

## DIVERSITY OF POLISH REGIONS IN THE LEVEL OF TECHNICAL INFRASTRUCTURE DEVELOPMENT

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### ABSTRACT

The study aims to identify spatial diversity and possible concentrations of 16 Polish regions regarding their infrastructure development levels in the period of 2005–2018. Measuring development of technical infrastructure requires the use of several variables due to its multidimensional character. It justifies the use of multivariate analysis. Based on the method of Hellwig's development measure, three groups of regions were defined. Five of the analysed regions did not change their position in the 2018 ranking as compared to 2005. These were regions from the top three: Śląskie, Dolnośląskie and Małopolskie (south-western Poland), as well as two regions in the class with the lowest level of technical infrastructure development: Warmińsko-Mazurskie and Podlaskie (north-eastern Poland). Although the leader of both rankings, Śląski region, took the most favourable values in 2018 concerning density and quality of roads, density of railway lines or green areas in towns, as a typically industrial, mining-related, intensely urbanized region it has needed to cope with a serious problem with air pollution, relating from the smallest amount of gas pollution retained or neutralized. In the other side, the two weakest regions were characterised by valuable environmental conditions (Warmińsko-Mazurskie) and a large share of agricultural area (Podlaskie). These natural and economic conditions may, on the one hand, prevent the development of technical infrastructure (e.g. road construction in Natura 2000 areas), and on the other hand, maintenance of such infrastructure could be unprofitable for both local government units and its users.

**Key words:** technical infrastructure, development potential, regional development, multivariate comparative analysis, Poland

**JEL codes:** O18, C30

### INTRODUCTION

Infrastructure in the broad sense is one of the factors traditionally indicated in development theories. It is of particular importance, for example, in the context of ensuring conditions for the diffusion of socio-economic development, assumed in the polarization-diffusion model [Drejerska 2010, Mucha-Leszko and Kąkol 2010, Kołodziejczyk 2014, Churski 2015, Nowaczyk 2018]. Moreover, Zarębski and Godlewska-Majkowska in their research [2013] define the infrastructure as one of four microclimates of the taxonomic indicator of the potential investment attractiveness of European

Union countries. What is more, Nadolny [2019] points to the multithreaded concept of regional development and the importance of infrastructure in this context.

The greatest importance in regional and local development is attached to the transport infrastructure [Chciałowski 2018]. According to Rietveld [1989], upgrading of transport infrastructure has a strong impact on production as well as household consumption. It leads to a reduction of cost and time of transportation and travel [von Thünen 1826]. Therefore, it may give rise to substantial redistribution effects among economic groups and regions [Górz and Kurek 1999, Zwolińska-Ligaj and Ciechańska 2012, Rokicki 2014, Satola 2015,

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Kaczmarek 2017, Bul 2018, Ozimek et al. 2019]. Button [1998] notes that although investments in road infrastructure may have primary multiplier implications combined with some secondary effects in terms of longer term maintenance, if the facility principally serves transit traffic there is unlikely to be a great deal of value added.

Similarly, if it serves trade flows into and from the region then the implications for an area's local GDP will depend on the region's comparative and competitive advantages [Sharp 1980, Button 1998]. The level of infrastructure development determines regional and local development [Kapusta 2012, Pomianek 2016].

## AIM AND METHOD

The aim of the paper was to show spatial diversity and possible concentrations of 16 Polish regions regarding the infrastructure development level. The multidimensional character of the infrastructure justifies the use of multivariate analysis. Based on the method of Hellwig's development measure [Hellwig 1968, Nowak 1990], a synthetic measure was constructed, enabling ranking of the regions according to their level of development of technical infrastructure. The variables mentioned in Table 1 were taken for

**Table 1.** Variables applied in the analysis

Symbol	Variable	Unit	Type <sup>a</sup>
X1	Density of total public roads	km per 100 km <sup>2</sup>	S
X2	Density of expressways and highways	km per 100 km <sup>2</sup>	S
X3	Density of roads with improved hard surface	km per 100 km <sup>2</sup>	S
X4	Share of poviats and municipal unsurfaced (ground) roads in the total length of these roads	%	D
X5	Road accidents	number per 100 thous. residents	D
X6	Density of railway lines in total	km per 100 km <sup>2</sup>	S
X7	Density of standard-gauge railway lines <sup>c</sup>	km per 100 km <sup>2</sup>	S
X8	Share of dwellings in cities equipped with central heating <sup>b</sup>	%	S
X9	Population using the water supply system as a percentage of the total population <sup>b</sup>	%	S
X10	Population using the sewage system as a percentage of the total population	%	S
X11	Population using the gas supply system as a percentage of total population	%	S
X12	Population using wastewater treatment plants as a percentage of total population <sup>c</sup>	%	S
X13	Industrial and municipal wastewater treated as a percentage of wastewater requiring treatment <sup>b</sup>	%	S
X14	Dust pollution retained or neutralized in pollution abatement equipment as a percentage of the pollution generated <sup>b</sup>	%	S
X15	Gas pollution retained or neutralized in pollution abatement equipment as a percentage of the pollution generated	%	S
X16	Area of parks, lawns and residential green areas as a percentage of the total area <sup>c</sup>	%	S
X17	Telephone main lines	number per 100 thous. residents	S
X18	Enterprises from the non-financial sector with broadband Internet access <sup>b</sup>	%	S

<sup>a</sup> S – stimulant, D – destimulant.

<sup>b</sup> Quasi-constant variables excluded from further analysis.

<sup>c</sup> Variables excluded from further analysis due to large statistically significant correlation with other variables.

Source: Author's elaboration based on the Local Data Bank of the Statistics Poland (Bank Danych Lokalnych GUS).

construction of the measure. Five variables (X8, X9, X13, X14 and X18) were quasi-constant and therefore they were excluded from further analysis. Then, to find the variables that presented large statistically significant correlation, Pearson's linear correlation coefficient was used. Due to the high level of correlation between the selected variables, X7, X12 and X16 were rejected. The data for the analysis was taken from the Local Data Bank of Statistics Poland (Bank Danych Lokalnych GUS) for 2005 and 2018. As data for 2005 were not collected for the X15 variable, the data for 2006 were used in the analysis.

The Hellwig development measure ( $d_i$ ) usually takes values in the range [0; 1]. The closer the object (a region) is to the pattern (the standard), the higher the measure value is [Hellwig 1968, Panek and Zwierzchowski 2013, Pomianek 2019]. Two parameters of the taxonomic measure were used to classify regions according to the level of development of technical infrastructure, i.e. the arithmetic mean ( $\bar{d}_i$ ) and standard deviation ( $S_{d_i}$ ). The examined objects (regions) were divided into three groups differing in terms of the degree of development of the tourism function. The following classes were defined:

- Class 1 (high level of infrastructure development)
  - $d_i > \bar{d}_i + S_{d_i}$  (regions at a distance from the pattern exceeding  $\bar{d}_i + S_{d_i}$ );
- Class 2 (medium level of infrastructure development) –  $\bar{d}_i - S_{d_i} < d_i \leq \bar{d}_i + S_{d_i}$  (regions at a distance from the pattern ranging  $\bar{d}_i - S_{d_i}, \bar{d}_i + S_{d_i}$ );
- Class 3 (low level of infrastructure development)
  - $d_i \leq \bar{d}_i - S_{d_i}$  (regions at a distance from the pattern not exceeding  $\bar{d}_i - S_{d_i}$ ), where:  $d_i$  is a value of synthetic measure calculated by Hellwig's method,  $\bar{d}_i$  is the arithmetic mean of  $d_i$ , and  $S_{d_i}$  is the standard deviation of  $d_i$ .

Two rankings were constructed based on the above-mentioned method (for 2005 and for 2018).

## RESULTS AND DISCUSSION

Sixteen regions of Poland (NUTS 2 level) were ranked according to Hellwig's development measure. Two regions were classified in the class with

a high level of technical infrastructure development in 2005: Śląskie and Dolnośląskie. Twelve regions were classified in the class with an average level of development, while the last two places belonged to the class with a low level of technical infrastructure development: Warmińsko-Mazurskie and Podlaskie (Table 2).

Five of the analysed regions did not change their position in the ranking in 2018 compared to 2005. These were regions from the top three: Śląskie, Dolnośląskie and Małopolskie, as well as two regions in the class with the lowest level of technical infrastructure development: Warmińsko-Mazurskie and Podlaskie. Another five regions moved up in the ranking during the period under study. Mazowieckie region moved from the 6th to the 4th position, but the greatest positive shifts (by three positions) were characteristic of the following regions: Podkarpackie (from 12th to 9th) and Świętokrzyskie (from 14th to 11th). In six regions there was a drop in the ranking in 2018 compared to 2005. The largest negative change was observed in the Zachodniopomorskie region (by four positions from 9th to 13th). Łódzkie region recorded a drop by two places to 12th position in 2018. In the regions: Opolskie, Wielkopolskie, Pomorskie and Lubelskie, the decrease was by 1 position, with the Lubelskie region moving to the last position in the class with an average level of technical infrastructure development. Comparing the values of the  $d_i$  Hellwig's measure, informing about the region's adjustment to the theoretical pattern of development, ten regions improved their results in 2018 related to 2005.

Regions with the highest level of technical infrastructure development (Dolnośląskie and Śląskie) were located in the south-western part of Poland. Opolskie region, located between these two, was 4th in the ranking in 2005, and 6th in 2018. Małopolskie region, neighbouring to Śląskie region, was 3rd in both rankings. Moreover, the 5th (2005) and 6th (2018) positions were occupied by Wielkopolskie region, adjacent to Dolnośląskie region. Therefore, a certain concentration of regions with a high level of development and regions with very good positions in the rankings in the group with an average level of technical infrastructure development can be noticed (the figure).

**Table 2.** Comparison of two rankings of the level of technical infrastructure development in 2005 and in 2018 according to the Hellwig's measure

Region (NUTS 2)	Year				Change in the ranking position in 2018 compared to 2005	Class (2005 and 2018)
	2005		2018			
	position	$d_i$	position	$d_i$		
Śląskie	1	0.660	1	0.665	no change	1 – high level of development
Dolnośląskie	2	0.540	2	0.512	no change	
Małopolskie	3	0.435	3	0.452	no change	
Opolskie	4	0.375	5	0.376	–1	
Wielkopolskie	5	0.303	6	0.374	–1	2 – medium level of development
Mazowieckie	6	0.299	4	0.388	+2	
Pomorskie	7	0.297	8	0.307	–1	
Kujawsko-Pomorskie	8	0.295	7	0.315	+1	
Zachodniopomorskie	9	0.278	13	0.233	–4	
Łódzkie	10	0.236	12	0.235	–2	
Lubuskie	11	0.233	10	0.290	+1	
Podkarpackie	12	0.210	9	0.290	+3	
Lubelskie	13	0.188	14	0.162	–1	3 – low level of development
Świętokrzyskie	14	0.180	11	0.242	+3	
Warmińsko-Mazurskie	15	0.125	15	0.070	no change	
Podlaskie	16	0.090	16	0.058	no change	

Note: Positive changes in the ranking position were marked with grey colour.

Source: Author's calculation.

On the other hand, there was also a concentration of regions with a low level of technical infrastructure development (Warmińsko-Mazurskie and Podlaskie) – in the north-eastern part of Poland. The neighbouring Mazowieckie region considered on a regional scale – was an area with a relatively very good level of infrastructure development (4th position in the 2018 ranking), but research conducted on a local scale [Chrzanowska et al. 2013] indicate high differentiation of this area, i.e. a high level of socio-

-economic development of the capital city of Warsaw and its suburban area as well as a low level of development of peripheral areas of the region.

Table 3 presents average values of the variables for three development classes and for Poland. The average values of thirteen variables assumed the most desirable values in Class 1 in 2018. What is more, the area of parks, lawns and residential green areas as a percentage of the total area was also on the highest average level in Class 1 – but in both



**Fig.** Spatial distribution of Polish regions by classes of technical infrastructure development in 2005 and 2018 according to the Hellwig's measure

Source: Author's calculation.

analysed years. On the other hand, the average number of telephone main lines per 100 thousand residents was the highest in Class 1 but in 2005.

The share of dwellings in cities equipped with central heating as well as industrial and municipal wastewater treated as a percentage of wastewater requiring treatment took the highest values in the low-developed infrastructure class in 2018. The best average result for gas pollution retained or neutralized in pollution

abatement equipment as a percentage of the pollution generated was observed in 2018 in regions of Class 2.

The leader of both rankings, Śląski region, took the most favourable values in 2018 for as many as six variables: density of expressways and highways, density of roads with improved hard surface, share of poviat and municipal unsurfaced (ground) roads in the total length of these roads, density of railway lines (in total and standard-gauge) as well as area of parks, lawns

**Table 3.** Average values of selected technical infrastructure indicators for the development classes in 2005 and 2018

Symbol	Indicator	Class 1		Class 2		Class 3		Poland	
		2005	2018	2005	2018	2005	2018	2005	2018
X1	Density of total public roads (km per 100 km <sup>2</sup> )	157.7	161.4	124.0	137.4	93.3	112.3	122.0	135.8
X2	Density of expressways and highways (km per 100 km <sup>2</sup> )	0.86	2.31	0.26	1.15	0.01	0.69	0.26	1.19
X3	Density of roads with improved hard surface (km per 100 km <sup>2</sup> )	116.5	130.9	73.7	92.4	46.0	57.3	72.7	90.1
X4	Share of poviat and municipal unsurfaced (ground) roads in the total length of these roads (%)	22.3	16.7	37.8	31.2	49.9	49.5	38.1	32.1
X5	Road accidents (number per 100 thous. residents)	122.2	72.5	123.0	83.6	117.1	73.2	126.0	82.5
X6	Density of railway lines in total (km per 100 km <sup>2</sup> )	13.1	12.2	6.4	6.1	4.2	4.2	6.5	6.2
X7	Density of standard-gauge railway lines (km per 100 km <sup>2</sup> )	13.1	12.2	6.2	6.1	4.2	4.2	6.3	6.2
X8	Share of dwellings in cities equipped with central heating (%)	79.2	83.1	84.9	88.5	88.7	91.6	83.9	87.7
X9	Population using the water supply system as a percentage of the total population (%)	92.0	95.4	85.5	91.8	87.1	92.8	86.1	92.1
X10	Population using the sewage system as a percentage of the total population (%)	66.7	77.4	57.0	69.3	61.1	69.5	59.2	70.8
X11	Population using the gas supply system as a percentage of total population (%)	62.2	61.9	49.2	49.9	35.5	35.4	51.7	52.1
X12	Population using wastewater treatment plants as a percentage of total population (%)	70.8	81.1	58.0	72.5	66.0	72.8	60.2	74.0
X13	Industrial and municipal wastewater treated as a percentage of wastewater requiring treatment (%)	92.1	90.9	92.2	97.3	97.3	97.7	91.2	95.2
X14	Dust pollution retained or neutralized in pollution abatement equipment as a percentage of the pollution generated (%)	99.6	99.8	99.0	99.6	97.6	99.0	99.5	99.8
X15	Gas pollution retained or neutralized in pollution abatement equipment as a percentage of the pollution generated (%)	59.1	59.5	36.3	67.3	5.9	15.4	49.7	66.7
X16	Area of parks, lawns and residential green areas as a percentage of the total area (%)	0.50	0.50	0.16	0.18	0.10	0.10	0.20	0.20
X17	Telephone main lines (number per 100 thous. residents)	331.8	110.3	295.7	103.1	295.4	74.5	308.3	106.2
X18	Enterprises from the non-financial sector with broadband Internet access (%)	78.1	96.0	77.0	94.9	77.8	92.8	77.5	95.0

Note: The most favourable values of the indicators were marked with grey colour.

Source: Author's calculation.

and residential green areas as a percentage of the total area. It is a typically industrial, mining-related, intensely urbanized region, hence the high density of railways and roads enabling rapid movement of people and goods is justified. Parks and green areas in cities are the result of the implementation of local brown-field revitalization programs. Unfortunately, the lowest among Polish regions share of dwellings in cities equipped with central heating and the smallest amount of gas pollution retained or neutralized in pollution abatement equipment as a percentage of the pollution generated, places the Silesia region in the first place in terms of air pollution.

The last in the ranking, the Podlaskie region, was distinguished in 2018 by the highest share of dirt (ground) local public roads (54%), the lowest density of railways of both types (3.8 km per 100 km<sup>2</sup>), the lowest share of households connected to the gas network (28.5%), and – together with the regions: Warmińsko-Mazurskie, Lubelskie, Świętokrzyskie and Podkarpackie – the lowest share of parks, lawns and residential green areas as a percentage of the total area in the cities (0.1%). Podlaskie region (next to Lubelskie region) is a typically agricultural region. Similarly, Warmińsko-Mazurskie region, characterised by the lowest density of roads with improved hard surface compared to the rest of the country and Europe, is distinguished by the richness of the natural environment, i.e. varied terrain, lakes (around 2,600), dense forest complexes (forest cover at the level of 30) and clean air. About 46% of the region's area is covered by legally protected areas, including those of international importance (Natura 2000).

## CONCLUSIONS

The analysis shows two concentrations of regions regarding the level of technical infrastructure development. Regions with the highest level (Dolnośląskie and Śląskie) and three other regions with quite high results of Hellwig's measure (Wielkopolskie, Opolskie and Małopolskie) were located in the western and south-western part of Poland. Another group of regions, those with a low level of technical infrastructure development (Warmińsko-Mazurskie and Podlaskie), was located in the north-eastern part of Poland.

Infrastructure development is a slow and complex process. Investments are usually long-term, and their impact on the environment, economy and local community is not immediate and not always positive. The two regions with the high level of technical infrastructure development presented the most desirable values of as many as 15 out of 18 analysed variables. Although the leader of both rankings, Śląski region, took the most favourable values in 2018 concerning density and quality of roads, density of railway lines as well as green areas in towns, as a typically industrial, mining-related, intensely urbanized region it has needed to cope with a serious problem with air pollution, relating from the smallest amount of gas pollution retained or neutralized. In the other side, the two regions from the last positions in the rankings, with the lowest level of technical infrastructure development, were characterised by valuable environmental conditions (Warmińsko-Mazurskie) and a large share of agricultural area (Podlaskie). These natural and economic conditions may, on the one hand, prevent the development of technical infrastructure (e.g. road construction in Natura 2000 areas), and, on the other hand, maintenance of such infrastructure could be unprofitable for both local government units and its users.

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## **ZRÓŻNICOWANIE POLSKICH REGIONÓW ZE WZGLĘDU NA POZIOM ROZWOJU INFRASTRUKTURY TECHNICZNEJ**

### **STRESZCZENIE**

Opracowanie ma na celu określenie zróżnicowania przestrzennego i możliwych skupień 16 regionów Polski pod względem poziomu rozwoju infrastruktury w latach 2005–2018. Mierzenie rozwoju infrastruktury technicznej wymaga użycia kilku zmiennych ze względu na jej wielowymiarowy charakter. Uzasadnia to zastosowanie analizy wielowymiarowej. Określono trzy grupy regionów z zastosowaniem metody miary rozwoju Hellwiga. Pięć spośród analizowanych regionów nie zmieniło swojej pozycji w rankingu w 2018 r. W porównaniu do 2005 r. były to województwa zajmujące trzy pierwsze lokaty w rankingach: śląskie, dolnośląskie i małopolskie (w południowo-zachodniej Polsce), oraz dwa w klasie o niskim poziomie rozwoju infrastruktury technicznej: warmińsko-mazurskie i podlaskie (w północno-wschodniej Polsce). Chociaż lider obu rankingów województwo śląskie w 2018 r. wykazywało najkorzystniejsze wartości w zakresie gęstości i jakości dróg, gęstości linii kolejowych oraz miejskich terenów zieleni, musiało sobie radzić z poważnym problemem zanieczyszczenia powietrza, gdyż jest regionem typowo przemysłowym, górniczym, intensywnie zurbanizowanym. Dwa regiony o najniższych lokatach w rankingach charakteryzowały się zaś cennymi warunkami przyrodniczymi (województwo warmińsko-mazurskie) i dużym udziałem użytków rolnych (województwo podlaskie). Takie uwarunkowania przyrodniczo-ekonomiczne mogą z jednej strony uniemożliwić rozwój infrastruktury technicznej (np. budowa dróg na obszarach Natura 2000), a z drugiej utrzymanie takiej infrastruktury może okazać się nieopłacalne zarówno dla jednostek samorządu terytorialnego, jak i dla jej użytkowników.

**Słowa kluczowe:** infrastruktura techniczna, potencjał rozwojowy, rozwój regionalny, wielowymiarowa analiza porównawcza, Polska

