from the natural environment, settlement patterns, technical infrastructure, and national economy;
3. science focused on studying the past and current state of spatial development in specific areas and exploring hidden and complex structures that determine the functionality of the whole.

Spatial management is a process of transforming and shaping space from its actual state to a desired state that meets societal needs. Therefore, the primary objective of spatial management should be the protection of specific spatial values and the rational and conscious shaping of space, adhering to the principles of spatial order. This is particularly relevant to degraded areas, which are regions in a state of crisis due to the concentration of negative social phenomena (e.g., unemployment, crime, low levels of education) and the presence of at least one other adverse factor, such as:

a) economic – e.g., low levels of entrepreneurship,
b) environmental – e.g., exceeding environmental quality standards,
c) spatial-functional – e.g., insufficient technical or social infrastructure, lack of access to services,
d) technical – e.g., degradation of the technical condition of buildings (Act on Revitalization of October 9, 2015; Act on Revitalization, Journal of Laws of 2021, item 485).

Revitalization is the process of resolving the crisis state of degraded areas through comprehensive, territorially-focused, and integrated actions targeting the local community, space, and economy. This process is carried out by revitalization stakeholders based on the municipal revitalization program. According to the Act on Revitalization of October 9, 2015 (Journal of Laws of 2021, item 485), the stakeholders of this process include:

a) residents of the area covered by the revitalization program, as well as property owners, perpetual usufruct holders, and property management entities, including housing cooperatives, housing communities, social housing initiatives, and social housing associations,
b) other residents of the municipality not listed under point a),
c) entities conducting or intending to conduct economic activities in the municipality,
d) entities conducting or intending to conduct social activities in the municipality (e.g., non-governmental organizations, informal groups),
e) local government units and their organizational entities,

f) public authorities and other entities specified in point f) that exercise the rights of the State Treasury in the revitalization area.

The term "revitalization" most commonly refers to urban areas that have undergone degradation due to economic, social, and economic transformations. These areas have partially or entirely lost their functions and intended purposes. Revitalization may include:

a) economic and social revival of abandoned urban areas, such as city centers, historic districts, or buildings that have lost their functions,
b) improvement of living conditions and restoration of social bonds in large residential complexes (housing estates),
c) urban renewal and redevelopment of post-industrial areas abandoned by the military, railways, etc.,
d) rehabilitation of destroyed and degraded areas, such as those affected by mining or industrial activities.

The primary goal of revitalization is to reverse negative transformations occurring in urban space, including the degradation of buildings, intensification of social pathologies, marginalization of areas, and devastation of architecturally valuable structures. The essence of the process lies in introducing new functions to replace those that have proven ineffective in a given location.

An effective tool used in such initiatives is multi-criteria analysis, which, through its fundamental principles, aids in decision-making in spatial planning, thereby avoiding potential conflicts. According to Kaliszewski (2008), multi-criteria decision-making involves selecting the most preferred option, which the decision-maker arrives at by "navigating" through the considered alternatives, guided by assessments of each option based on predefined criteria, thereby maximizing decision-making efficiency.

Multi-criteria analysis supports decision-making processes when several, or even numerous, criteria are available. Its purpose is to arrive at a single, consolidated result (Hejmanowska & Hnat, 2009; Biłozor et al., 2014).

The criteria used in multi-criteria analysis can be:

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

In connection with spatial management, these criteria often pertain to fulfilling specific social, economic, or ecological requirements.

This study presents the process of identifying problematic areas that could be included in the revitalization program of a selected city. The research was conducted using ESRI's ArcGIS Pro software. The aim of the study is to utilize multi-criteria GIS analysis in the urban revitalization process. For this purpose, the city of Wrocław was chosen as the study area. The selection of the area considered its characteristics and the availability of geospatial information. The analysis was developed through the collection of appropriate data and the application of Geoprocessing tools. As a result of the conducted analysis, urban neighborhoods were identified and assigned to specific categories. Each factor included in the mentioned indicators significantly influenced the final outcome of the analysis. The result is a map with a five-point classification designed

to identify problematic areas. Such analyses can serve as an important source of information for government institutions and local authorities. Similar approaches, emphasizing the synergy between human expertise and machine capabilities, have been shown to enhance spatial planning and decision-making processes (Renigier-Biłozor & Janowski, 2024).

Material and methods

This analysis aimed to identify urban areas that should be included in the revitalization process. These areas were delineated using multi-criteria analysis and GIS tools, particularly Geoprocessing in the ArcGIS Pro software.

The conducted analysis followed the following procedure:

1. definition of the study area and compilation of an appropriate database consisting of vector data, numerical data, and documents,
2. creation of a new project in ArcGIS Pro and integration of the database,
3. execution of multi-criteria analysis using Geoprocessing tools available in ArcGIS Pro,
4. generation of analysis results in the form of maps,
5. summary and conclusions of the analysis.

The initial stage of the analysis involved gathering and verifying data related to the boundaries of the study area, the factors constituting the four indicators, and their spatial locations. The reference system was set to ETRS 1989 Poland CS92. The boundary layer of the districts was downloaded in SHP format from the Wrocław Spatial Information System website [www.geoportal.wroclaw.pl/osiedla].

For the GIS analysis in urban revitalization, four indicators were adopted: social, economic, environmental, and functional-spatial phenomena. These indicators were included in accordance with Article 9 of the Act on Revitalization of October 9, 2015 (Journal of Laws of 2021, item 485), which specifies that an area is in a crisis state if it experiences a concentration of negative phenomena.

According to the Act, the following negative phenomena are identified:

- social phenomena: e.g., unemployment, poverty, crime, low levels of education, etc.,
- economic phenomena: e.g., low levels of entrepreneurship, etc.,
- environmental phenomena: e.g., the presence of hazardous waste posing risks to life and health, exceeding environmental quality standards, etc.,
- functional-spatial phenomena: e.g., insufficient or poor technical infrastructure, lack of infrastructure, urban planning deficiencies, etc.,
- technical phenomena: e.g., the degradation of building conditions, non-functioning technical solutions, etc.,

To qualify as degraded, an area must meet the social conditions and at least one other condition.

Technical phenomena were not considered in the analysis due to the lack of data and the inability to conduct field inspections. A field survey would have allowed the identification of buildings in a state of degradation.

For all indicators, specific factors were identified as the basis of the analysis. The number of factors depended on data availability. The negative phenomena included in the analysis are as follows:

- W1 – Social phenomena:
  W1_1 – personal and public safety;
  W1_2 – number of individuals subject to the "blue card" procedure per 1,000 inhabitants;
  W1_3 – number of crimes per 1,000 inhabitants;
  W1_4 – number of individuals receiving social assistance due to poverty per 1,000 inhabitants.
- W2 – Economic phenomena:
  W2_1 – bridging capital deficit;
  W2_2 – overall unemployment rate;
  W2_3 – level of economic wealth.
- W3 – Environmental phenomena:
  W3_1 – noise levels in decibels.
- W4 – Functional-spatial phenomena:
  W4_1 – spatial distribution of public transport stops;
  W4_2 – spatial distribution of green areas;
  W4_3 – spatial distribution of access to services.

The data for the indicators related to social phenomena and economic phenomena were obtained from the Diagnostic Report of Wrocław (Diagnostic report for determining the crisis area recommended for revitalization in Wrocław, 2019). The factor for the environmental phenomena indicator was sourced from the Strategic Noise Map of Wrocław, available on the website of the Wrocław Spatial Information System (gis.um.wroc.pl). The factors for the functional-spatial phenomena indicator were downloaded in SHP format from the Geofabrik website (www.geofabrik.de).

The selected study area for achieving the objectives of this research is the city of Wrocław. This historic city, with centuries-old traditions, is a significant cultural, academic, economic, and tourist hub. Wrocław is a county-level city located in southwestern Poland, serving as the capital of the Lower Silesian Voivodeship (Fig. 1). The city covers an area of 292.8 km^2, with a population exceeding 673,000 inhabitants.

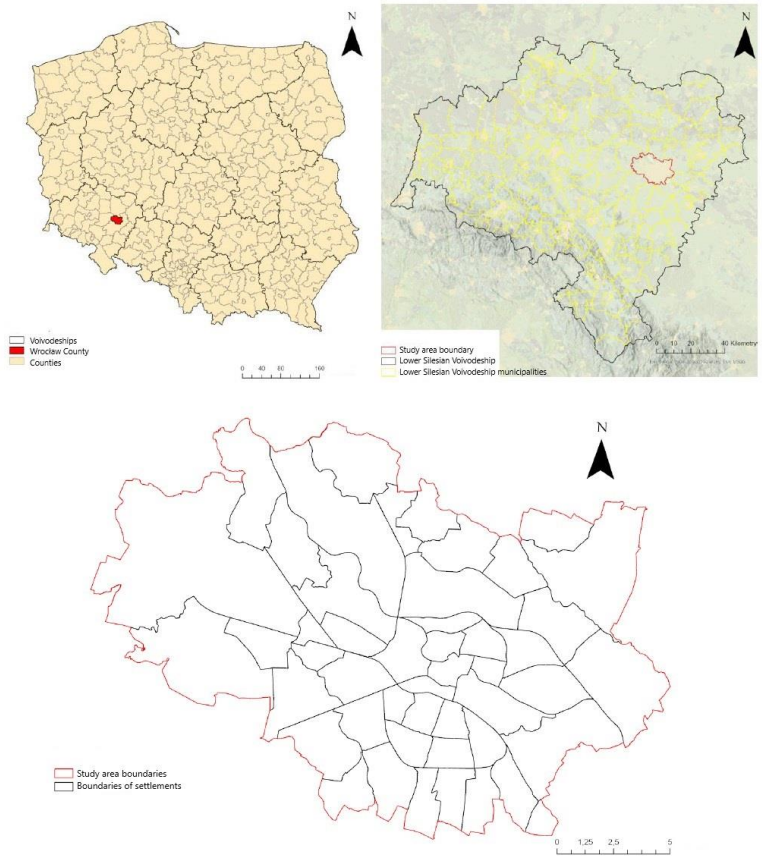

Fig. 1. Location of the study area with division into districts
Source: own elaboration

The geographical location of Wrocław positively influences its economic development. Key industrial sectors include transport, consumer electronics, pharmaceuticals, biotechnology, information technology, and the production of household appliances and audiovisual equipment. Services related to scientific, technical, leisure, and recreational activities also play a significant role.

The high availability of social services contributes to a high standard of living in the city. A broad range of public services and their quality (e.g., education and early childhood care, healthcare, public safety, etc.) contribute to residents' satisfaction with their choice of place of residence.

Results and discussion

All factors included in the indicators W1 (social phenomena), W2 (economic phenomena), and W3 (environmental phenomena) are numerical data. Each dataset was aggregated to the appropriate polygon using the "Polygon to Raster" function, which converts vector data into raster data. The data standardization process (using the "Reclassify" tool) allowed for unifying the values of each characteristic on a standardized scale from 1 to 5.

Table 1. Designation and classification of settlement types

Type	Color	Meaning
1		Very Poor
2		Poor
3		Average
4		Good
5		Excellent

Source: own elaboration

Figure 2 presents maps of the analyzed social phenomena: W1_1 – personal and public safety, W1_2 – the number of individuals subject to the "blue card" procedure per 1,000 inhabitants, W1_3 – the number of crimes per 1,000 inhabitants, and W1_4 – the number of individuals receiving social assistance due to poverty per 1,000 inhabitants, classified on a five-point scale.

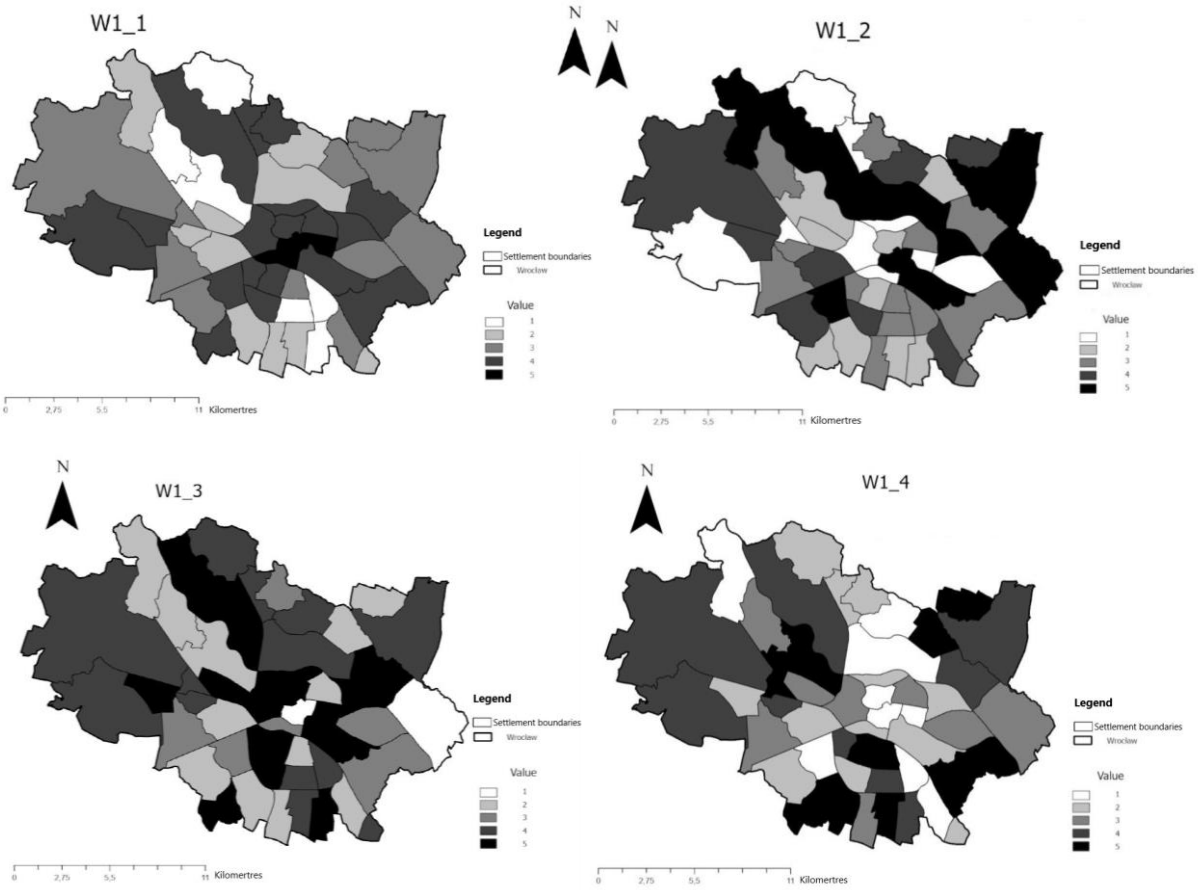

Fig. 2. Maps of analyzed social phenomena: W1_1 – personal and public safety; W1_2 – number of people under the blue card procedure per 1,000 residents; W1_3 – number of crimes per 1,000 residents; W1_4 – number of people receiving social assistance benefits due to poverty per 1,000 residents
Source: own elaboration

The map of social indicators, developed using the "Raster Calculator" tool, is presented in Fig. 3.

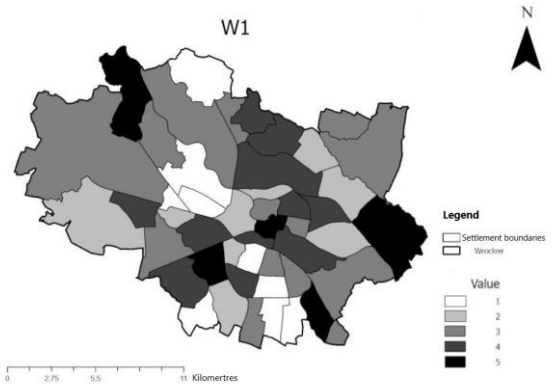

Fig. 3. Output map for social indicators
Source: own elaboration

In Fig. 4, maps of the analyzed economic phenomena are presented: W2_1 – bridging capital deficit, W2_2 – total unemployment, W2_3 – level of economic wealth, classified on a five-point scale.

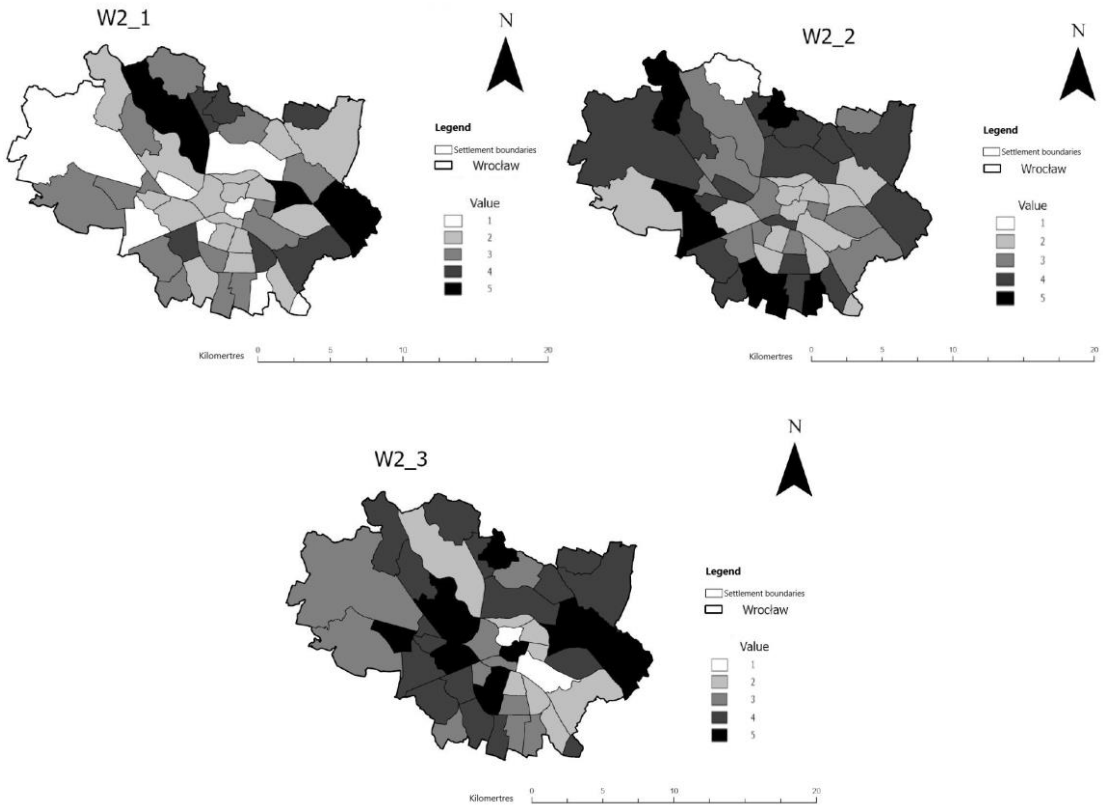

Fig. 4. Maps of analyzed economic phenomena: W2_1 – bridging capital deficit, W2_2 – total unemployment, W2_3 – level of economic wealth, classified on a five-point scale
Source: own elaboration

The map of economic indicators, developed using the "Raster Calculator" tool, is presented in Fig. 5.

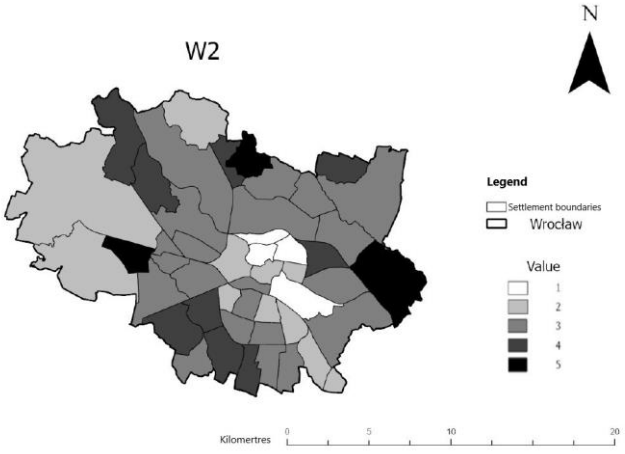

Fig. 5. Output map for economic indicators
Source: own elaboration

The output map of the environmental indicator is presented in Fig. 6.

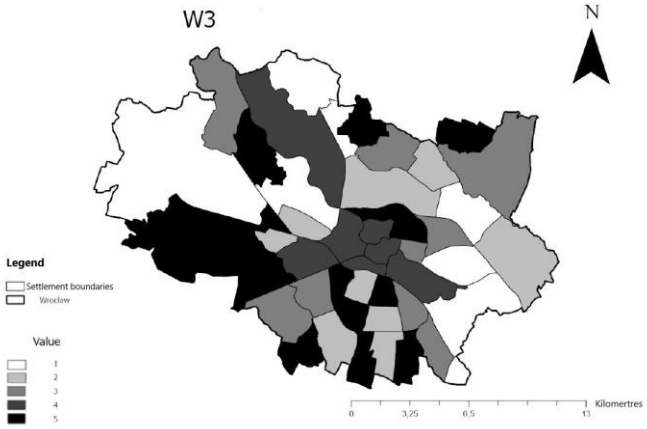

Fig. 6. Output map for the environmental indicator
Source: own elaboration

In Fig. 7, maps of the analyzed functional-spatial phenomena are presented: W4_1 – spatial distribution of public transport stops, W4_2 – spatial distribution of green areas, W4_3 – spatial distribution of access to services, classified on a five-point scale using the "Euclidean Distance" and "Kernel Density" tools to determine the range of factors.

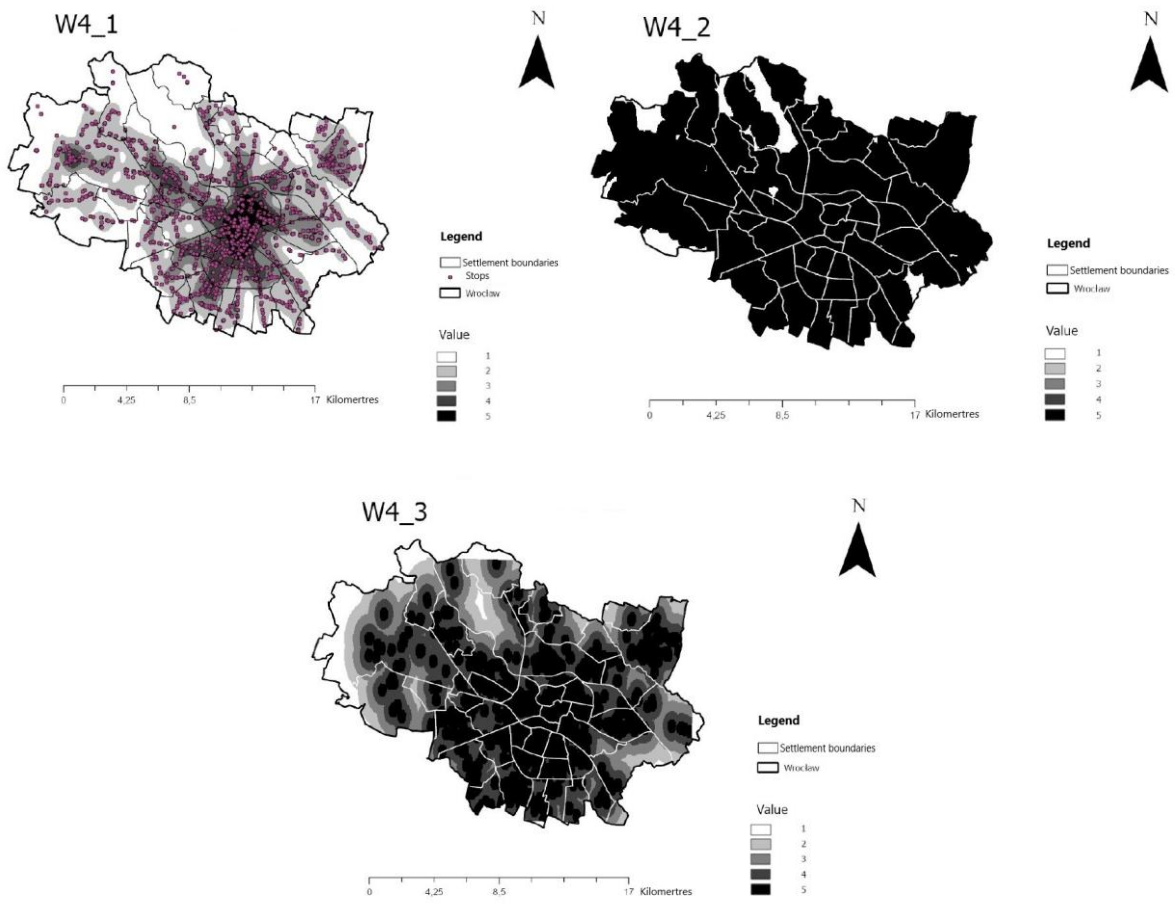

Fig. 7. Maps of analyzed functional and spatial phenomena: W4_1 - spatial distribution of stops; W4_2 - spatial distribution of green areas; W4_3 - spatial distribution of accessibility to services
Source: own elaboration

The output map of functional-spatial indicators, developed using the "Raster Calculator" tool, is presented in Fig. 8.

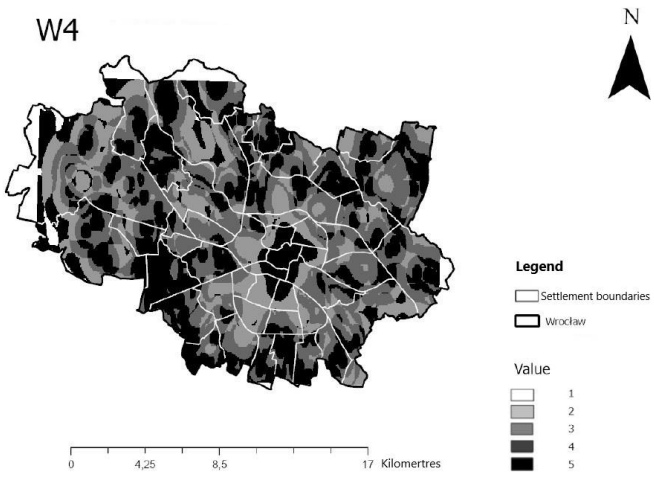

Fig. 8. Maps of analyzed functional-spatial phenomena
Source: own elaboration

The final stage of the analysis involves utilizing the developed outputs from all four indicators. This stage focused on creating a resultant map using multi-criteria GIS analysis to identify and locate urban areas where the revitalization process appears necessary – Fig. 9.

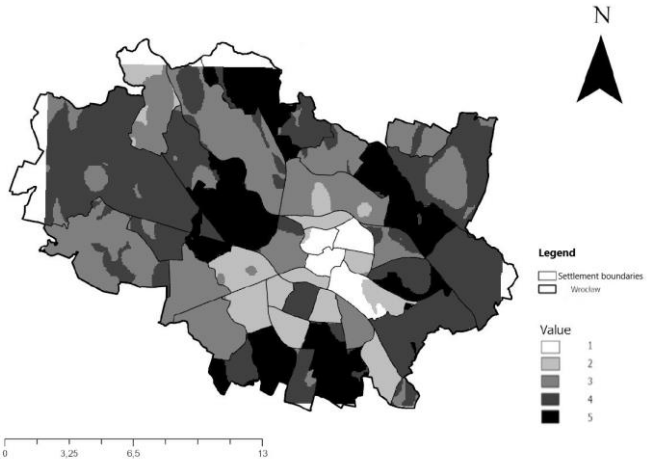

Fig. 9. Result map of multi-criteria GIS analysis in revitalization of Wroclaw areas
Source: own elaboration

The analysis identified five types of neighborhoods. The dominant groups are those belonging to the third, fourth, and fifth types, which account for 73% of all analyzed areas.

The first group includes neighborhoods such as Ołbin, Nadodrze, Stare Miasto, and Przedmieście Oławskie, comprising only 8% of the analyzed areas. These districts were identified mainly due to a high number of individuals receiving social assistance benefits due to poverty per 1,000 residents, a bridging capital deficit, unemployment, and an average level of economic wealth. Despite these issues, they showed strong results in the spatial distribution of public transport stops, green areas, and services.

The second group includes neighborhoods such as Grabiszyn – Grabiszynek, Muchobór Mały, Gajowice, Borek, Huby, Przedmieście Świdnickie, Plac Grunwaldzki, Kleczków, and Brochów, which account for 19% of the analyzed areas. These areas are characterized by low bridging capital deficit, personal and public safety, low numbers of individuals subject to the "blue card" procedure per 1,000 residents, low numbers of people receiving social assistance due to poverty per 1,000 residents, and an average spatial distribution of access to services.

The third group includes neighborhoods such as Osobowice – Rędzin, Pracze Odrzańskie, Jerzmanowo – Jarnołtów – Strachowice – Osiniec, Muchobór Wielki, Oporów, Tarnogaj, Pawłowice, Polanowice – Poświętne – Ligota, Karłowice – Różanka, Szczepin, Zacisze – Zalesie – Szczytniki, representing 23% of the analyzed areas. These neighborhoods are characterized by low or average indicators such as bridging capital deficit, economic wealth, unemployment, the number of people receiving social assistance due to poverty per 1,000 residents, and the spatial distribution of public transport stops.

The fourth group consists of neighborhoods such as Maślice, Leśnica, Kuźniki, Żerniki, Klecina, Ołtaszyn, Księże, Bieńkowice, Strachocin – Swojczyce – Wojnów, Psie Pole – Zawidawie, Widawa, Powstańców Śląskich, and Biskupin – Sępolno – Dąbie – Bartoszowice, which account for 27% of the analyzed areas and form the largest group. These neighborhoods exhibit above-average indicators such as personal and public safety, the number of crimes per 1,000 residents, the number of people receiving social assistance benefits due to poverty per 1,000 residents, unemployment, economic wealth, the spatial distribution of green areas, and the spatial distribution of access to services.

The fifth group includes neighborhoods such as Świniary, Lipa Piotrowska, Pilczyce – Kozanów – Popowice Północne, Gądów – Popowice Południowe, Nowy Dwór, Krzyki – Partynice, Wojszyce, Gaj, Jagodno, Kowale, and Sołtysowice, representing 23% of the analyzed areas. These neighborhoods are characterized by high levels of economic wealth and low unemployment rates, except for Świniary. Their classification within this group is also due to high indicators such as the spatial distribution of access to services and the spatial distribution of green areas.

Districts of the city belonging to the fourth and fifth types of neighborhoods will not play a significant role in the target revitalization efforts due to their well-developed socio-developmental policies. In general, these districts are well-functioning. Crisis areas can be identified among neighborhoods belonging to the first three types. These areas exhibit low factor values, resulting in a negative overall outcome. The concentration of districts in crisis is located in the central part of Wrocław as well as in the northern and western areas.

Conclusions

This analysis aimed to utilize multi-criteria GIS analysis, geospatial information, and Geoprocessing tools in the process of urban revitalization and to identify areas eligible for this process.

Based on the analyzed indicators, it can be observed that Wrocław coexists harmoniously with nature. The city actively promotes a well-maintained, eco-friendly, and environmentally conscious image. It implements actions under the anti-smog program, which aims to reduce air pollution emissions. Residents are encouraged to switch to more environmentally friendly heating sources. Additionally, Wrocław executes numerous educational and investment programs and projects, such as planting greenery, modernizing and renovating playgrounds, managing rainwater, and converting impervious surfaces into biologically active areas.

Analyzing the W4_1 indicator – spatial distribution of public transport stops – reveals transportation issues in the studied area, particularly in districts located in the northwestern parts of the city. Improving transportation connections would enhance mobility for residents. This improvement would allow residents to secure jobs in the city center and commute using public transport. In the long run, this could reduce the unemployment rate.

Another critical action should focus on addressing the bridging capital deficit, which plays a fundamental role in building civil society. Bridging capital facilitates integration and collaborative efforts among individuals from various social groups for the common good. It enhances the functioning of local communities through better communication, prevents conflicts, and resolves issues. Wrocław should implement clear actions encouraging active social integration. The benefits of such initiatives would be visible for both the city and its residents.

Similar conclusions were drawn by the authors of the diagnostic report for determining the revitalization area in Wrocław (2019). The difference in analyses may result from the time period, data diversity, and the fact that the functional-spatial phenomena were not considered in Wrocław's diagnostic report.

The analysis also highlights the utility of the program in planning-related studies by pinpointing problematic areas. The conducted analyses will be a crucial step in the legislative process for designating degraded areas and initiating revitalization efforts. When supplemented with more extensive data and public consultations, this method will result in even greater accuracy.

Using the above analysis will ensure a focus on areas qualifying for actions under the revitalization program.

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