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## Application of GIS Tools in Spatial Distribution Modeling of Historical Monuments

**Abstract:** Entry in the register of objects of cultural heritage (Polish: *rejestr zabytków*) is one of the statutory forms of legal protection of monuments in Poland. The registers of objects of cultural heritage are maintained by territorially competent voivodeship conservators of monuments. Voivodeship registers of objects of cultural heritage contain approx. 76,000 entries related to non-movable monuments that are differentiated by type. These objects can be cultural landscapes, urban and rural systems, construction units, works of architecture and construction, defensive structures, monuments of technology, cemeteries, parks, gardens, and other forms of designed greenery as well as places that commemorate historical events or the activities of outstanding figures on institutions. In this paper, research was conducted on the possibilities of using GIS tools in analyses regarding the spatial distribution of historical monuments in Poland. Data from the National Heritage Board of Poland (Polish: Narodowy Instytut Dziedzictwa) obtained from the [dane.gov.pl](http://dane.gov.pl) website was analyzed. Maps showing the density of non-movable monuments specifying their types and locations were created. Warmian-Masurian Voivodeship was an area of detailed research. The generated maps can be used for creating and updating the national spatial development concept (Polish: *konceptcja przestrzennego zagospodarowania kraju*) as well as voivodeship spatial management plans.

**Keywords:** GIS, protection of monuments, register of objects of cultural heritage, spatial analysis, spatial distribution modeling

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## 1. Introduction

Entry in the register of objects of cultural heritage (Polish: *rejestr zabytków*) is one of the legal forms of protection of monuments in Poland in accordance with Art. 7 of the Act of July 23, 2003, on the protection and care of monuments [1] along with the recognition of an object or area as a historic monument (Polish: *pomnik historii*), an entry on the List of Heritage Treasures (Polish: *lista skarbów dziedzictwa*), establishment of a cultural park (Polish: *park kulturowy*), and protection regulations in spatial planning documents. Such objects become elements of cultural heritage and are subject to the principles of protection characteristic of this type of object. Such activities can be observed all over the world [2–4].

In accordance with Art. 3 of the above-mentioned act, a non-movable monument is a piece of real estate, its part, or a unit that is the work of man or related to human activity that is evidence of a bygone era or event whose preservation is in the public interest due to its historical, artistic, or scientific value. On the other hand, Art. 6 indicates that non-movable monuments may include cultural landscapes, urban and rural systems, building units, works of architecture and construction, works of defense construction, technical objects, cemeteries, parks, gardens, and other forms of designed greenery as well as places commemorating historical events or the activities of remarkable personalities or institutions. Voivodeship registers of objects of cultural heritage currently include approx. 76,000 entries of non-movable monuments diversified by type. A non-movable monument is entered into a register on the basis of a decision issued by a voivodeship conservator of monuments *ex-officio* or at the request of the owner of a non-movable monument or the perpetual usufructuary of the land on which the non-movable monument is located.

The spatial distribution of non-movable monuments as well as cultural parks and historical monuments greatly influences spatial development and is taken into account in spatial planning [5–7].

In this article, the authors carried out a statistical quantitative and qualitative analysis related to non-movable monuments in Poland. Next, using GIS tools, maps of saturation with various forms of non-movable monuments for the test area of Warmian-Masurian Voivodeship were generated.

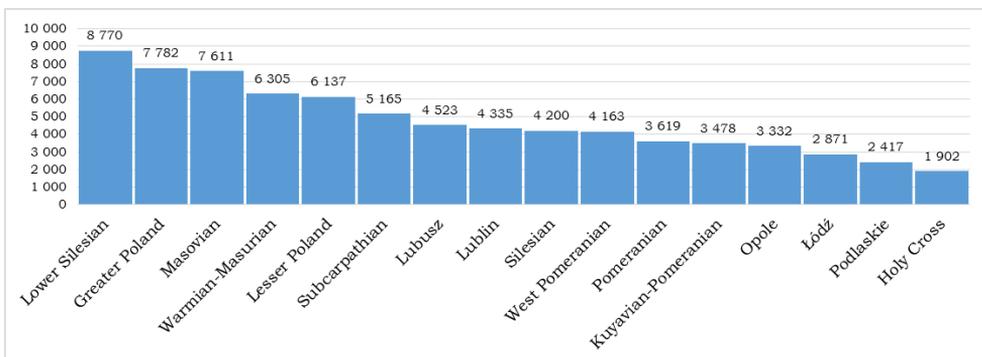
## 2. Materials and Methods

The starting point for the research conducted in the article was an analysis of legal regulations and thematic literature. The data published by the National Heritage Board of Poland (Polish: *Narodowy Instytut Dziedzictwa – NID*) and the *dane.gov.pl* website were used to gather the necessary information. For the quantitative and generic analysis of non-movable monuments, it was decided to use the division used by the NID.

According to it, one can distinguish the following types of non-movable monuments in Poland:

- urban (urban and rural systems, districts, squares and streets as urban interiors, protection zones, canals, railways, and others);
- sacral (churches of different religions, monasteries, belfries, chapels, morgues, roadside shrines, sacral statues, and others);
- defensive (castles, residential towers, defensive buildings, city walls and gates, fortresses and their elements, forts, and others);
- public (public buildings, seats of government, schools, banks, postal offices, hotels, theatres and cinemas, barracks and prisons, train stations, hospitals, administrative buildings, and others);
- mansions (village and city palaces, residential units, and others);
- greenery (palace and mansion parks, gardens, city parks, avenues, villas and home gardens, elements of natural landscapes, and others);
- farm (farm buildings, all individual farm buildings in rural homesteads, granaries, barns, warehouses, and others);
- residential (residential buildings, houses, tenements, rural huts, vicarages and presbyteries, and others);
- industrial (industrial buildings, production halls in factory units, engine houses, boiler rooms, shaft towers in mines, single-production buildings, forges, mills, windmills, water towers, bridges and viaducts, power plants, gas and water supply plants, and others);
- cemeteries (cemeteries, single graves, church areas, and others);
- miscellaneous (fences, gates and guardhouses, statues, fountains and wells, small park architecture, and others).

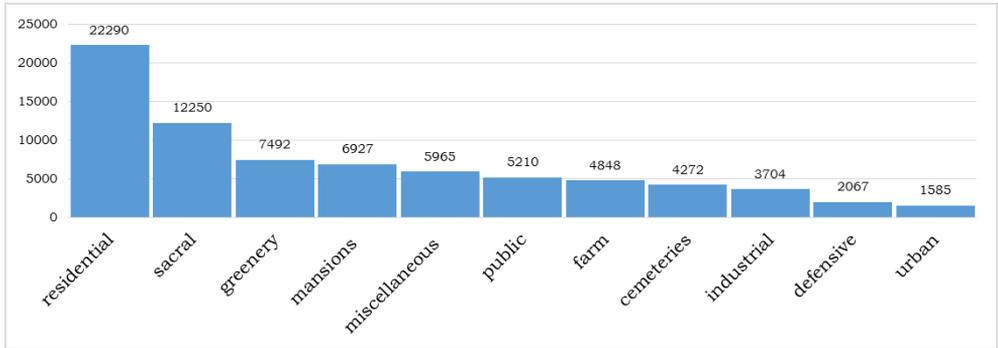
Figure 1 presents statistical quantitative and generic data on the historical monuments in the individual voivodeships of Poland.



**Fig. 1.** Number of non-movable monuments in voivodeships (as of end of 2017)

Source: own elaboration based on <https://dane.gov.pl/dataset/154>

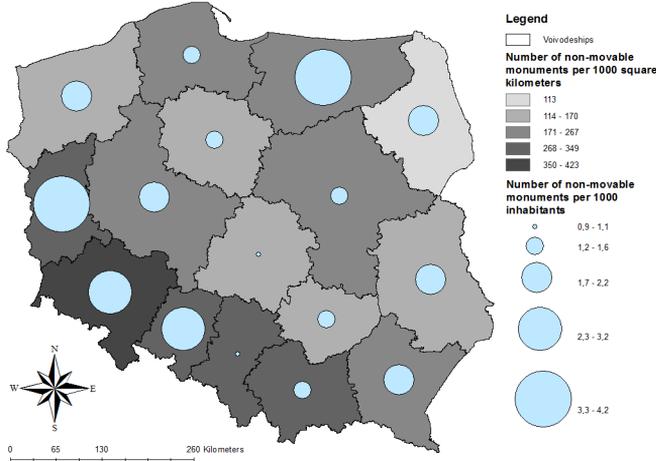
Figure 2 presents data on the number of individual types of non-movable monuments.



**Fig. 2.** Number of non-movable monuments in Poland by type (as of end of 2017)

Source: own elaboration based on <https://dane.gov.pl/dataset/154>

Due to the large number of objects in Poland, it was decided to concentrate on the test area of Warmian-Masurian Voivodeship for further detailed analyses. In terms of the number of non-movable monuments, the voivodeship ranks fourth in the country. The situation changes after referring the data to the area and the number of inhabitants (Fig. 3).

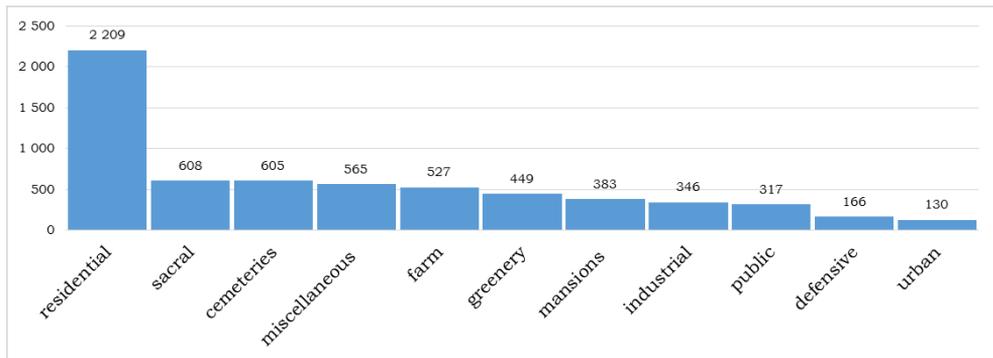


**Fig. 3.** Number of non-movable monuments with division into Polish voivodeships normalized by area (graduated colors, value per 1000 km<sup>2</sup>), and population (graduated symbols, value per 1000 inhabitants)

Source: own elaboration based on [8]

The number of non-movable monuments per 1000 km<sup>2</sup> was visualized using a choropleth map with graduated colors, and the number of non-movable monuments per 1000 inhabitants – with the use of graduated symbols. The number of non-movable monuments in Warmian-Masurian Voivodeship normalized by area is an average result (as it relates to other voivodeships). However, normalizing it by the number of inhabitants places the voivodeship second in the country. The unusual character of the obtained result was an element contributing to the selection of a given voivodeship for further analysis.

Figure 4 shows statistical data for the studied area of Warmian-Masurian Voivodeship.



**Fig. 4.** Number of non-movable monuments in Warmian-Masurian Voivodeship by type (as of end of 2017)

Source: own elaboration based on <https://dane.gov.pl/dataset/154>

Data provided by the NID via [dane.gov.pl](https://dane.gov.pl) should be current and accurate; however, this does not apply to spatial aspects. In order to prepare the point data necessary to carry out the planned analyses, the tabular data had to be associated with geographic coordinates. All of the tabular records were matched to their respective locations, and the locations were connected to geographical coordinates. However, the functional division of data from the [dane.gov.pl](https://dane.gov.pl) website seemed to be incompatible with the functional division developed by the NID – the data from [dane.gov.pl](https://dane.gov.pl) was described in more detail in terms of function (which is understandable) due to the nature of this data (each row of the table means one object entered in the register of objects of cultural heritage). The lack of compatibility, however, was only apparent – the precise functional division with [dane.gov.pl](https://dane.gov.pl) perfectly fit into the overall functional division developed by the NID. The prepared table was converted into a point cloud using the “Make XY Event Layer” of the ArcMap component of the ArcGIS software. The data collected thusly was the starting point for further analyses using the GIS tools.

A cartogram is a good way to visualize data if it results from (or is related to) a territorial division. In another case, this method gives an erroneous idea of the continuity of a feature within a territorial division unit [9]. The utilized software gives us the possibility to make a wide range of geospatial analyses. Spatial distribution can be analyzed by interpolating the total number of monuments in territorial division units considering the particular levels of accuracy (voivodeships, counties, municipalities) to estimate the values at unobserved locations. A Voronoi diagram can also be used to visualize the summary point data. In order to show density, the total number of monuments can be grouped in clusters to identify the locations of statistically significant hot and cold spots. However, the above analyses require additional factors [10]. Therefore, for a continuous and more accurate examination of the spatial distribution of non-movable monuments in this article, the kernel density function was used [11–13].

### 3. Results and Discussion

With the use of the prepared point cloud, an estimation of the density of non-movable monuments in Warmian-Masurian Voivodeship was created (Fig. 5). A large density of non-movable monuments in the belt in the central part of the voivodeship can be noticed from east to west, with a particular accumulation of monuments in the vicinities of major cities.

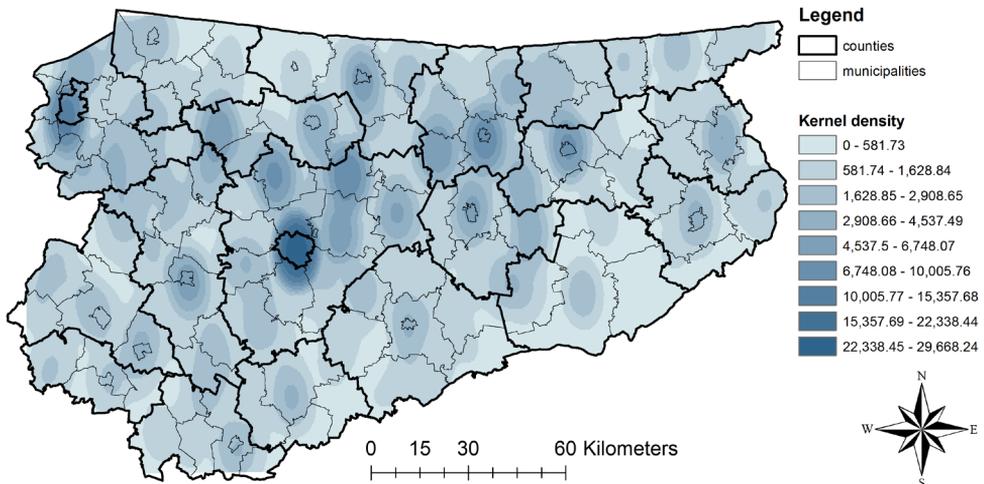


Fig. 5. Density of location of non-movable monuments in Warmian-Masurian Voivodeship

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

To further examine the spatial distribution, the point cloud was divided into individual function groups. Figure 6a shows the density of non-movable monuments in the “urban” function group. Due to the description of the group (presented in Chapter 2), one can notice the accumulation of objects in large urban centers (Olsztyn, Elbląg, Kętrzyn, and Mrągowo). A similar spatial distribution can be seen in the case of monuments from the following function groups: “greenery” (Fig. 6b); “industrial” (Fig. 7a); “public” (Fig. 7b); “mansion” (Fig. 8a); “farm” (Fig. 8b); and “miscellaneous” (Fig. 9).

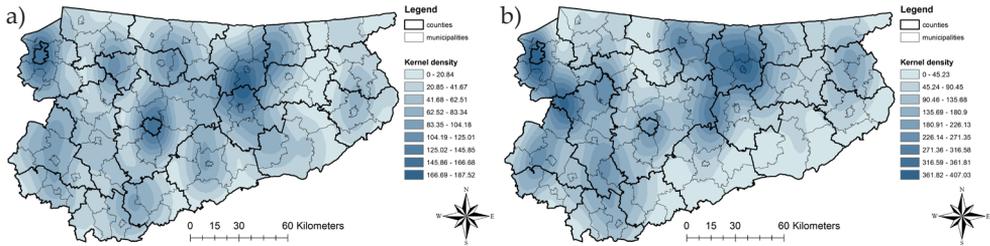


Fig. 6. Non-movable monuments in “urban” (a) and “greenery” (b) function groups

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

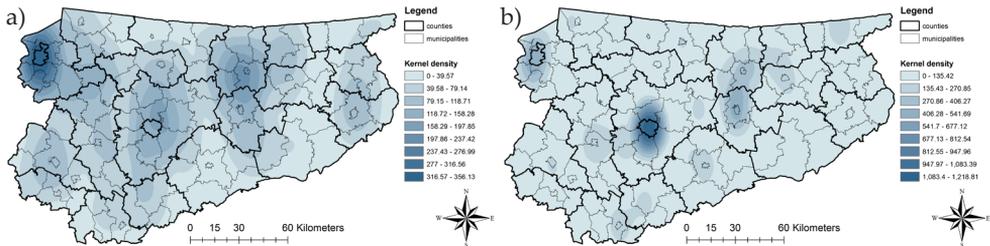


Fig. 7. Non-movable monuments in “industrial” (a) and “public” (b) function groups

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

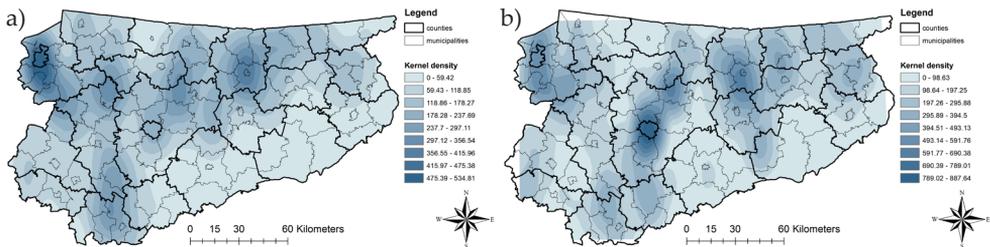


Fig. 8. Non-movable monuments in “mansion” (a) and “farm” (b) function groups

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

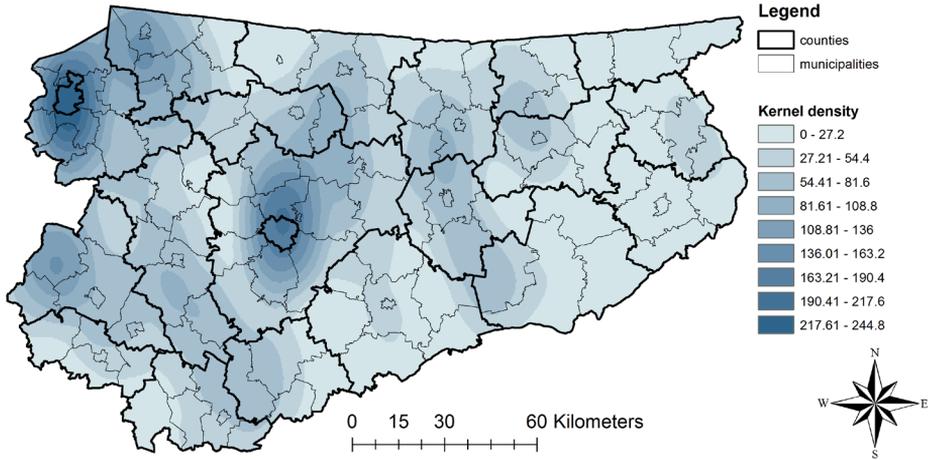


Fig. 9. Non-movable monuments in “miscellaneous” function group

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

The description of the “residential” function group also favors larger urban centers; however, due to the large accumulation of such objects within the city of Olsztyn (with more than 16% of all voivodeship residential monuments), the city generates the largest density in the spatial distribution presented in Figure 10a and overwhelms the rest of the voivodeship. The “defensive” function group (Fig. 10b) presents the region as rich in these objects (with the exception of the counties of Goldap and Pisz).

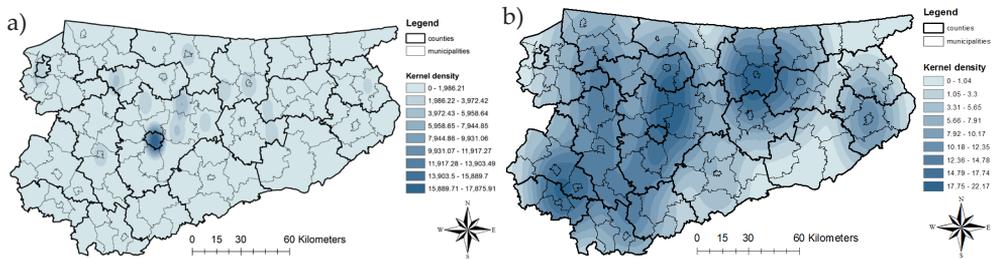


Fig. 10. Non-movable monuments in “residential” (a) and “defensive” (b) function groups

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

Most sacral buildings are located in the central part of the voivodeship in the vicinity of the city of Olsztyn (Fig. 11a). Surprisingly, the objects from the group of “cemeteries” (Fig. 11b) do not show a spatial correlation with the “sacral” group and are rather focused in the eastern part of the voivodeship.

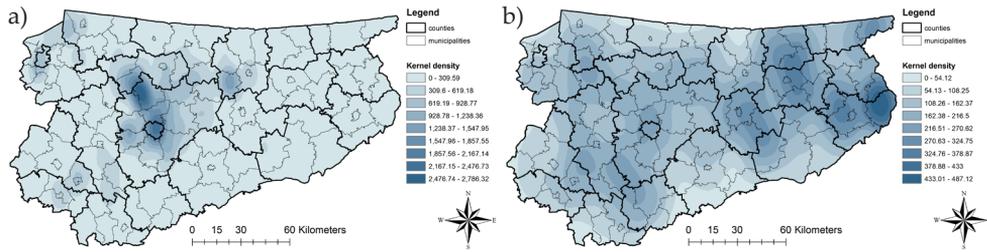


Fig. 11. Non-movable monuments in “sacral” (a) and “cemeteries” (b) function groups

Source: own elaboration based on <https://dane.gov.pl/dataset/1385>

## 4. Conclusions

1. In the case of an analysis of such a subject as non-movable monuments, the abundance of analyzed points and magnitude of the surface area of the analysis allows us to obtain very good results for approximate data – in the case of this article, within the administrative borders of the town where the monument is located.
2. The presented analyses are universal in terms of area and can be performed both locally and for the whole country. It can be performed for any administratively, functionally, or spatially separated area.
3. The article presents the possibilities of using GIS technology as a tool for spatial analysis related to the location of non-movable monuments. Extended to the entire country, the technologies indicated in the article can be used to create or update the national spatial development concept (Polish: *konceptcja przestrzennego zagospodarowania kraju*).
4. Local governments at the county level may use similar analyses when creating or updating a voivodeship development strategy (Polish: *strategia rozwoju województwa*) and voivodeship spatial management plan (Polish: *plan zagospodarowania przestrzennego województwa*) to locate areas of exceptional historical value in a simple and quick manner.
5. When creating a municipality development strategy (Polish: *strategia rozwoju gminy*) and study of the conditions and directions of the spatial management of a municipality (Polish: *studium uwarunkowań i kierunków zagospodarowania przestrzennego gminy*), local self-government needs to take into account the cultural and historical conditions of the commune. The presented analyses are a useful and easy-to-read tool that supports the process of creating these documents.
6. The analyses made it possible to verify the spatial distribution of non-movable monuments from various functional groups, showing the non-uniformity of their spatial distribution in the analyzed area.

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## Wykorzystanie narzędzi GIS w modelowaniu rozkładu przestrzennego obiektów zabytkowych

**Streszczenie:** Wpis obiektu do rejestru zabytków to jedna z ustawowych form prawnej ochrony zabytków w Polsce. Rejestry zabytków są prowadzone przez właściwych terytorialnie wojewódzkich konserwatorów zabytków. W wojewódzkich rejestrach zabytków obecne znajduje się ok. 76 tys. wpisów dotyczących zabytków nieruchomości, zróżnicowanych pod względem rodzajowym. Obiekty te mogą być: krajobrazami kulturowymi, układami urbanistycznymi, ruralistycznymi i zespołami budowlanymi, dziełami architektury i budownictwa, dziełami budownictwa obronnego, obiektami techniki, cmentarzami, parkami, ogrodami i innymi formami zaprojektowanej zieleni, a także miejscami upamiętniającymi wydarzenia historyczne bądź działalność wybitnych osobistości lub instytucji. W niniejszym artykule przedstawiono wyniki badań możliwości wykorzystania technologii GIS w analizach dotyczących przestrzennego rozkładu obiektów zabytkowych w Polsce. Przeanalizowano dane pochodzące z Narodowego Instytutu Dziedzictwa, które pozyskano z serwisu internetowego dane.gov.pl. Uzyskano w ten sposób mapy ukazujące zagęszczenie zabytków nieruchomości, z wyszczególnieniem różnych ich typów i lokalizacji. Obszarem szczególnych badań było województwo warmińsko-mazurskie. Wygenerowane mapy mogą być wykorzystywane przy tworzeniu i aktualizacji koncepcji przestrzennego zagospodarowania kraju, a także wojewódzkich planów zagospodarowania przestrzennego.

### Słowa

**kluczowe:** GIS, ochrona zabytków, rejestr zabytków, analizy przestrzenne, modelowaniu rozkładu przestrzennego