REMV
REAL ESTATE MANAGEMENT AND VALUATION

Journal homepage:
www.remv-journal.com

QUANTITATIVE AND SPATIAL ASPECTS OF THE REAL ESTATE MARKETS IN THE WARMIAN-MASURIAN VOIVODESHIP, POLAND

Mirosław Bełej[1]*, Marta Gwiaździńska-Goraj[2]

[1] University of Warmia and Mazury in Olsztyn, ul. Rakowicka 27, 31-510 Kraków, Poland, (MB) email: miroslaw.belej@uwm.edu.pl, ORCID: 0000-0001-8650-6990; (MG-G) email: marta.gwiazdzinska-goraj@uwm.edu.pl, ORCID: 0000-0002-6993-7235

** Corresponding author*

ARTICLE INFO

Keywords:

calendar effects, behavioral finance, real estate market

JEL Classification:

A10, R30

ABSTRACT

The aim of this paper is a quantitative and spatial analysis of the attributes determining local housing markets in the Warmian-Masurian voivodeship in Poland. The study assumed 21 counties treated as local housing markets and environmental, social, economic, and infrastructural data concerning the analyzed counties. The source of data was the Central Statistical Office. The research carried out, using principal component analysis (PCA) and the development of a synthetic indicator, made it possible to identify groups of counties with similar socio-economic characteristics (clusters). This refers to the valuer using data from specific counties when there is a lack of information in the local market being analyzed. The research results showed significant differences between urban and rural districts in the Warmian-Masurian Voivodeship in Poland. The data presented provide knowledge which will help to shape the region's spatial policy and infrastructure planning.

Citation:

Bełej, M. & Gwiaździńska-Goraj, M. (2025). Quantitative and spatial aspects of the real estate markets in the Warmian-Masurian Voivodeship, Poland. *Real Estate Management and Valuation*, *33*(4), 1-14. https://doi.org/10.2478/remav-2025-0031

1. Introduction

The housing market (of all categories of real estate markets) is the closest to society, as everyone needs to provide a roof over their head, i.e. to fulfill a basic human need. In this sense, housing is not a technical element but an essential socio-economic element of humanity. Firstly, housing contributes to a sense of stability and security (Ball, 2017) and, as a result, affects the functioning of the family community or individuals. On the other hand, housing (like other expensive goods) plays a key role in positioning people in the hierarchical structure of society (Lindstrom, 1997), through which social relations and spatial clustering of similar social groups are formed.

The housing market is the cornerstone of any country's economy, as it influences the construction sector, the financial sector or the sector of goods needed to renovate homes (Antczak - Stępniak et al., 2021; Doling et al., 2013; Muellbauer & Murphy, 2008). Classical definitions of the housing market generally focus on buying and selling a dwelling from the perspective of classical economics (Hannonen, 2014; Hincks & Baker, 2012). It seems, however, that this market should be looked at much more broadly, not only through the transaction process itself (the specific commodity) but through social, economic, political, historical, cultural or environmental conditions. From this perspective, the housing market (housing system) can be understood as a mutual relationship of private and public actors involved in the process of planning, construction and consumption of housing resources, together with a set of rules established by institutions sustainably regulating the above relations (Lis, 2012). A broad view of the housing market is represented by several authors, e.g., in the field of economics (Adams & Füss, 2010; Anselin & Bera, 1998; Ball, 2017), demography (Vignoli et al., 2013), government policy (Leung, 2004), the labor market (Lewandowska-Gwarda, 2018), society (Bełej, 2022; Butler, 2022) or ecology (Zambrano-Monserrate & Ruano, 2019).

Housing market analysis is generally defined as the process of examining the current dynamics of housing prices in terms of demand or supply, generally in a

specific local market. Therefore, an important element of this analysis is understanding the factors determining the substitution of housing prices or rental rates. At the same time, the dynamics of housing prices and the forecast of these dynamics are analyzed. Within the framework of the housing market analysis, many procedures are used (Basu & Thibodeau, 1998; Belke & Keil, 2018a; Bieda, 2017; Cellmer et al., 2021; Kisiała & Rącka, 2021; Rącka et al., 2017; Renigier-Biłozor et al., 2022; Tomal, 2019; Trojanek et al., 2018) i.e.:

- identification of market trends
- identification of demand and supply levels,
- identification of business environment factors,
- identification of investment risk levels,
- identification of the demographic and socio-economic structure of housing buyers,
- analysis of business cycles,
- analysis of the location and neighborhood of the flat,
- analysis of construction costs and their impact on housing prices,
- analysis of housing prices in local and regional terms,
- analysis of developer market activity,
- analysis of housing investment.

Analysis of the housing market is not only an analysis of the market for a specific commodity (housing); it is also a kind of analysis of the quality (economic-technical-environmental) of life of a community in a specific region of the country. This is because the price of a dwelling reveals important characteristics of the environment, i.e., the political and economic importance of the region, the level of unemployment in the region, road infrastructure, demographics, migration, ecological areas or GDP per capita, among others. As a result, the analysis of the housing market does not necessarily focus only on the analysis of housing prices (Batóg et al., 2019; Belke & Keil, 2018b; Berg, 2002; Pichler et al., 2021) but also focuses on analyzing regional aspects, as these are what determine the price of housing in a particular region (Bełej et al., 2016; Broitman & Koomen, 2015; Renigier-Biłozor et al., 2017; Vatansever et al., 2020).

This way of thinking is not alien to the property valuation profession in Poland. Although its primary purpose is to determine the property's value, it must be preceded by an analysis of the property market, considering particular property prices, property rental rates, the terms of the transaction and a visual inspection of the property. In the provisions of Polish law (Regulation of the Minister of Development and Technology of 5 September 2023 on the valuation of real estate) concerning the valuation of real estate, the following statements can be found:

- in determining the value of properties which, owing to their unique characteristics and nature, are not traded on the local real estate market, or where no rents are available on that market, or where the number of transactions or rents for similar properties is insufficient, transaction prices or rents obtained for similar properties on the regional or national real estate market may be used as appropriate
- the area of the property market analyzed should reflect the socio-economic similarity influencing the level of property prices.

Both formulations point to issues of regional or national markets and the socio-economic similarity of these areas. At the same time, the Interpretative Note "Application of the comparative approach in property valuation" of the Polish Federation of Valuers' Associations indicates that the assessment of the impact of market characteristics on the differentiation of housing prices can be determined based on relationships occurring in similar local markets in terms of type and area.

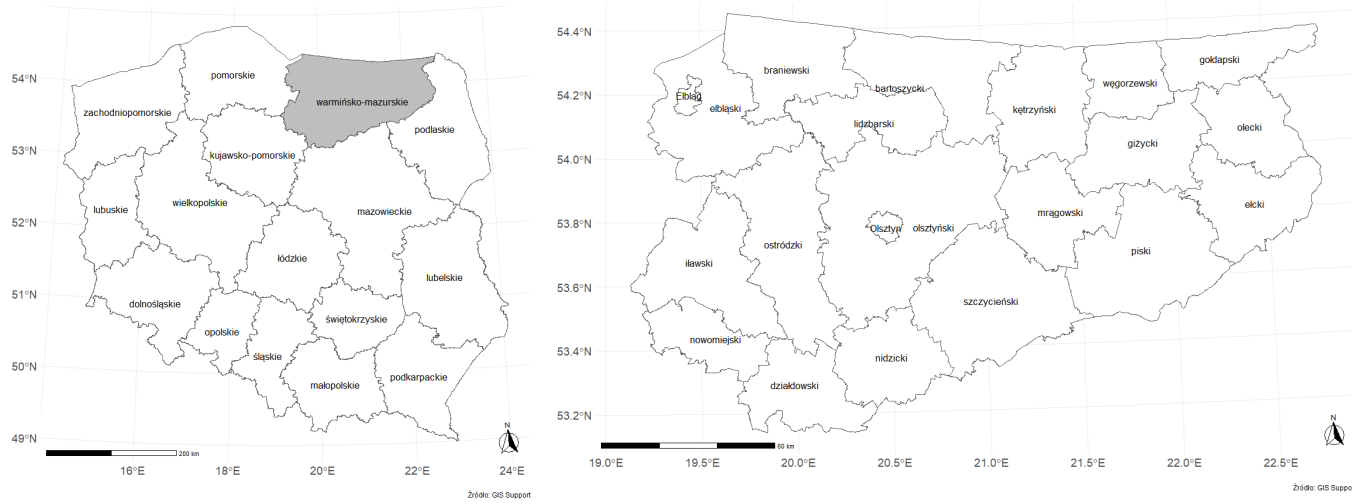
This raises the question that the valuer should determine in his work: which housing markets are similar, and can the area of housing market analysis be extended to them? This should not be done based on the subjective opinions of a housing market expert but on objective analyses of the socio-economic characteristics of the regions. Such an assumption is the basis of the research concept of this scientific work.

Generally speaking, the study presented in this article aims to analyze the similarity of housing markets (within counties) to determine property values with the limitations of local market data. The study adopted 21 counties in the Warmian-Masurian Voivodeship in Poland for analysis and environmental, social, economic, and infrastructure data for the counties under analysis. The decision on whether a given county belongs to a specific group (cluster) of similar units should be based on several different attributes of the counties and not only on the housing price in them. The similarity of regions (counties), treated as local housing markets was analyzed using statistical methods and spatial visualization. R software was used in the study, along with the available packages of this software (Kassambara & Mundt, 2020; Maechler et al., 1999; Wickham, 2016; Wickham & Bryan, 2023).

2. Material and methods

2.1. Study Area and Data Description

The research was carried out in 21 districts (including two urban districts) of the Warmian-Masurian voivodeship in Poland. Figure 1 locates this voivodeship within the country (Fig. 1a) and shows the borders of the studied districts. (Fig. 1 b).



a) b)

Fig. 1. Warmian-Masurian voivodship: a) location of the voivodship within Poland, b) location of poviats in the voivodship. *Source*: own study.

The Warmian-Masurian Voivodeship is located in northeastern Poland on the border with Königsberg Oblast. The province covers an area of 24,173 square kilometers, is inhabited by 1,357,000 people, and has an average population density of 56 persons/km^2. The urbanization rate, meanwhile, is at 58.9% (GUS, 2025). The demographic structure of the voivodeship was decisively influenced by mass migration movements after World War II, making it largely populated by incomers. At present, the low birth rate (-4.48%) and low migration balance (-0.04%) result in a highly dynamic population ageing process. Thus, in 2023, the ageing index for this voivodeship was recorded at the same level as for the country, i.e. 133 (GUS, 2025).

The labor market and its economic structure have a significant impact on the attractiveness of living in the voivodship. The Warmian-Masurian voivodeship is characterized by a low level of social and economic development in comparison to the country. The process of transformation of socialized agriculture, which involved the liquidation of State Agricultural Farms, resulted in high unemployment among the voivodship's residents. In 2025, the unemployment rate stands at 8.3% and is still significantly unfavorable in comparison to the national figure of 5.1% (GUS, 2025). This condition is also influenced by the possibility of obtaining a job. In the Warmian-Masurian voivodship, the ratio of newly created jobs to lost jobs was 1.1, and in the country 1.7 (GUS, 2025). One of the main factors in job creation is the development of entrepreneurships, which is characterized by a low level in the voivodship under study (the number of national economy entities per 10,000 inhabitants of working age is 1845.2, compared to a national average of 2342.5 (GUS, 2025).

Demand for labor and the financial condition of enterprises translates into the size of remuneration. In the Warmia and Mazury region in 2023, it was below the average gross monthly salary in the country (PLN 7 595) and amounted to PLN 6 447 (GUS, 2025). The voivodship is characterized by a low level of industrialization (mainly food as well as wood and furniture industries). It can be concluded that it is primarily an agricultural region. Agricultural land accounts for more than half of the voivodeship (54.3% - 2021) and is dominated by arable land (66.3%) and permanent grassland: meadows and pastures (28.8% - 2021). In comparison with the country, Warmian-Masurian Voivodeship is distinguished by a favorable farm size structure (average area of agricultural land in a farm in 2020. - 23.25 ha) (GUS, 2025). High natural values, including large forest complexes (the share of forests in the total area in 2023 - 32.6%), numerous lakes (more than 3,000 lakes, including Poland's largest lake - Śniardwy) and rich fauna and flora, have caused tourism to play an increasingly important role in the economic development of the voivodeship. Legally protected areas in the total area of the voivodship in 2023 constituted as much as 46.8% of (GUS, 2025). Almost the entire voivodship (with the exception of the

Kisielice municipality) has been classified as one of the Green Lungs of Poland functional areas, which include naturally unique areas situated in the north-eastern part of Poland. Warmian-Masurian voivodeship low transport accessibility is due to, among other things: a poorly developed road and rail transport system. The density of hard-surfaced roads per 100 km2 of the voivodeship's area in 2023 was 60.9 km, with the national average at 101.9 km and the density of railways at 4.5 km as compared to 6.8 km for the country. The most important transport connections of the voivodeship on the north-south axis include national road No. S7 and the E65 railway trunk line, and on the east-west axis: a sequence of national roads No. 5 and 16. The dispersion of the settlement network in the Warmian-Masurian Voivodeship undoubtedly does not have a favorable effect on the development of technical infrastructure (density: water supply network - 75.9 km/km2; sewerage network - 33.0 km/km2) (GUS, 2025).

To examine the relationship between interest in purchasing a dwelling and the importance of the attractiveness of the location of that dwelling (a given county), a series of data was collected from the Central Statistical Office (web portal www.stat.gov.pl - accessed 25.02.2025). To assess the interest in purchasing a dwelling - the indicator X1 - Average price per 1 m^2 of dwellings sold in market transactions (Table 1) was adopted. This indicator refers to data from the primary market. Then, from the remaining nine indicators, five indicators were selected to determine the attractiveness of residence through housing stock (X3), infrastructure availability (X5) and labor market (X2, X4, X6), with three indicators determining the intangible attractiveness of residence, i.e. (demographic conditions (X7, X8, X9) and environmental conditions (X10).

Table 1

A summary of the considerations for choosing the lag level in the VAR model

	Name	Name - abbreviation
X1	Average price per m^2 of dwellings sold in market transactions	**price1m**
	Material conditions	
X2	entities by size class per 10,000 inhabitants of working age	**buisness_entities**
X3	number of completed dwellings per 1 000 inhabitants	**housing**
X4	unemployment rate	**unemployment**
X5	water supply network per 100 km^2	**water_network**
X6	average gross monthly salaries	**salary**
	Non-material conditions	
X7	urbanization rate [%]	**urbanisation**
X8	population per $1km^2$	**population**
X9	total migration balance per 1,000 population	**migration**
X10	share of legally protected areas in the total area	**ecological_areas**

Source: own study.

R software was then used to select a number of characteristics most relevant to the price of 1 m^2 of housing in each county (R Core Team, 2021), and package vip (Variable Importance Plots) (Greenwell & Boehmke, 2020). It is a tool for calculating and visualizing the variables' validity in various statistical models. The VIP model uses various supervised learning algorithms, including gradient-boosted decision trees (GBM), the feature importance ranking measure (FIRM) method or the permutation method for random forest (RF). The methodology of the described research methods can be found in several studies (Archer & Kimes, 2008; Inglis et al., 2022). The results of the analysis of the importance of the selected characteristics of the districts in regards to price of 1 $m^2$of housing are presented in Fig. 2.

The Variable Importance Plots (Fig.2) result in a visualization of the importance of individual characteristics, with the length of the bars representing the importance of each characteristic to the price of housing in the districts. The analysis shows the highest importance of features: "buisness_entities", "urbanization" and "water_network", which prove to be extremely important in predicting the phenomenon under study. Interestingly, characteristics related to the population's monthly earnings or unemployment level were less important than others. This may be due to the low unemployment and average salary increase between 2020 and 2025. Finally, six characteristics were selected for further research, without "migration",

"salary" and "unemployment".

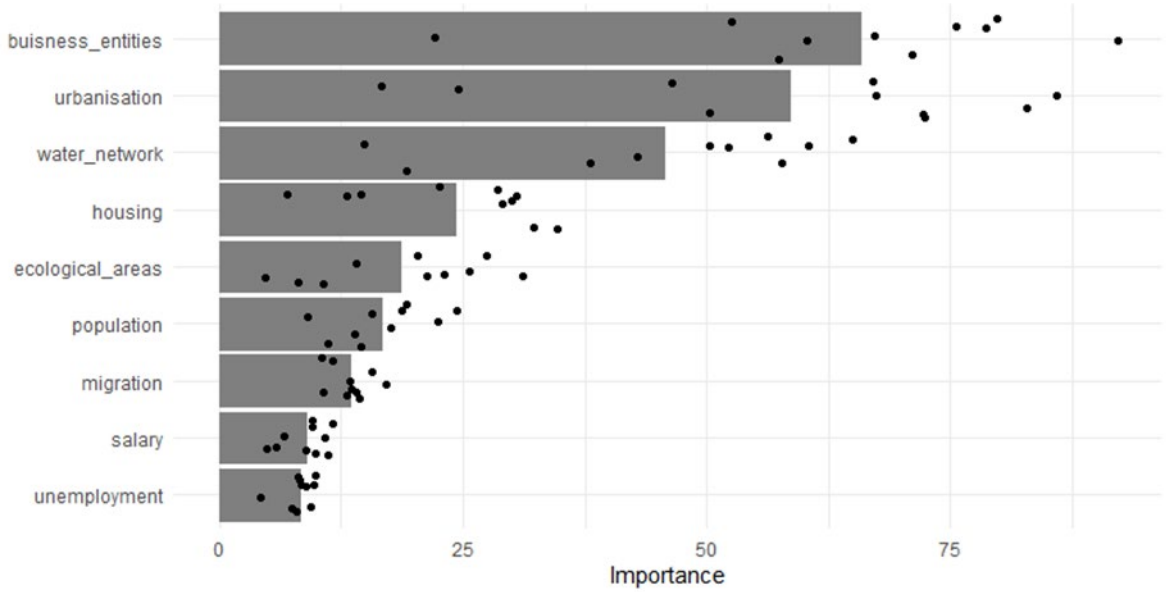


Fig. 2. Level of importance of the data used in the Variable Importance Plots (vip) package in R software. *Source*: own study.

2.2. Methods

The first stage of the research used the vip (Variable Importance Plots) package in R to assess the data's validity, i.e., to determine which variables in the predictive model have the most significant impact on the outcome. The method uses various computational algorithms, i.e. Classification and Regression Trees (CART), Random Forest (RF), Gradient Boosting Machines (GBM), Linear Regression (LM), Support Vector Machines (SVM), Shapley Additive Explanations (SHAP) or naive Bayes classifiers (Greenwell & Boehmke, 2020). This method allows for the effective classification of levels of importance in a predictive model of individual features of the model, while at the same time, the results can be visualized in the form of, for example, bar plots, dot plots, sparklines, partial dependence plots or individual conditional expectation. The vip model in R helps in the decision to select specific variables for further modeling. It allows the selected choice of a given set of variables to be optimised in order to improve the performance of the underlying research mode. In the next step, a particular variant of factor analysis, Principal Components Analysis (PCA), was applied. This method is a technique for dimensionality reduction that transforms data into a new coordinate system with uncorrelated principal components. It transforms the existing data into a new coordinate system in which the principal components are linear combinations of the original variables and are uncorrelated. The principal components are then ordered according to decreasing variance. This is calculated by calculating the covariance matrix, finding its eigenvectors and eigenvalues and sorting them by decreasing eigenvalue (Groth et al., 2013; Korfiatis, 2007). PCA PCA basic steps (Lee & Jemain, 2021; Palma & Pierdominici-Sottile, 2023):

- data standardization, where each variable has a mean equal to 0 and a standard deviation equal to 1,
- calculation of the covariance matrix, where for dataset X with n observations and p variables, the formula is used:

$$C = \frac{1}{n-1} X^T X \quad (1)$$

- calculation of the eigenvalues and eigenvectors of the covariance matrix by solving the equation:

$$Cv = \alpha v \quad (2)$$

where α are the eigenvalues and v are the corresponding vectors.

- sorting eigenvectors,
- data transformation, where the original data is projected onto the principal components, which can be written with the formula:

$$Z = XW \quad (3)$$

where W is the matrix having the selected eigenvectors in the columns and Z is the transformed data.

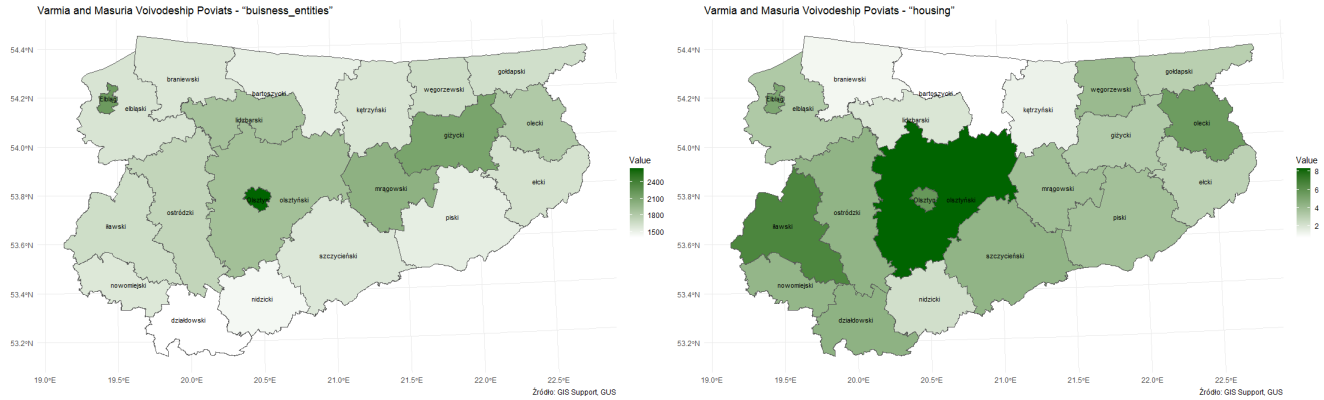
Principal Components Analysis generally identifies a smaller set of principal components that reflect the most significant variability in the original data. In effect,

it identifies (mainly 2 or 3) principal component variables so that visualization of the results can be carried out to identify similarities and differences between the analyzed data (Groth et al., 2013; Jolliffe & Cadima, 2016; Pöge & Reinecke, 2021).

3. Results

3.1. Basic research – data study

The research was carried out in the Warmian-Masurian Voivodship for 21 poviats based on data from the Central Statistical Office (GUS) for data values in 2023. More on the adopted six attributes describing the specificity of poviats can be found in Chapter 2.1. To better describe the collected six attributes (important for the development of local housing markets), cartograms were prepared to show the diversity of the values of the studied attributes at the level of poviats. First, the spatial distribution in the counties of the "business_entities" feature (Fig. 3a) and "housing" feature (Fig. 3b) is presented.



a) b)

Fig. 3. Cartogram of the values of the characteristics describing the poviats in Warmian-Masurian Voivodship in Poland: a) business_entities, b) housing. *Source*: own study.

The attribute "business_entities", i.e. business entities by size class per 10,000 inhabitants of working age (Fig. 3a), is an important factor influencing a given location's attractiveness. In Warmian-Masurian Voivodship, this indicator ranges from 2644.8 (the city of Olsztyn) to 1392 (Działdowski poviat). Analyzing the spatial distribution of this indicator, it was noted that the highest values were obtained by the poviats constituting the main labor markets (Olsztyn and Elbląg) and those connected with the development of tourism, such as Mrągowski and Giżycki. At the same time, these poviats are distinguished from other poviats in the voivodeship by high spatial accessibility (voivodeship road), which is not without significance. The "housing" characteristic, i.e. the number of dwellings completed per 1,000 inhabitants (Fig. 3b), shows that the highest transactional interest was recorded in the Olsztyn Poviat, which exceeded the figures even for the cities of Olsztyn and Elbląg. The reasons for this can be seen in the allocation of land for housing adjacent to the city of Olsztyn, an important labor market. The lowest figures were recorded for the poviats in the northern part of the voivodship, i.e. Bartoszycki, Braniewo and Kętrzyn. A common feature distinguishing these three poviats is their unfavorable location at the state border and, at the same time, the external border of the European Union. In the past, these poviats were characterized by high unemployment rate of 14.5-17% in the voivodeship. Consequently, this condition may lead to a lack of financial opportunities and, thus, a need to purchase new housing.

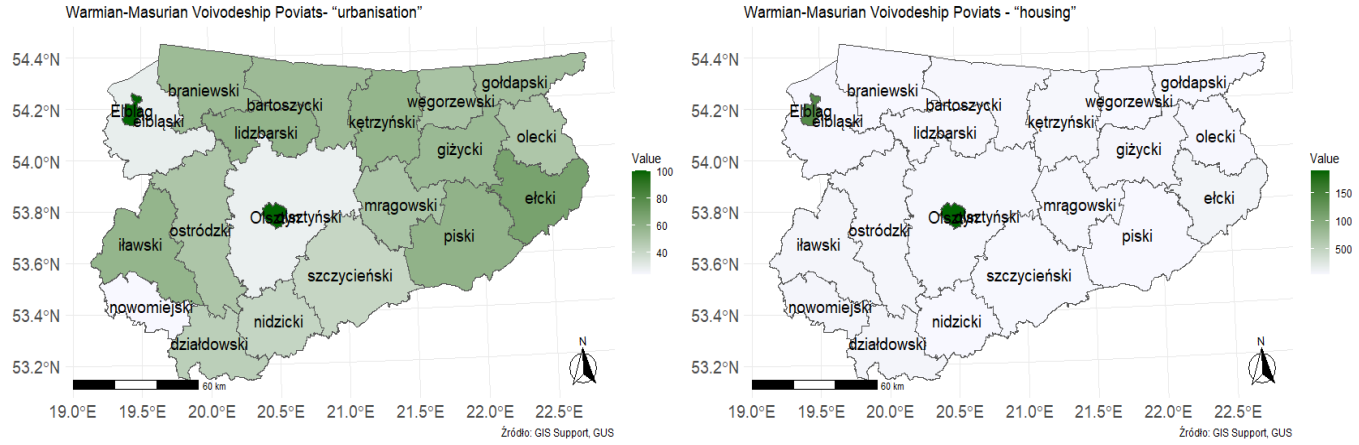
The spatial distribution of the "urbanization" feature (Fig. 4a) and the "population']" feature (Fig. 4b) within the counties is presented next.

The feature "urbanization", i.e. the percentage urbanization index (Fig. 4a), illustrates the relationship between the urban population and the total population. In Warmian-Masurian voivodeship, its highest values were recorded for the capital city of Olsztyn, the urban poviat of Elbląg and the rural poviat of Ełk, where the third important center of balancing development in the voivodeship is located. As a result, the lowest figures were recorded for the rural poviats of Olsztyn and Elbląg, where the largest cities of Warmia and Mazury are located. The feature "population", i.e. population per 1 km^2 (Fig. 46), generally confirms that the Warmian-Masurian Voivodeship, in comparison to the country, is characterized by the lowest population density, which is at the level of 56.2 persons/km^2. Obviously, the highest values were recorded for urban poviats. In

eISSN: 2300-5289

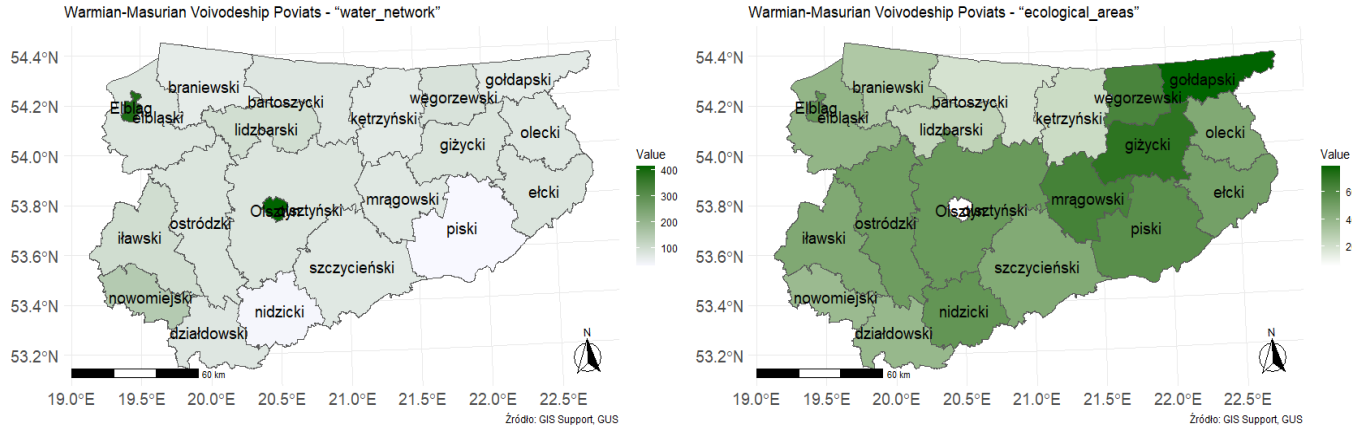
contrast, the lowest values were recorded for poviats located in the northern part, which are simultaneously characterized by poor communication accessibility.

Finally, the spatial distribution in the districts of the "water-network" feature (Fig. 4a) and the "ecological_areas" feature is presented (Fig. 4b).



a) b)

Fig. 4. Cartogram of the values of the characteristics describing the powiats in Warmian-Masurian Voivodship in Poland: a) urbanisation, b) population. *Source*: own study.



a) b)

Fig. 5. Cartogram of the values of the characteristics describing the poviats in Warmian-Masurian Voivodship in Poland: a) water_network, b) ecological areas. *Source*: own study.

The attribute "water-network", i.e. the density of the water-supply network (Fig. 5a), is closely linked to the settlement network of Warmian-Masurian voivodeship, which is characterized by high dispersion. Thus, once again, the highest values were recorded for the urban poviats of Olsztyn and Elbląg. The feature "ecological_areas", i.e. the share of legally protected areas in the total area (Fig. 5b), indicates high natural values in Warminsko-Mazurskie, where the share of legally protected areas in the total area is as high as 46.8%. High values were recorded for counties in the Mazurian Lake District, especially in its eastern part, for which this indicator was above 60%. Poviats with the lowest share of legally protected areas in the total area (below 30%) are concentrated in the northern part of the voivodeship, which is associated with the development of agriculture.

3.2. Principal Components Analysis

In the first stage of the research, 21 counties in the Warmian-Masurian Voivodeship were subjected to exploratory data analysis in order to group them. The research used Principal Components Analysis (PCA) to identify groups of similar counties (creating a hierarchy of clusters) and to show these clusters graphically. This task is accomplished by reducing the original data to mainly two principal components, which, despite the reduction, still describe the variability of the characteristics well. The data for the six characteristics (buisness_entities, housing, urbanization, population, water_network, and ecological areas) selected in Chapter 2.1, whichdetermine the specific characteristics

of the districts,in the context of housing markets, were standardized and prepared for further calculations.

The first step presents basic statistics for the principal components (Table 2). The results, shown in Table 3, indicate that the first two principal components (PC1, PC2) explain a total of 80.45% (Cumulative Proportion 0.8045) of the variation in the data. The three principal components (PC1, PC2, PC3) explain up to 92.39% of the variability in the data. However, only two principal components were adopted for further calculations because they provide a sufficiently reasonable interpretation of the raw data, with a significantly simplified understanding of the results in two-dimensional space. Table 3 shows the values of the calculated factor loadings for the first two components (PC1, PC2).

Table 2

Basic statistics on principal components

	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
Standard deviation	1.8873	1.1248	0.8464	0.5128	0.4109	0.1572
Proportion of Variance	0.5937	0.2109	0.1194	0.0438	0.0281	0.0041
Cumulative Proportion	0.5937	0.8045	0.9239	0.9677	0.9959	1.0000

Source: own study

Table 3

Factor loadings for PC1 and PC2

	PCA1(59,4%)	PCA2 (21,1)%	Dimension
housing	0.1798	**0.7160**	Dim2
water_network	**0.5103**	0.0005	Dim1
business_entities	**0.4608**	0.1863	Dim1
population	**0.5176**	-0.0361	Dim1
urbanization	**0.4426**	-0.1856	Dim1
ecological_areas	-0.1765	**0.6457**	Dim2

Source: own study.

The results of the Principal Components Analysis calculations, shown in Table 2, allow us to attribute a reduced dimension to two principal components (PC1, PC2) for specific six primary variables. The first principal component (PC1) explains almost 60% of the variance, while the second principal component explains about 20% of the variance in the core variables. PC1 is strongly correlated with the characteristics, i.e. "water-network", "business_entities", "population" and "urbanisation"; these variables' loading values are between 0.44 and 0.52. This principal component can, therefore, be interpreted as the overall level of infrastructural and demographic development in the district. The second principal component (PC2) is strongly correlated with the characteristics, i.e. ''housing'' and ''ecological_areas'' (0.71, 0.65), which allows it to be interpreted in the direction of environmental and residential development.

The PCA analysis allowed for the reduction of the six primary variables to 2 main factors, which contain more than 80% of the information in the primary variables. As a result, the values of the two variables were created for each county to interpret the locations of the counties in a two-dimensional space, where the dimensions are the factor loadings PC1 and PC2. Fig. 6 shows the dispersion of poviats in the Warmian-Masurian Voivodeship in Poland in a two-dimensional space for PC1 (Dim1) and PC2 (Dim2).

Figure 6 shows the location of the 21 poviats in Warmian-Masurian Voivodeship in Poland, depending on the calculated factor loads in the coordinate system PC1 and PC2. The horizontal axis of this coordinate system corresponds to the first principal component (level of infrastructural and demographic development), while the vertical axis corresponds to the second principal component (level of environmental and residential development). As a result of the reduction of dimensions in the PCA method, clusters of similar counties can be observed to classify their similarity, generally with the adopted primary data. Figure 6 shows a group of dominant counties, i.e. Elbląg and Olsztyn, with a strongly developed infrastructure and economy. On the other hand, the counties of Bartoszycki, Kętrzyn and Braniewo show a cluster of counties exhibiting the worst macroeconomic indicators, which shows the similar areas that can be used in the valuation of real estate (so-called similar local markets in terms of type and area). At the same

time, the applied coloring for specific values allows for better identification of groups of similar counties.

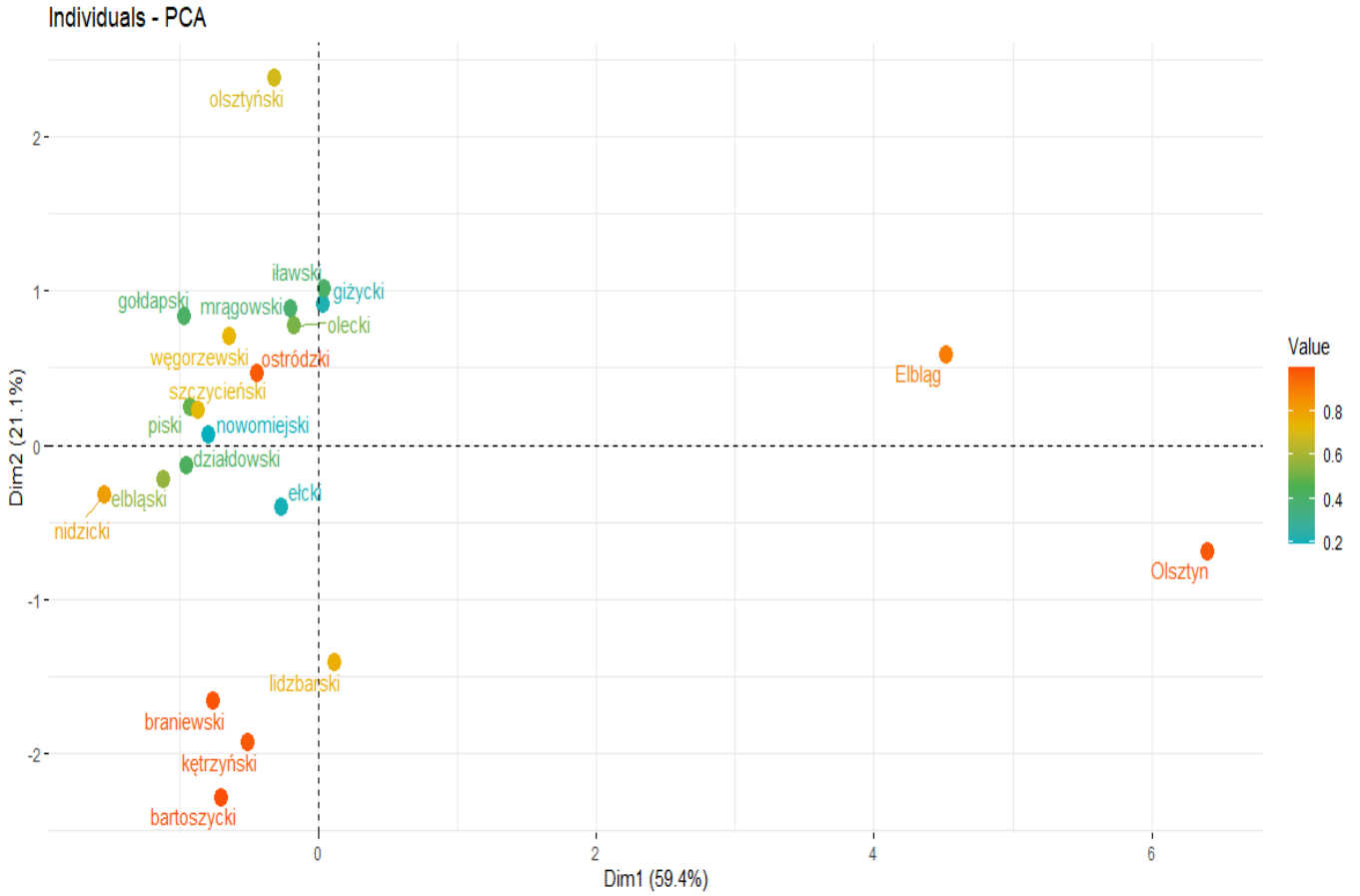


Fig. 6. Dispersion of districts in Warmian-Masurian voivodeship in Poland in two-dimensional space. *Source*: own study

3.3. PCA – weighted synthetic indicator

In a further stage of the study, it was decided to further simplify the interpretation of the results obtained in Principal Components Analysis by calculating a unidimensional value of the factor loadings for PC1 and PC2. For this purpose, the PC_weighted index was determined as a weighted average of the factor loadings for the individual districts, where the weights are the percentage values of PC1 (58.4%) and PC2 (21.1%). This resulted in a new synthetic value, which was visualized in the form of a cartogram (Fig. 7).

Fig. 7 shows the spatial distribution of the obtained PCA_weighted index. Its highest values were recorded in the urban poviats of Olsztyn and Elbląg, as well as the poviats located in the lake districts (Mazurian Lake District and Iława Lake District). This is because these areas stand out from the voivodeship in terms of the attractiveness of living. The location near large labour markets (Olsztyn, Elbląg) and the development of entrepreneurship, mainly related to the development of tourism, are important. In addition, these are counties that, apart from favorable housing conditions in material terms, are distinguished by high natural values and play an increasingly important role. The favorable location at the most important road arteries for the voivodeship running from west to east and north to south is not without significance. The poviats that obtained the lowest value of the index were concentrated in the northern part of the voivodeship. In the past, socialized agriculture was predominant there, and in relative terms, they stand out in comparison with Warmian-Masurian Voivodship in terms of unfavorable unemployment rates. Poor development of entrepreneurship, as well as an unfavorable border location and limited transport accessibility, further reduce the attractiveness of living in these districts.

eISSN: 2300-5289 | Received 2025-03-18 | Revised 2025-05-09 | Accepted 2025-07-14

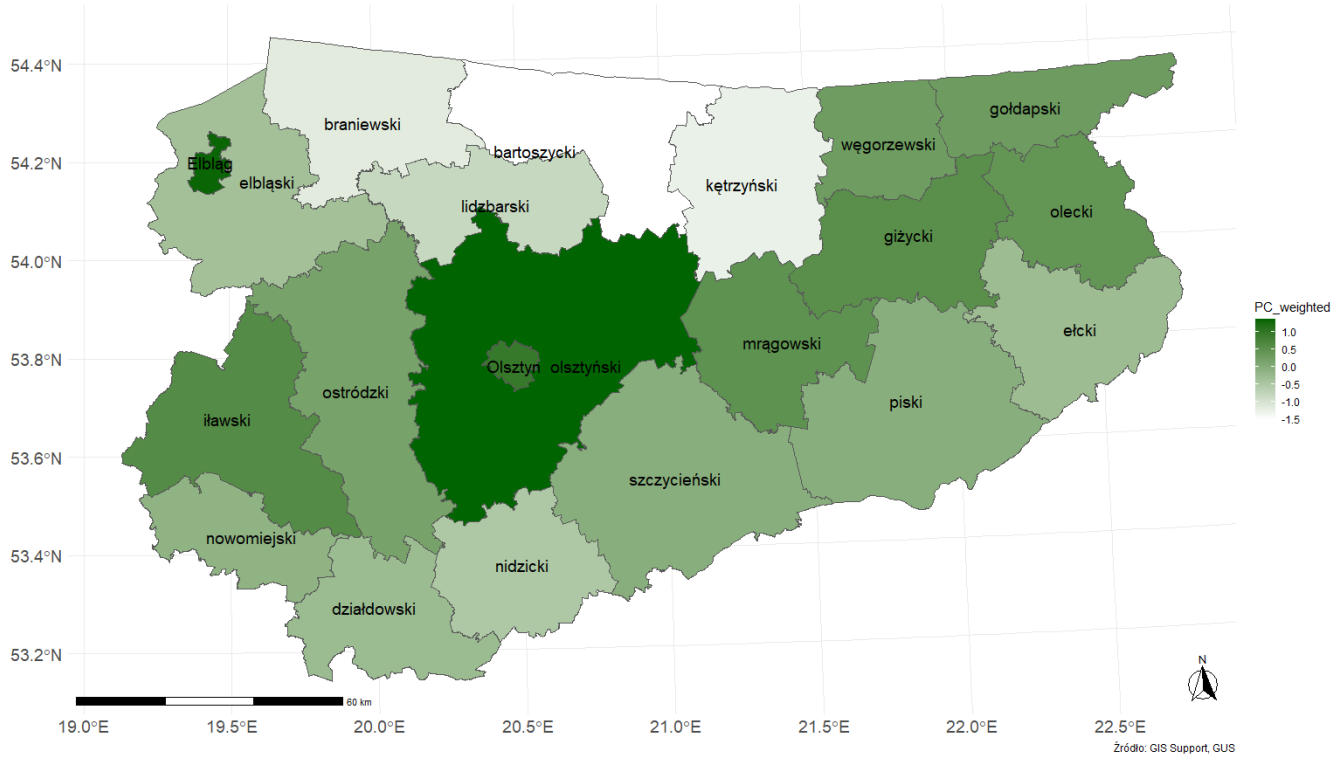


Fig. 7. PCA_weighted cartogram, synthetic value weighted by PC1 and PC values 2. *Source*: own study.

4. Discussion

Similar studies on regional variation are based on different methods and data. For example, six groups of data have been identified in studies specifically concerning the Warmian-Masurian Voivodeship (Witkowska-Dąbrowska & Bączkowski, 2010): environmental impact, employment, investment, entrepreneurship, agriculture and availability of products, services and infrastructure. A further study of this province assumed the following (Gornowicz & Wichowska, 2017): population, population density, migration balance, number of marriages, GDP per capita income, and grant income. In studies comparing the living conditions in the regions of Poland and Germany, the following were assumed in subsequent studies (Gwiaździńska-Goraj et al., 2022) two main types of data:

- material conditions indicators (income per capita, unemployment levels, number of dwellings, social welfare expenditure, road infrastructure,
- indicators of intangible conditions (availability of education, access to health care, proportion of residents enjoying culture, level of satisfaction with life).

The present research adopts a similar data division into tangible conditions (e.g. number of businesses, unemployment rate, number of dwellings) and intangible conditions (population, migration balance, ecological areas). It can, therefore, be assumed that the use of similar data in our study reinforces the assumption of the correctness of the adopted research procedure. An important element of the adopted data was the inclusion of ecologically valuable areas, which are important for Giżycko, Węgorzewo and Gołdap counties. The adoption of this is in line with previous research indicating the observation of an increase in the value of dwellings in naturally attractive areas (Daams et al., 2016; Trojanek et al., 2018; Źróbek-Różańska, A., Źróbek-Sokolnik, A., & Dynowski, P., 2017)

Applying the Principal Components Analysis (PCA) method in the study allowed the original data to be reduced to two main components that determine the differentiation of the studied counties: PC1 - level of environmental and residential development and PC2 - level of environmental and residential development. This method has been used in many studies (Groth et al., 2013; Jolliffe & Cadima, 2016; Lee & Jemain, 2021; Palma & Pierdominici-Sottile, 2023). For example, in one of the articles (Celepcikay et al., 2009), regional patterns were discovered using just the PCA method. This paper uses clustering algorithms to discover regions with strong regional correlation relationships between attributes and then determines the underlying regional structures and correlation patterns. In

eISSN: 2300-5289

Romania, Principal Components Analysis was also used to assess levels of regional development, compare socio-economic indicators, and identify key variables for social, economic, and infrastructural aspects (Rotaru et al., 2024). In this study, two principal components were also identified, the first of which refers to economic elements in the regions. In contrast, the second refers to social and agroecological issues. Thus, this is quite similar to the results obtained for the principal components in this article. In the following article (Caruso et al., 2020), the PCA method was applied to analyze economic activity in different areas of central Italy. In Austria, on the other hand, the PCA method was used to delineate three homogeneous areas based on rainfall levels (Ehrendorfer, 1987). This study reduced the original data dimension to 2-3 principal components, which explained 68% and 79% of the total variance in the data, respectively. Our study obtained much higher variance explanation rates of 80% and 92%.

Our research resulted in the highest indicators of socio-economic development in the urban district of the Warmian-Masurian Voivodship, Olsztyn. However, according to other studies (Bojarowicz, 2024), in comparison with the rest of the country, Olsztyn does not have the status of an agglomeration unit, has a low level of urbanization and underdeveloped transport links, which results in a low level of socio-economic development in the capital of Warmian-Masurian Voivodeship. At the same time, the overall assessment of sustainable economic development was lower than the average for the other Polish voivodeships, from 72.18% to 78.88% (Witkowska-Dąbrowska & Bączkowski, 2010). This interesting correlation between local research on just one province and spatially broader research is interesting. Olsztyn dominates in our research in terms of development, while compared to other urban districts in Poland, other research (Dembicka-Niemiec, 2020; Stanowicka, 2015) places it low in such a ranking. In general, the study yielded clusters of similar counties, and treating them as similar local housing markets in type and area allows these results to be applied to property valuation with limited market development. Different variants of Principal Components Analysis modeling in property valuation have been applied in several studies (Bełej et al., 2016; Chaphalkar & Sandbhor, 2016; Mostofi et al., 2022). This confirms the applicability of the proposed methods, which were applied in the Warmian-Masurian Voivodeship in Poland.

5. Conclusions

The essence of property valuation is determining the property's value in an appraisal report. There are many scientific publications (Chmielewska et al., 2025; Gaca et al., 2020; Isakson, 1998; Konowalczuk et al., 2021; Krajewska & Pawłowski, 2019; O'Byrne et al., 1985; Renigier-Biłozor et al., 2018; Limlomwongse Suksmith & Nitivattananon, 2015), mainly concerning valuation methodology, theoretical and practical aspects of valuation or specific valuation objectives and property types. Such studies (apart from case-study type discussions) also apply a range of modern technologies and methods to the analysis of valuation data i.e. machine learning, spatial analysis using GIS tools, automated valuation models or property price forecasting (Benjamin et al., 2004; Bjørgve & Sandnes, 2023; Cellmer et al., 2014; Droj et al., 2024; Foryś, 2022; Ho et al., 2021; Renigier-Biłozor et al., 2022).

If there are no similar properties in a given local market, the research can (according to Polish law) be extended to similar local markets. As a result, an important element of the valuation is the search for regions with similar socio-economic conditions. This article identifies similar areas in the Warmian-Masurian Voivodeship, with 21 counties treated as local housing markets.

The research used Principal Components Analysis and constructed a synthetic PC_weighted index to identify groups of counties with similar socio-economic characteristics. This makes it possible to show specific counties for the valuer to use in his search for data (in the absence of these in the local market under analysis). The research confirmed that multidimensional analytical methods can be successfully applied in the analysis of real estate markets for valuation purposes, as they are devoid of subjectivity and objectively allow clusters or groups of similar areas (counties) to be obtained. The research results showed a significant difference between urban and rural districts in the Warmian-Masurian voivodship, Poland. This is particularly evident in the difference between large urban centers such as Olsztyn (the voivodeship capital), Elbląg, and the other counties in the entire voivodeship. In the analyzed area of Warmian-Masurian Voivodship, the road infrastructure network (voivodeship road No. 16), along which the poviats located obtained the highest scores in the study and formed a relatively compact group of similar poviats, turned out to be an essential element.

It seems that the research can be continued, further research methods can be applied, and the local market area should be reduced (from counties to

municipalities), which can delineate similar areas for property valuation purposes. This type of research may be important for valuers and several state or local government institutions to coordinate or optimize their social, economic or environmental policies.

References

Adams, Z., & Füss, R. (2010). Macroeconomic determinants of international housing markets. *Journal of Housing Economics, 19*(1), 38–50. Advance online publication. https://doi.org/10.1016/j.jhe.2009.10.005

Anselin, L., & Bera, A. K. (1998). Introduction to spatial econometrics. *Handbook of Applied Economic Statistics, 237*(5).

Antczak - Stępniak, A., Grodzicka-Kowalczyk, M., Sobczak, M., Zaleczna, M., & Żelazowski, K. (2021). *Rynek nieruchomości mieszkaniowych – współczesne aspekty przestrzenne, prawne i finansowe*. Wydawnictwo Uniwersytetu Łódzkiego. https://doi.org/10.18778/8220-423-0

Archer, K. J., & Kimes, R. V. (2008). Empirical characterization of random forest variable importance measures. *Computational Statistics & Data Analysis, 52*(4), 2249–2260. https://doi.org/10.1016/j.csda.2007.08.015

Ball, M. (2017). Housing policy and economic power: The political economy of owner occupation (Vol. 828). Routledge. https://doi.org/10.4324/9780203472613

Basu, S., & Thibodeau, T. G. (1998). Analysis of spatial autocorrelation in house prices. *The Journal of Real Estate Finance and Economics, 17*(1), 61–85. https://doi.org/10.1023/A:1007703229507

Batóg, J., Foryś, I., Gaca, R., Głuszak, M., & Konowalczuk, J. (2019). Investigating the impact of airport noise and land use restrictions on house prices: Evidence from selected regional airports in Poland. *Sustainability, 11*(2), 412. Advance online publication. https://doi.org/10.3390/su11020412

Bełej, M. (2022). Does Google trends show the strength of social interest as a predictor of housing price dynamics? *Sustainability 2022, Vol. 14, Page 5601, 14*(9), 5601. https://doi.org/10.3390/su14095601

Bełej, M., Cellmer, R., Źróbek, S., & Subic-Kovac, M. (2016). Factor analysis in determining the similarity of local real estate markets' conditions. *Acta Scientiarum Polonorum. Oeconomia, 15*(4), 27–39.

Belke, A., & Keil, J. (2018a). Fundamental determinants of real estate prices: A panel study of German regions. *International Advances in Economic Research, 24*, 25–45. Advance online publication. https://doi.org/10.1007/s11294-018-9671-2

Benjamin, J., Guttery, R., & Sirmans, C. F. (2004). Mass appraisal: An introduction to multiple regression analysis for real estate valuation. *Journal of Real Estate Practice and Education, 7*(1), 65–77. https://doi.org/10.1080/10835547.2004.12091602

Berg, L. (2002). Prices on the second-hand market for Swedish family houses: Correlation, causation and determinants. *European Journal of Housing Policy, 2*(1), 1–24. https://doi.org/10.1080/14616710110120568

Bieda, A. (2017). Parametric model of real estate valuation for land located in different land-use zones. *Geomatics and Environmental Engineering, 11*(4).

Bjørgve, E., & Sandnes, C. (2023). *Improving AVM prediction performance in the housing market: A stacked generalization approach with diverse model selection* [Master thesis, NTNU]. https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/3093951

Bojarowicz, T. (2024). Determinants of the diversification of regional development on the example of Wielkopolska and Warmia and Mazury. *Journal of Modern Science, 55*(1), 138–154. https://doi.org/10.13166/jms/183980

Broitman, D., & Koomen, E. (2015). Regional diversity in residential development: A decade of urban and peri-urban housing dynamics in The Netherlands. *Letters in Spatial and Resource Sciences, 8*(3), 201–217. https://doi.org/10.1007/s12076-014-0134-y

Butler, S. M. (2022). Optimizing investment in housing as a social determinant of health. *Jama Health Forum*. https://doi.org/10.1001/jamahealthforum.2022.3626

Caruso, G., Di Battista, T., & Gattone, S. A. (2020). A micro-level analysis of regional economic activity through a PCA approach. In E. Bucciarelli, S.-H. Chen, & J. M. Corchado (Eds.), *Decision Economics: Complexity of Decisions and Decisions for Complexity*, vol. 1009, pp. 227–234. Springer International Publishing., https://doi.org/10.1007/978-3-030-38227-8_26

Celepcikay, O. U., Eick, C. F., & Ordonez, C. (2009). Regional pattern discovery in geo-referenced datasets using PCA. In P. Perner (Ed.), *Machine learning and data mining in pattern recognition*, vol. 5632, pp. 719–733. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-03070-3_54

Cellmer, R., Bełej, M., Źróbek, S., & Subic-Kovac, M. (2014). Urban land value maps - A methodological approach. *Geodetski Vestnik, 58*(3), 535–551. https://doi.org/10.15292/geodetski-vestnik.2014.03.535-551

Cellmer, R., Cichulska, A., & Bełej, M. (2021). The regional spatial diversity of housing prices and market activity – Evidence from Poland. *Acta Scientiarum Polonorum. Administratio Locorum, 20*(1). Advance online publication. https://doi.org/10.31648/aspal.6111

Chaphalkar, N. B., & Sandbhor, S. (2016). Sample sufficiency for principle component analysis in real property valuation. *2016 SAI Computing Conference (SAI)*, 507–512. https://doi.org/10.1109/SAI.2016.7556028

Chmielewska, A., Walacik, M., & Grover, R. (2025). Property valuation principles – How policy changes can be detrimental to urban development. *Land Use Policy, 150*, 107474. https://doi.org/10.1016/j.landusepol.2025.107474

Daams, M. N., Sijtsma, F. J., & Van Der Vlist, A. J. (2016). The effect of natural space on nearby property prices: Accounting for perceived attractiveness. *Land Economics, 92*(3), 389–410. https://doi.org/10.3368/le.92.3.389

Dembicka-Niemiec, A. (2020). Rozwój miast metropolitalnych Polski w kontekście rozwoju zrównoważonego. *Konwersatorium Wiedzy o Mieście, 33*(5), 31–42. https://doi.org/10.18778/2543-9421.05.03

Doling, J., Vandenberg, P., & Tolentino, J. C. (2013). Housing and housing finance - a review of the links to economic development and poverty reduction. *SSRN* Electronic Journal. https://doi.org/10.2139/ssrn.2309099

Droj, G., Kwartnik-Pruc, A., & Droj, L. (2024). A comprehensive overview regarding the impact of GIS on property valuation. *ISPRS International Journal of Geo-Information, 13*(6), 175. Advance online publication. https://doi.org/10.3390/ijgi13060175

Ehrendorfer, M. (1987). A regionalization of Austria's precipitation climate using principal component analysis. *Journal of Climatology, 7*(1), 71–89. https://doi.org/10.1002/joc.3370070107

Foryś, I. (2022). Machine learning in house price analysis: Regression models versus neural networks. *Procedia Computer Science, 207*, 435–445. https://doi.org/10.1016/j.procs.2022.09.078

Gaca, R., Zygmunt, R., & Gluszak, M. (2020). Comparative analysis of transaction prices and the values of forest properties in Poland.

Forests, 11(12), 1323. Advance online publication. https://doi.org/10.3390/f11121323

Gornowicz, M., & Wichowska, A. (2017). demographic structure and incomes of municipalities of Warmia and Mazury in 2010–2014. *Społeczeństwo i Ekonomia, 1*(7), 61–72. https://doi.org/10.15611/sie.2017.1.05

Greenwell, B. M., & Boehmke, B. C. (2020). Variable importance plots - An introduction to the VIP package. *The R Journal, 12*(1), 343–366. https://doi.org/10.32614/RJ-2020-013

Groth, D., Hartmann, S., Klie, S., & Selbig, J. (2013). Principal components analysis. In B. Reisfeld & A. N. Mayeno (Eds.), *Computational toxicology* (Vol. 930, pp. 527–547). Humana Press. https://doi.org/10.1007/978-1-62703-059-5_22

GUS. (2025). *Bank Danych Lokalnych*. https://bdl.stat.gov.pl/bdl/start

Gwiaździńska-Goraj, M., Jezierska-Thöle, A., & Dudzińska, M. (2022). Assessment of the living conditions in polish and German transborder regions in the context of strengthening territorial cohesion in the European union: Competitiveness or complementation? *Social Indicators Research, 163*(1), 29–59. https://doi.org/10.1007/s11205-022-02889-7 PMID:35194294

Hannonen, M. (2014). Urban housing policy considerations: Perspectives from the Finnish housing market. *Journal of Heterodox Economics, 1*(2), 114–130. https://doi.org/10.1515/jheec-2015-0007

Hincks, S., & Baker, M. (2012). A critical reflection on housing market area definition in England. *Housing Studies, 27*(7), 873–897. https://doi.org/10.1080/02673037.2012.725826

Ho, W. K. O., Tang, B.-S., & Wong, S. W. (2021). Predicting property prices with machine learning algorithms. *Journal of Property Research, 38*(1), 48–70. https://doi.org/10.1080/09599916.2020.1832558

Inglis, A., Parnell, A., & Hurley, C. B. (2022). Visualizing variable importance and variable interaction effects in machine learning models. *Journal of Computational and Graphical Statistics, 31*(3), 766–778. https://doi.org/10.1080/10618600.2021.2007935

Isakson, H. (1998). *The review of real estate appraisals using multiple regression analysis*. Social science research network. https://papers.ssrn.com/abstract=121208 https://doi.org/10.1080/10835547.1998.12090922

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: A review and recent developments. *Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences, 374*(2065), 20150202. https://doi.org/10.1098/rsta.2015.0202 PMID:26953178

Kassambara, A., & Mundt, F. (2020). *factoextra: Extract and visualize the results of multivariate data analyses* (Version 1.0.7) [Computer software]. https://cran.r-project.org/web/packages/factoextra/index.html

Kisiała, W., & Rącka, I. (2021). Spatial and statistical analysis of urban poverty for sustainable city development. *Sustainability, 13*(2), 858. https://doi.org/10.3390/su13020858

Konowalczuk, J., Habdas, Magdalena., Foryś, Iwona., & Drobiec, Łukasz. (2021). *Wartość nieruchomości w sąsiedztwie lotnisk: Metodyka szacowania szkód i ustalania odszkodowań*. Wydawnictwo C. H. Beck.

Korfiatis, G. (2007). *Principal Component Analysis*. https://www.semanticscholar.org/paper/Principal-Component-Analysis-Korfiatis/889747da82a09f7be9caa2709112281e8116ad8a

Krajewska, M., & Pawłowski, K. (2019). Coherent land policy and land value. *Geomatics and Environmental Engineering, 13*(4), 33–48. Advance online publication. https://doi.org/10.7494/geom.2019.13.4.33

Lee, L. C., & Jemain, A. A. (2021). On overview of PCA application strategy in processing high dimensionality forensic data. *Microchemical Journal: Devoted to the Application of Microtechniques in All Branches of Science, 169*, 106608. https://doi.org/10.1016/j.microc.2021.106608

Leung, C. (2004). Macroeconomics and housing: A review of the literature. *Journal of Housing Economics, 13*, 249–267. Advance online publication. https://doi.org/10.1016/j.jhe.2004.09.002

Limlomwongse Suksmith, P., & Nitivattananon, V. (2015). Aviation impacts on property values and management: The case of Suvarnabhumi International Airport. *IATSS Research, 39*(1), 58–71. https://doi.org/10.1016/j.iatssr.2014.07.001

Lindstrom, B. (1997). A sense of place: Housing selection on Chicago's North Shore. *The Sociological Quarterly, 38*(1), 19–39. https://doi.org/10.1111/j.1533-8525.1997.tb02338.x

Lis, P. (2012). *Wahania cykliczne rynków mieszkaniowych. Aspekty teoretyczne i praktyczne*. Wydawnictwo Adam Marszałek.

Maechler, M., Rousseeuw, P., Struyf, A., & Hubert, M. (1999). *cluster: Finding groups in data: Cluster analysis extended,* (p. 2.1.8) [Dataset]. https://doi.org/10.32614/CRAN.package.cluster

Mostofi, F., Toğan, V., & Başağa, H. B. (2022). Real-estate price prediction with deep neural network and principal component analysis. *Organization, Technology and Management in Construction. International Journal (Toronto, Ont.), 14*(1), 2741–2759. https://doi.org/10.2478/otmcj-2022-0016

Muellbauer, J., & Murphy, A. (2008). Housing markets and the economy: The assessment. *Oxford Review of Economic Policy, 24*(1), 1–33. https://doi.org/10.1093/oxrep/grn011

O'Byrne, P. H., Nelson, J. P., & Seneca, J. J. (1985). Housing values, census estimates, disequilibrium, and the environmental cost of airport noise: A case study of Atlanta. *Journal of Environmental Economics and Management, 12*(2), 169–178. https://doi.org/10.1016/0095-0696(85)90026-9

Palma, J., & Pierdominici-Sottile, G. (2023). On the uses of PCA to characterise molecular dynamics simulations of biological macromolecules: Basics and tips for an effective use. *Chemphyschem: A European Journal of Chemical Physics and Physical Chemistry, 24*(2), e202200491. https://doi.org/10.1002/cphc.202200491 PMID:36285677

Pichler, M., Skutnik, F., Vlad, A., Shahri, H., & Ridwan, M. (2021). Housing Price Index, wealth, and protective shield against Covid-19. *SIASAT, 6*(1), 1–8. https://doi.org/10.33258/siasat.v6i1.84

Pöge, A., & Reinecke, J. (2021). Principal component analysis. In U. Engel, A. Quan-Haase, S. X. Liu, & L. Lyberg, *Handbook of Computational Social Science, Volume 2* (1st ed., pp. 322–333). Routledge. https://doi.org/10.4324/9781003025245-22

R Core Team. (2021). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rącka, I., Palicki, S., Krajewska, M., Szopińska, K., & Kempa, O. (2017). Changes on the housing market of the downtown area in selected Polish cities. *Real Estate Management and Valuation, 25*(2), 79–90. https://doi.org/10.1515/remav-2017-0015

Renigier-Biłozor, M., Biłozor, A., & Wisniewski, R. (2017). Rating engineering of real estate markets as the condition of urban areas assessment. *Land Use Policy, 61*, 511–525. Advance online publication. https://doi.org/10.1016/j.landusepol.2016.11.040

Renigier-Biłozor, M., Walacik, M., Źróbek, S., & d'Amato, M. (2018). Forced sale discount on property market–How to assess it? *Land Use Policy, 78*, 104–115. https://doi.org/10.1016/j.landusepol.2018.06.026

Renigier-Biłozor, M., Źróbek, S., & Walacik, M. (2022). Modern technologies in the real estate market - Opponents vs. proponents of their use: Does new category of value solve the

problem? *Sustainability, 14*(20), 13403. Advance online publication. https://doi.org/10.3390/su142013403

Rotaru, A., Hegedus, C., Pop, I., Vatca, S., Vatca, A., & Andronie, L. (2024). Assessment of regional development level in Romania through principal component analysis. *Journal of Central European Agriculture, 25*(2), 588–605. https://doi.org/10.5513/JCEA01/25.2.4176

Stanowicka, A. (2015). Metropolitan areas in Poland - State of development and its barriers. *Olsztyn Economic Journal, 10*(2), 143–156. https://doi.org/10.31648/oej.3143

Suksmith, P.

Tomal, M. (2019). The impact of macro factors on apartment prices in Polish counties: A two-stage quantile spatial regression approach. *Real Estate Management and Valuation, 27*(4), 1–14. https://content.sciendo.com/view/journals/remav/27/4/article-p1.xml https://doi.org/10.2478/remav-2019-0031

Trojanek, R., Gluszak, M., & Tanas, J. (2018). The effect of urban green spaces on house prices in Warsaw. *International Journal of Strategic Property Management, 22*(5), 358–371. https://doi.org/10.3846/ijspm.2018.5220

Vatansever, M., Demir, I., & Hepsen, A. (2020). Cluster and forecasting analysis of the residential market in Turkey. *International Journal of Housing Markets and Analysis*. https://doi.org/10.1108/IJHMA-11-2019-0110

Vignoli, D., Rinesi, F., & Mussino, E. (2013). A home to plan the first child? Fertility intentions and housing conditions in Italy. *Population Space and Place, 19*(1), 60–71. https://doi.org/10.1002/psp.1716

Wickham, H. (2016). *Ggplot2.* Springer International Publishing., https://doi.org/10.1007/978-3-319-24277-4 https://doi.org/10.1575/1912/bco-dmo.775229.1

Wickham, H., & Bryan, J. (2023). *readxl: Read excel files*. https://CRAN.R-project.org/package=readxl

Witkowska-Dąbrowska, M., & Bączkowski, T. (2010). Wskaźniki zrównoważonego rozwoju województwa warmińsko-mazurskiego w aspekcie gospodarczym. [Indicators of Warmińsko-Mazurskie Voivodship sustainable development in the economic aspect]. *Olsztyn Economic Journal, 5*(2), 258–268. https://doi.org/10.2478/v10021-010-0020-4

Źróbek-Różańska, A., Źróbek-Sokolnik, A., & Dynowski, P. (2017). Czy mieszkańcy miast preferują tereny cenne przyrodniczo pod budowę domu pod miastem? Studium strefy podmiejskiej Olsztyna. *Przegląd Geograficzny, 149*, 123–139. https://doi.org/10.4467/20833113PG.17.013.6929