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## Analysis of the Diversity of Regional Development of Road Transport Infrastructure in Poland

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**Abstract:**

**Purpose:** The main scientific purpose of the article is to present the results and analyze research on the level of development of road infrastructure in Poland in 2010-2019.

**Design/Methodology/Approach:** The research object was sixteen voivodeships in Poland. The analysis was carried out using quantitative data from 2019 available in the sources of the Central Statistical Office. The linear ordering method was used based on the taxonomic measure of development (TMR) according to Hellwig's concept, which allowed distinguishing the ranking of the development of road transport infrastructure. The main source used to write this article was the available literature on logistic infrastructure and publications on road infrastructure. Thus, they made it possible to draw conclusions.

**Findings:** The first section presents an analysis of the foundations of the theory of transport infrastructure. The second part describes the research methodology and presents the results of the research representing the issues discussed. The analysis result is the presentation of the development of road transport infrastructure in individual voivodeships in terms of the adopted measures.

**Practical Implications:** The article provides an analysis of the road infrastructure and the state of its surface, in Poland. Corrective actions are also presented depending on the parameters used, as well as geostatistical statements with a percentage distribution of the technical status classes of the selected paving parameters.

**Originality/value:** As a result of the research undertaken, using the methods presented in the paper, on the one hand contributed to the enrichment of knowledge on transport infrastructure, on the other, the issues of the technical condition of road infrastructure in Poland were identified.

**Keywords:** Road infrastructure, regional development, logistics.

**JEL classification:** R0, R1.

**Paper Type:** Research study.

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## 1. Introduction

Emerging transport needs are the result of technological developments, spatial diversity of material production of natural resources, in the sphere of scientific or recreational culture (Tomanek, 2004). The availability of sources of financing for infrastructure investments affects the development of road infrastructure (Li and Chen, 2018). Poland is experiencing an investment boom on an unprecedented scale thanks to membership of the European Union. Poland's accession to the European Union, associated with significant financial support, created an opportunity to improve the conditions for economic development of individual regions of Poland, including infrastructure development.

Additional support for these purposes was received by the provinces with the lowest zoning rates. Road transport, due to the largest share of handling the transport needs of cargo and the population, is the main mode of transport in Poland (Tubis, 2018), which is why road infrastructure has become a priority in the disposal of EU funds. Therefore, the analyses contained in this article concern the development of regional road infrastructure in Poland.

## 2. Road Transport Infrastructure – Literature Overview

Infrastructure is the arrangement and interconnected relations of the elements (parts) constituting the whole. In Polish literature, the concept of infrastructure defines all the basic facilities and institutions necessary for the proper functioning of the economy. According to Drewak, these are permanently located objects of public use, which are the foundation of socio-economic life, due to their functions (Drewak, 2015). Ratajczak defines infrastructure as: "objects, facilities, institutions or any other phenomena that are perceived as the foundation without which it is not possible to create, develop or properly function a part of the social system or of that system as a whole" (Grzywacz, 1982).

Transport infrastructure, its basic components include roads, points and transport hubs, and the facilities and equipment by which they function efficiently (Grazyna, 1982). Infrastructure, as the basis for the development of transport, is closely linked to the other elements of transport systems – means of transport, transport technologies and the latest developments in this field, taking into account national and international requirements (Kaczynski and Koryn's, 2014). To assess the development of transport infrastructure, it is essential to define the role of transport infrastructure throughout the transport and logistics system. This approach identifies the factors and conditions that influence the development of transport infrastructure (Corroborative and Kuzmina-Merino, 2017).

Transport infrastructure has become an essential and sustainable element of the regions' technical infrastructure, creating the conditions for further economic

development (Symone, 2012). The development of transport infrastructure, quantitative, qualitative, and spatial, is therefore determined by two types of conditions resulting from:

- external political and economic systems,
- the internal needs of the country, the need to ensure the internal cohesion and cooperation (Mężyk and Makowski, 2014).

The shaping of infrastructure parameters is closely linked to the appropriate selection of technical and operational parameters of the rolling stock (cargo and traction vehicles) used for transport. The selection of the value of transport infrastructure parameters takes place in the process of its dimensioning and is usually preceded by the development of transport forecasts (Jacinta, Poza, and Wasiak, 2008).

There are three categories of benefits resulting from the construction or modernization of transport infrastructure:

- measurable value: operating costs of means of transport, reduction of travel time, inter-branch shifts in transport, increase in economic activity;
- socio-economic: redistribution of income between regions and socio-economic groups, decrease in unemployment;
- environmental and safety protection: impact on air and noise pollution levels (Domańska, 2006).

Transport infrastructure is currently one of the most important elements of infrastructure. The transport infrastructure fosters the development of connections between regions in the country and between countries, and thus fosters mutual economic, social, and cultural relations (Skorobogatova and Kuzmina-Merlino, 2017).

### **3. Materials and Methods**

The aim of the work is to try to show the scale of diversity in the development of road transport infrastructure in Poland. An analysis of the road infrastructure and the condition of its surface was carried out in individual provinces in Poland. The article also presents corrective actions depending on the parameters present, as well as geostatistical statements with a percentage distribution of the technical status classes of the selected paving parameters.

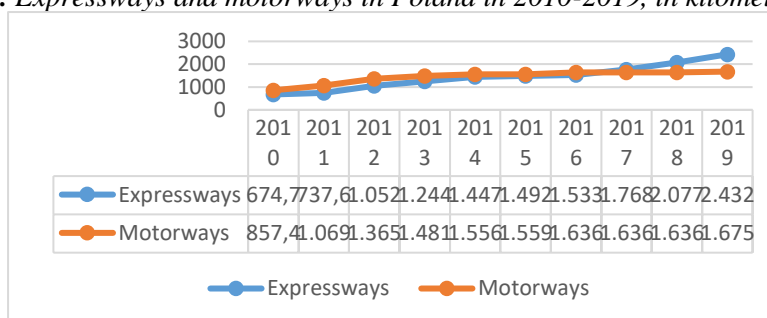
The number of roads at the critical level is shown in the form of an indicator expressed as a percentage. This is the ratio of roads at a critical level to the total number of all national roads. In order to identify the level of communication accessibility of cities in Polish voivodeships, the concept of a taxonomic development meter was used, which was determined using the Hellwig development pattern method. The main

sources of information were reports prepared by GDDKiA, the industry press and the source literature.

#### 4. Technical Condition of Road Infrastructure

The construction of road infrastructure for the transport of cargo in practice faces numerous barriers. These include the barriers that usually occur in the creation of infrastructure, i.e., the creation of infrastructure, environmental barriers or insufficient capital. The development of Polish road infrastructure between 2000 and 2016 was most influenced by Polish's accession to the European Union in 2004, as well as the co-hosting of the Euro 2012 European Football Championship with Ukraine (Sendek-Matysiak, 2017). In these years there has been a significant increase in the length of motorways and expressways in Poland (GDDKiA, 2017). Motorways in Poland are part of national roads. The motorway class is intended for the most important national roads of a transit nature (Pyza, 2010).

**Figure 1.** Expressways and motorways in Poland in 2010-2019, in kilometers



*Source:* Own calculation based on reports GDDKiA.

In 2010, the length of motorways in Poland was 857.4 km, while in 2019 it was already 1 675.8 km (an increase of 95, %). By contrast, the length of expressways in Poland was 674.7 km, while in 2019 it was already 2 432.0 km (an increase of 361%).

**Table 1.** Road surface condition in individual voivodeships

	2010	2015	2019	2010	2015	2019
Voivodeship	Expressways			Motorways		
Polska	674,7	1 492,2	2 432,0	857,4	1 559,2	1 675,8
Dolnośląskie	13,0	64,3	202,6	199,2	221,9	221,9
Kujawsko-Pomorskie	45,0	35,0	74,3	23,5	165,0	165,0
Lubelskie	4,2	79,3	135,7	0,0	0,0	0,0
Lubuskie	59,4	142,4	168,7	0,0	89,2	89,2
Łódzkie	0,0	217,8	223,0	77,2	187,6	226,2
Małopolskie	21,8	21,8	31,0	79,5	151,0	151,0
Mazowieckie	123,5	188,6	345,2	0,0	66,4	66,4
Opolskie	0,0	0,0	0,0	88,1	88,1	88,1
Podkarpackie	0,0	11,0	30,0	0,0	111,9	152,5
Podlaskie	0,0	45,9	103,0	0,0	0,0	0,0

Pomorskie	54,4	72,3	103,3	65,8	65,9	65,9
Śląskie	102,5	130,9	132,5	107,4	176,4	213,8
Świętokrzyskie	29,4	57,1	105,5	0,0	0,0	0,0
Warmińsko-Mazurskie	57,7	140,5	241,2	0,0	0,0	0,0
Wielkopolskie	42,3	150,2	267,7	195,1	210,5	210,5
Zachodniopomorskie	121,5	135,1	268,3	21,6	25,3	25,3

*Source:* Own calculation based on reports GDDKiA.

The number of motorways is uneven in voivodeships (Grzelakowski and Matczak, 2014). The best situation (most highways) in the voivodeships, Dolnośląskim, Łódzkim and Śląskim. The fewest motorways are found in the following regions: Podlaskim, Lubelskim, Świętokrzyskim and Warmińsko-Mazurskim. In contrast, in 2019, the most expressways were in the voivodeships, Łódzkim, Warmińsko-Mazurskim Wielkopolskim and Zachodniopomorskim. The fewest expressways are found in the following regions, Opolskim, Podkarpackim, Małopolskim (Table 1).

Transport infrastructure is characterized by a long service life. For example, the use of steel bridges is 50-70 years, circular roads 15-30 years, railway routes 20-40 years, breakwaters in seaports up to 80 years. This feature necessitates a detailed analysis of future transport needs, as poorly made forecasts, and adopted technical and spatial solutions can be a barrier to the development of transport systems (Urbanyi-Popiołek, 2013).

The road infrastructure in Poland continues to require a large investment in the development and provision of adequate standards for the existing network in order to meet market needs resulting from ever-increasing passenger traffic (Targosz and Wiederek, 2019). Although modern technical solutions in the field of transport infrastructure construction allow to overcome all barriers, their implementation is associated with extremely high costs of individual transport projects (Ilies and Wiskulski, 2014). Different types of road repair, the length of the sections on which they must be carried out and the percentage to the length of the entire road network are shown in Table 2.

**Table 2.** *Types of works necessary for roads at the critical level in 2018 and 2019*

		2018		2019	
		[Km]	%	[Km]	%
Work necessary	Surface work	1 034	4,8	788,6	3,6
	Leveling roads	338	1,6	304,7	1,4
	Modernization work	1 832	8,5	1 829,0	8,3
Sections under renovation or reconstruction		537	2,5	524,4	2,3
It does not require the necessary		17 858	82,7	18 599,3	84,4
Total		21 599	100	22 046	100

*Source:* Own calculation based on reports GDDKiA.

Table 2 shows that the procedures must be performed immediately on more than 2 900 km of roads that have reached critical level (are in critical condition). Depending on the parameters, appropriate corrective action must be taken on these sections. At the critical level, modernization work prevails 8.3%. The length of these sections shall be comparable to that recorded in the previous year. Modernization work must be carried out on more than 300 km of roads. This length has decreased by more than 10% compared to 2018. On almost 800 km of roads, or 3.6% of roads, surface work should be carried out. This is more than 200 km less than in 2018.

The diversity of the quality structure and density of transport infrastructure is a seriously disruptive element in the implementation of transport needs (Merkisz-Guranowska, Merkisz, Kozak, and Jacyna, 2013). The consequences of non-adaptation of the technical and operational parameters of the surface to increasing transport needs can be very severe. In the Polish standard, there are distinguished four classes of technical conditions of the pavement (Grabowski, Szczodrak, and Czyzewski, 2018):

- Class A – road surface is in very good condition (desired level),
- Class B – road surface is in good condition (desired level),
- Class C – road with surface in unsatisfactory condition (warning level),
- Class D – road with numerous and extensive damages, requires immediate repair (critical level).

Table 3 shows the technical condition of the surface of national roads in 2013-2019.

**Table 3.** *Technical condition of the surface of national roads in 2013-2019*

Level/status	2013	2014	2015	2016	2017	2018	2019
desired/good [%]	66,1	61,7	60,6	53,7	59,7	60,7	63,0
satisfactory cy [%]	21,4	25,1	25,3	30,2	25,1	22,7	22,0
critical level [%]	12,5	13,2	14,1	16,1	13,9	14,2	12,7
non-aggregated/in refurbishment	-	-	-	-	1,3	2,4	2,3

**Source:** *Own calculation based on reports GDDKiA.*

The change in road surface is influenced by:

- reducing the increase in road sections put into service,
- reducing the length of road sections renovated,
- weather conditions associated with frequent temperature transitions of °C, during winter and high summer temperatures (these phenomena have a significant impact on accelerating the degradation of the road surface, including a reduction in its fatigue life),
- increasing traffic of heavy goods vehicles, resulting in an acceleration of technical cushioning of roads (GDDKiA, 2019).

Table 2 shows that, almost 63% of national road sections were in good condition and 34.7% were unsatisfactory. Compared to 2018, there has been a more than 2% improvement in the technical condition of national road surfaces. A major barrier to road transport is the state of road infrastructure (Mindur, 2008). The parameters of the transport infrastructure, as well as its maintenance status and technical level of construction, the distribution in geographical areas have an impact on the possibilities of movement, the time of transport cost or quality. When planning a carriage, particular account must be taken of the condition of the road surface on which the carriage is to take place.

### 5. Selection of Variables

The main advantages of simple measures include both the possibility of obtaining statistics and the ease of interpretation. However, these measures provide information on the state of the infrastructure, but do not make it possible to identify the nature of the infrastructure linking the different areas, much less the destinations outside the area under analysis (Waniewska, 2020).

Following the above remarks and previous experience, as well as the availability of statistical data (the Central Statistical Office was an important source of the numerical information) (Waniewska, 2020), to measure the degree of diversification of transport development in Polish voivodship, it was assumed that the potential variables proposed for the research cover the following set of diagnostic features:

**Table 4.** *Diagnostic features*

Nazwa	Skrót	Charakter
highways per 1000 km <sup>2</sup>	X <sub>1</sub>	stimulant
expressways and per 1000 km <sup>2</sup>	X <sub>2</sub>	stimulant
hard surface roads [km <sup>2</sup> ]	X <sub>3</sub>	stimulant
injured per 100,000 vehicles	X <sub>4</sub>	stimulant
fatalities per 100 000 population	X <sub>5</sub>	destimulant
road accidents per 100 000 population	X <sub>6</sub>	destimulant
the number of parking lots in the Park & Ride system	X <sub>7</sub>	destimulant

*Source:* Own study based on data from the Regional Data Bank.

**Table 5.** *Statistical characteristics of diagnostic variables*

Voivodeship	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>
Dolnośląskie	11,12	10,16	8 046,7	96,14	7,41	66,5	47
Kujawsko-Pomorskie	9,18	4,14	6 710,7	57,19	10,17	45,3	3
Lubelskie	0	5,40	9 320,7	67,12	8,05	53,9	2
Lubuskie	6,38	12,06	3 469,4	88,00	9,08	65,2	1
Łódzkie	12,42	12,24	7 444,6	190,47	9,71	136,2	8

Małopolskie	9,95	2,04	6 540,7	139,08	5,17	92,1	26
Mazowieckie	1,87	9,71	14 098,6	86,60	8,67	70,3	55
Opolskie	9,36	0,00	3 701,4	83,54	7,42	62,4	8
Podkarpackie	8,55	1,68	6 482,1	102,38	7,38	69,6	18
Podlaskie	0	5,10	6 700,1	66,47	8,99	49,6	0
Pomorskie	3,60	5,63	5 260,2	149,48	6,84	98,3	22
Śląskie	17,34	10,74	6 059,0	105,69	4,40	65,5	19
Świętokrzyskie	0	9,01	5 864,1	118,35	10,59	85,3	1
Warmińsko-Mazurskie	0	9,98	6 910,5	138,67	7,22	85,4	0
Wielkopolskie	7,06	8,97	11 284,5	141,44	7,98	111,4	48
Zachodniopomorskie	1,10	11,72	6 927,2	106,65	7,60	71,9	3

*Source: Own study based on data from the Regional Data Bank.*

The verified set of variables included in the analysis, basic information about them and the results of statistical verification are summarized in Table 5. Next, the data was statistically verified for the coefficient of variation.

## 6. Construction of a Taxonomic Measure of the Level of Diversity of Regional Development of Road Transport Infrastructure in Poland

The method of capacity of information bearers (also called the method of optimal choice of predictors or, after its author, the Hellwig method) is one method of selecting independent variables for an econometric model. As many others, the method consists in selecting such variables which are strongly correlated with the dependent variables and, simultaneously, weakly correlated with other independent variables (Kowalik, 2014). These methods assume that the result obtained following the application of an appropriate algorithm will be such an arrangement of a set of objects in which (Bağ, 2018):

- each object has at least one neighbor and no more than two neighbors,
- if the object  $a$  is a neighbor of object  $b$ , then the object  $b$  is a neighbor of the object  $a$ ,
- there are only two objects with one neighbor.

The concept of a taxonomic development meter is a useful tool that gives the possibility of universal use in economic research. The great advantage of Hellwig's concept lies in its cognitive qualities in the process of explaining economic reality and the flexibility of its application (Pietrzak, 2014). The construction of Hellwig's synthetic measure is as follows:

- a) normalization of variables (standardization):

$$z_{ij} = \left( \frac{x_{ij} - \bar{x}_j}{s_j} \right), \quad (1)$$



where:

$x_{ij}$  - observation of the  $j$ -th variable for the object  $i$ ,

$\bar{x}_j$  - arithmetic mean of observations of the  $j$ -th variable,

$s_j$  - standard deviation of the observation of the  $j$ -th variable,

b) distances of objects from the pattern:

$$d_{io} = \left[ \sum_{j=1}^m (z_{ij} - z_{oj})^2 \right]^{\frac{1}{2}} \quad (2)$$

c) aggregate variable values:

$$q_1 = 1 - \frac{d_{io}}{d_o}, \quad (3)$$

where:

$q_i \in [0; 1]$ ,  $d_{io}$  — the best object,  $d_o$  — the worst object,

wherein:

$$S(d_o) = \left[ \frac{1}{n} \sum_{i=1}^n (d_{io} - \bar{d}_o)^2 \right]^{\frac{1}{2}}. \quad (4)$$

The measure  $d_i$  usually takes values from the interval  $[0; 1]$ . These values are the higher, the closer the object is to the pattern.

## 7. Selection and Statistical Verification of Variables

The verified set of variables included in the analysis, basic information about them and the results of statistical verification are summarized in Table 6. Next, the data was statistically verified for the coefficient of variation. Only those features were selected for the analysis where the coefficient of variation  $V(x)$  was within 10% - 40%, which indicates that the selected variables can be considered diagnostic (Waniewska, 2020).

**Table 6.** Organizing Polish voivodeships according to the Hellwig's method

Lp.	Voivodeship	TMR Hellwig
1.	Mazowieckie	0,7329
2.	Świętokrzyskie	0,6694
3.	Dolnośląskie	0,5630
4.	Pomorskie	0,2733
5.	Łódzkie	0,2313
6.	Małopolskie	0,2206
7.	Opolskie	0,1931
8.	Lubuskie	0,1789

9.	Wielkopolskie	0,1744
10.	Zachodniopomorskie	0,1613
11.	Podkarpackie	0,1602
12.	Kujawsko-Pomorskie	0,1594
13.	Śląskie	0,1295
14.	Warmińsko-Mazurskie	0,0950
15.	Podlaskie	0,06933
16.	Lubelskie	0,0056

*Source: Own study.*

The results of organizing the voivodships using the Hellwig's method are presented in Table 6. The Mazowieckie, Świętokrzyskie and Dolnośląskie voivodships are in the leading positions in terms of transport development. In the Mazowieckie voivodship, the maximum values were reached by the variable  $X_3$  (hard surface roads in km<sup>2</sup>) and  $X_7$  (the number of parking lots in the Park & Ride system). The last positions (in different order) are taken by the following voivodships: Warmińsko-Mazurskie, Podlaskie and Lubelskie (positions 14 to 16). The low position in the ranking of these voivodships is due to low values of variables.

## 8. Conclusions

The development of road infrastructure is an important factor in determining the socio-economic development of regions, but it is also a factor facilitating the professional mobility of society (Kruszyński and Waniewska, 2019). The systemic transformation, the membership Polish in the European Union and factors of a global nature have brought about changes in the conditions of operation of transport infrastructure in Poland. The technical condition of national road surfaces has improved in recent years with slight fluctuations. The current system is multi-branch, with the dominance of car and rail transport in both passenger and cargo transport. Transport infrastructure is one of the most important drivers of the country's economic development. The availability of this infrastructure and its adequate capacity make it possible to diffusion of economic growth from strong regions to underdeveloped regions. It occupies an important place among the priorities that relate to the innovation of economies.

To achieve the objective of the study, it was necessary to implement the research procedure in the context of the sources of information used and the methodology for their use. The main source used to write this article was the available literature on logistics infrastructure and publications on road infrastructure. The inference was based on the results of an empirically verified logical analysis using statistical methods. Efficient road infrastructure is essential to achieve the required economic level. On the other hand, the pace of economic development affects the size of investment in infrastructure development and the speed with which it is modernized in a given area. It is therefore necessary to look for solutions that will enable infrastructure investments to be realized while maintaining a dynamic pace of

economic growth. In the development of the infrastructure of individual modes of transport in Poland there are serious disparities, which have caused unequal conditions of their functioning and limited competitiveness. Low inputs and other mistakes in the development of transport have meant that even the most developed infrastructure does not meet European standards.

The article presents the level of development of road infrastructure in Polish based on statistical data using the Hellwig's linear ordering method. In the case of the method used, the Mazowieckie province ranked first in the survey. In the case of the method applied, the Mazowieckie voivodeship was ranked first in the study. Furthermore, based on the analysis, it can be concluded that Polish voivodeships are characterized by a diversified level of development of road infrastructure.

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