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The Influence of Transport Infrastructure Development on Transport Accessibility of Rural Areas in Poland

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Abstract:

Purpose: *The article analyzes and evaluates the impact of changes in the development of transport infrastructure on the level of transport accessibility of rural areas in Poland.*
Design/Methodology/Approach: *The study used the desk research method in the field of statistical resources. The empirical layer demonstrates changes in the length of commune and poviat roads in Poland as well as the spatial and demographic assessment of infrastructure density. This has provided grounds for determining the weighted average indicator reflecting transformations in the transport accessibility of rural areas. The calculations are presented for the years 2000-2020, in the national and provincial cross-section. We used the ArcGIS software to depict the changes in the level of transport accessibility of rural areas in Poland.*
Findings: *The increase in the length of infrastructure positively influenced the spatial and demographic density index in rural areas in Poland which differs from the spatial density index. They have a growing tendency, although the growth rate is not lower than in the case of the growth of infrastructure networks. It is influenced by the increase in the number of rural population in Poland (the effect of suburbanization) and the increase of roads diversified in individual voivodeships. When assessing the changes in transport accessibility with the use of a weighted average indicator, its improvement can be noticed in the regions of central and eastern Poland.*
Practical Implications: *Transport infrastructure is an important factor supporting socio-economic development. The differences in the development of infrastructure should be used in the search for solutions to its more balanced development from the point of view of improving transport accessibility.*
Originality/value: *The results contribute to the discussion on the development of infrastructure in the context of improving transport accessibility. Infrastructure development plans should take into account to a greater extent the general mega-trends occurring in society, including, among others, mega-trend related to suburbanization, important for changes in rural population.*

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1. Introduction

Transport infrastructure is a major element influencing the level of transport accessibility of the area. In this respect, the density thereof is important. It may be assumed that an increased density of the road network has a positive effect on transport accessibility. Spatial and demographic density indicators are helpful in measuring and assessing this phenomenon. They are used as the base for determining the weighted average indicator for these two characteristics, i.e., space and population.

Rural centers are an area for which transport accessibility can be assessed. In relation to cities, the transport needs of rural residents have different characteristics. First of all, it is related to the spatial aspect. Inhabitants of these areas have to cover greater distances to satisfy their needs (work, education, other). Hence, both the infrastructure quality and density have an impact on their transport accessibility.

2. Transport Infrastructure as the Determinant of Socio-Economic Development

In domestic literature, especially from the 1960s, the issue of transport infrastructure was taken up by a number of researchers, including Grzywacz (1982), Wojewódzka-Król and Rolbiecki (2008), Ciesielski (1992), Ratajczak (1999), Piskozub (1977). The scope of the researchers' assessment of transport infrastructure was related to its qualities (social and economic), functions, and classification, and the effects of its economic, social or environmental development.

An alternative approach to transport infrastructure analysis can be seen in foreign literature, where attention was focused on interactions, an attempt to define the primary and secondary (Banister and Berechman, 2000) impact, as well as direct and indirect outturns and demand (Heggie 1978) and supply effects related to the functioning and development of transport infrastructure.

The importance of transport infrastructure is closely linked to its function of socio-economic integration. This can be considered as fundamental in the context of combining areas (countries, regions) that are diverse in terms of socio-economic development. This aspect is referred to in the OECD report (OECD, 2003), which stated that infrastructure investments in two countries may bring about the desired effects if complementary measures are taken to reduce the integration barriers, e.g., integrated spatial planning.

Transport infrastructure is recognized as the basis for the area’s proper development. In this scope, research on transport infrastructure as a pro-development factor has been present in the economy since its inception. A vital role was played by both the classical economics (Smith, 1954) as well as researchers who developed the theory of transport in a direct manner, including in partic, ular the theory of social and

economic location. This group includes Weber (1909), Lösch (1961), and Christaller (1933).

Grzywacz (1982) drew attention to another question related to the analysis of the development of transport infrastructure. He argued that in the model approach, the outlays on infrastructure in relation to the socio-economic needs may assume three variants. In the first variant, the transport infrastructure may be developed more slowly than the socio-economic needs of the country (region). This variant is associated with high social and economic costs resulting from inadequate saturation with infrastructure. It is also characterized by prominent environmental spending. On the other hand, the second variant, which indicates that the development of infrastructure may be even in relation to needs, is an extremely difficult task. Especially taking into account the lengthy period associated with the formation of transport infrastructure. The last variant, which is extremely high-priced, means that the infrastructure can be developed faster, in anticipation of needs, but with high maintenance costs, capital freeze, and destruction despite non-use.

The state and/or local self-governments play a special role in the development and maintenance of transport infrastructure. Private capital is poorly involved (apart from a few examples, e.g., motorways, tunnels, bridges) in this major area for the functioning of the state and society. This may be attributable to a lengthy return on capital and uncertainty about the profitability of investments. In Poland, responsibility for the development and maintenance of transport infrastructure is related to its functions and we may distinguish the state, the voivodeship self-government, the poviat, and the commune as the administrator. In other areas, also rural ones, the responsibility lies with the road managers, which is the reason for the different quality of roads. This is above all a result of the lack of a common and coherent policy for the development of transport infrastructure of various categories, the absence of unified road management rules in Poland, and inadequate financial outlays in relation to the needs.

Synthesizing the research results, we may conclude that a properly developed transport infrastructure with good qualitative and quantitative parameters:

1. Improves the quality of life of residents, including citizens' mobility, safety, and travel comfort. In this (social) dimension, the role of transport infrastructure results from its function as a determinant of social mobility. By ensuring spatial connections, the infrastructure enables access to jobs, science, healthcare, and culture. On the wider stage, the transport infrastructure positively influences the leveling of social disproportions.
2. Enhances the competitive ability of business entities. Proponents of the concept of structural competitiveness recognize infrastructure as one of the most important elements in competitive competition (Chesnais, 1986). It contributes to the improvement of utilizing its potential, allows to save travel time and cut down operating costs in the micro- and macroeconomic dimension.

3. Contributes to the reduction of transport costs, including external costs (air pollution, accidents, congestion), and has a positive effect on the level of employment (directly and indirectly).

In the literature, there are opinions that negate the thesis that transport infrastructure is a major factor in socio-economic development. Examples are found in infrastructure investments and the analysis of their impact on development in other countries. Such example is the investment entitled *The Appalaska Programme*, which consists in the dynamic development of transport infrastructure (especially road infrastructure). Despite the creation of proper roads, and thus the improvement of transport accessibility, the resources of this area were "leached out". Still another example are infrastructure investments in Spain, which encountered two infrastructural problems. The first resulted from the reduction in traffic on toll sections of motorways, which led to financial issues with their maintenance, and the second – from a lower-than-expected usage of rail transport for carriage of passengers - high-speed rail (Hay, 1993; Peters 2003).

One consequence of improving transport infrastructure involves shifting the resources ("sucking out") of residents to better-paid activities. Due to the lack of engagement in non-transport factors, most people changed the area of their professional activity thanks to the improvement of transport infrastructure (Pike, Rodriguez-Pose, Tomaney, 2006). In some cases, the mere advance of transport infrastructure (especially in regions with lower wages) may be too weak a factor in its development. It should be considered as a basis, which must, however, be strengthened by other development factors. An example is expenditure on education, which allows for better usage of transport infrastructure (de la Fuente and Doménech, 2007).

To resume, transport infrastructure may be treated as a public good which fosters development and economic growth, betters socio-economic cohesion throughout the country, revives underdeveloped areas and peripheral regions, and affects the efficient movement of people and goods. It affects the market for goods and services, and its improvement makes them more extensive.

3. Influence of Transport Infrastructure on Transport Accessibility

Transport infrastructure affects transport accessibility. This impact can have a direct or indirect nature. The development of transport infrastructure directly influences spatial, temporal, and cost-effective transport accessibility, shortening the distance and travel time as well as lowering the cost of transport. The indirect impact of transport infrastructure on transport accessibility is reflected in increasing the competitiveness of the region and enterprises. This is referenced by the views of Tolley and Turton (2014), who argue that the development of transport infrastructure contributes to an enhanced transport accessibility by reducing the time and cost needed to cover a given distance (Measuring What Matters, 2010).

Space, time, and costs can be considered as fundamental determinants of transport accessibility (Krzyżanowski, 1957). This approach is enough to distinguish spatial, temporal, and economical accessibility. Spatial accessibility is related to the ease of achieving the assumed destination by means of transport infrastructure. It is shaped by nodal and linear transport infrastructure. Network density has a major impact on spatial transport accessibility. In the spatial system, the reference of the length of the transport infrastructure to the area (network spatial density indicator) or to the number of population (network demographic density indicator) is used to assess transport accessibility. This reflects the degree of saturation with transport infrastructure – a denser one creates a greater possibility of reaching other areas. Such an approach is referenced in the works by Rosik (2012).

Time availability means the actual time necessary for travelling to a specific point (e.g., city) by a given means of transport. The quality of transport infrastructure has a major impact on temporary transport availability. In the economic system, taking account of the changes (quantitative and qualitative), it is possible to present their impact on such parameters of transport accessibility as travel time and cost.

Transport accessibility in the context of transport infrastructure shapes the inhabitants' quality of life. This is pointed out by Pred (1977), according to whom it is the result of the possibility of reaching different areas that serve the needs of, for example, employment, education, health services. The possibility of accessing more such areas gives a sensation of improvement in the quality of life.

An interdisciplinary approach can be taken into account in the analysis of transport accessibility. For instance, within the spatial and economic approach, one can point to the transport infrastructure factor, which affects both systems by changing the resistance factors (distance, time, cost). A new (modernized) infrastructure with better technical parameters allows to cut down the travel time and cost.

Territorial cohesion is a vital area in assessing the level of transport accessibility, for which the base is the transport infrastructure (linear and nodal). This is important for peripheral areas of the country, regions (peripheral) that are socially or economically backward. That view is supported by Spiekermann and Wegner (2012), according to whom transport infrastructure enables spatial interaction and improves social cohesion.

In addition to the quantitative approach, the quality of transport infrastructure is also key for the analysis of transport accessibility, which affects the course of the transport process, the level of safety, duration of movement, energy consumption, which in turn translates into a lower environmental burden. A special role is played by communication stops, including their location, technical aspects (e.g., the degree of their adaptation to the means of transport – platform height) as well as the quality, legibility and timeliness of timetables. In this theory, infrastructure influences the temporal and economic scope of transport accessibility.

4. Research Methodology and Results

The inhabitants of rural areas in Poland perceive commune and poviat roads as having a fundamental importance in meeting transport needs. They link the place of residence with various travel destinations. It results from commuting to school, but also places of culture, shopping or health centers. The length of public, hard-surfaced, rural, poviat and commune roads in Poland is presented in Table 1.

Table 1. *The length of public, hard-surfaced, rural, poviat and commune roads in Poland*

Specification	*2000*	*2010*	*2020*	*2020:2000 (w %)*
Polska	162,0	180,5	211,9	31
Dolnośląskie	10,6	10,5	13,0	23
Kujawsko- pomorskie	9,0	10,6	13,6	51
Lubelskie	12,9	14,8	18,1	40
Lubuskie	4,3	4,3	5,6	30
Łódzkie	11,2	13,3	15,2	36
Małopolskie	15,6	17,4	19,5	25
Mazowieckie	18,1	22,7	27,6	52
Opolskie	5,7	5,5	5,4	-5
Podkarpackie	9,7	10,4	12,3	27
Podlaskie	7,3	8,4	10,2	40
Pomorskie	6,6	7,2	9,6	45
Śląskie	9,7	10,2	10,8	11
Świętokrzyskie	8,7	9,9	11,3	30
Warmińsko-mazurskie	7,7	8,2	9,3	21
Wielkopolskie	16,4	18,3	21,4	30
Zachodniopomorskie	7,8	7,8	8,3	6

Source: *Prepared by the authors based on: Transport – activity results in 2000, 2010, 2020, Central Statistical Office, Warsaw 2001, 2011, 2021.*

In Poland during 2000-2020 the length of hard-surfaced, rural, poviat and commune roads increased (by over 30%). The spatial unevenness of infrastructure development is characteristic. Voivodeships with an above-average increase in the length of commune and poviat roads are: Mazowieckie and Kujawsko-Pomorskie (an increase by over 50%), as well as Pomorskie, Lubelskie, and Podkarpackie (an increase by over 40%). The voivodships with a similar growth rate of infrastructure network length to the national one are Lubuskie, Świętokrzyskie, and Wielkopolskie. On the other hand, the areas with a minor increase in the length of rural roads are the Zachodniopomorskie and Śląskie voivodships. Against this backdrop we distinguish the Opolskie Voivodeship, in which, according to the data from the Central Statistical Office, the total length of hard-surfaced, rural roads with the status of poviat roads and communal roads has decreased (-5%). It is notable, however, that in addition to the lack of new investments, the decrease in length may be the result of shifts between different road categories.

Eastern and central Poland are characterized by a more dynamic development of transport infrastructure. Financing the development of these roads is provided by the state and local self-governments, and additionally by the EU program to support this area (Operational Program Eastern Poland). The funds were dedicated, among others, for the development of transport infrastructure. The research methodology which served to determine transport accessibility and changes resulting from the development of transport infrastructure in rural areas used two indicators:

1. Indicator for the spatial density of the road network taking into account the length of hard-surfaced rural roads and the area (country and voivodships),
2. Indicator for the demographic density of the road network taking into account the length of hard-surfaced rural roads to the number of inhabitants in rural areas (country and voivodships).

For the purpose of analysis, it was assumed that for rural areas in Poland, the basic transport network used by the inhabitants consists of commune and poviat roads with the status of hard-surfaced rural roads.

Rural areas in Poland cover approx. 93% of the country's area (290 thousand km^2). Changes in this respect in recent years have been insignificant. Transformations in the spatial density index, reflected in the degree of saturation with transport infrastructure in relation to the area and population number, are presented in Table 2.

The increased length of rural commune and poviat roads in Poland had a positive impact on the spatial density indicator of transport infrastructure in rural areas in Poland. In the absence of changes in rural areas, both within the country and in individual voivodships, in terms of direction and strength the dynamics of increase in the spatial density of roads coincides with the increase in the length of infrastructure. The only exception is the Opolskie Voivodeship, where a decrease in this indicator is visible. The main reasons for this include a general decrease in the length of poviat and commune roads in this voivodeship. Assessing the changes in the spatial density index, it can be concluded that the transport accessibility in the spatial system (except for the Opolskie Voivodeship) has improved.

Over 15.3 million people live in rural areas in Poland (2020), compared to 23.1 million city residents (2020). To note, back in 2000, the number of rural inhabitants in Poland amounted to approx. 14.7 million. The increase in the number of inhabitants of rural areas is mainly related to the progressing suburbanization (the relocation of city dwellers and inhabitants from peripheral towns to suburban areas). Nonetheless, this process does not apply to all voivodships. There are areas where we still deal with urbanization or a decline in the number of rural inhabitants in a given region. In particular these are voivodeships such as: Lubelskie, Lubuskie, Łódzkie, Opolskie, Podkarpackie, Podlaskie, and Świętokrzyskie.

Table 2. *Development of spatial and demographic density in Poland over the period 2000-2020*

Specification	Area (in thous.	Population (in thous.)		Spatial density (length of line		Demographic density	
		2000	*2020*	*2000*	*2020*	*2000*	*2020*
Polska	290,0	14710	14831	55,86	73,06	11,01	13,88
Dolnośląskie	17,7	832	838	59,89	73,44	12,74	14,49
Kujawsko-pomorskie	17,1	788	804	52,63	79,53	11,42	16,15
Lubelskie	24,1	1195	1178	53,53	75,10	10,79	15,79
Lubuskie	13,1	358	364	32,82	42,74	12,01	15,73
Łódzkie	17,0	924	918	65,88	89,41	12,12	16,52
Małopolskie	13,5	1606	1652	115,56	144,44	9,71	11,22
Mazowieckie	33,3	1817	1825	54,35	82,88	9,96	14,45
Opolskie	8,6	507	497	66,28	62,79	11,24	11,29
Podkarpackie	16,6	1258	1262	58,43	74,09	7,71	9,84
Podlaskie	19,2	507	495	38,02	53,12	14,40	21,79
Pomorskie	17,2	691	723	38,37	55,81	9,55	11,70
Śląskie	8,5	992	1001	114,12	127,05	9,78	10,33
Świętokrzyskie	11,0	714	707	79,09	102,72	12,18	16,25
Warmińsko-mazurskie	23,5	577	579	32,77	39,57	13,34	15,78
Wielkopolskie	28,2	1418	1455	58,16	75,88	11,57	13,66
Zachodniopomorskie	21,4	520	527	36,45	38,78	15,00	15,45

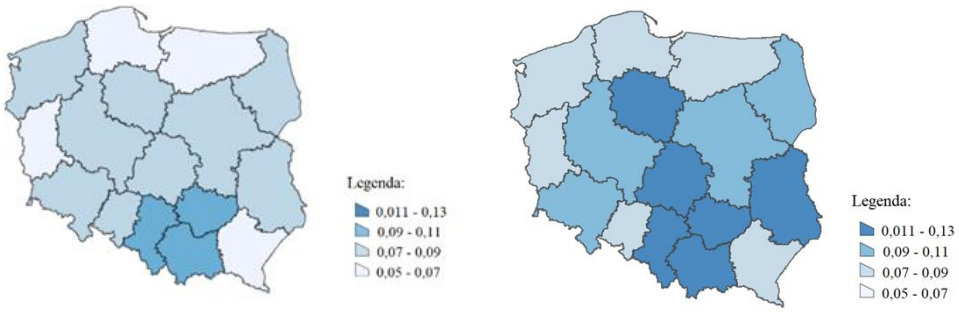
Source: *Own calculations based on Transport – activity results in 2000, 2010, 2020, CSO, Warszawa 2001, 2011, 2021 and Area and population in the territorial profile in 2016, CSO Warsaw 2017 and date from the Local Data Bank (stat.gov.pl).*

Changes in the demographic density index in rural areas in Poland differ from the spatial density index. Generally, they are on an upward trend. In Poland, the dynamics of the increase in demographic density over the period 2000-2020 amounted to 25%. The increase in the length of rural commune and poviat roads in rural areas in Poland was 31%, which was consistent with the dynamics of the increase in spatial density.

Similarly to spatial density, there is a different rate of increase in demographic density, which is influenced by the road network development rate and the change in population. The above-average growth rate of the demographic density indicator occurs in the voivodeships Kujawsko-Pomorskie, Lubelskie, Lubuskie, Łódzkie, Mazowieckie, Podlaskie, and Świętokrzyskie. However, in some of them, this process was influenced by a general decline in the population. A low growth rate of the demographic index was recorded in the Zachodniopomorskie, Śląskie, and Opolskie voivodships. An influence on that is due to low road growth and population growth. In the latter voivodship, both the population and the length of rural roads decreased.

Indicators for demographic density and spatial density of road infrastructure can be used for the comparative assessment of one feature – lengths of roads per area or specific population. The above indicators can be used for a more advanced analysis consisting in the calculation of the weighted average density ratio[2], which helps to identify regions with better and worse transport accessibility, taking into account the area and population at the same time. The level of weighted average accessibility is illustrated in Figure 1. The dynamics of the increase in weighted average accessibility in individual regions of Poland are demonstrated in Figure 2.

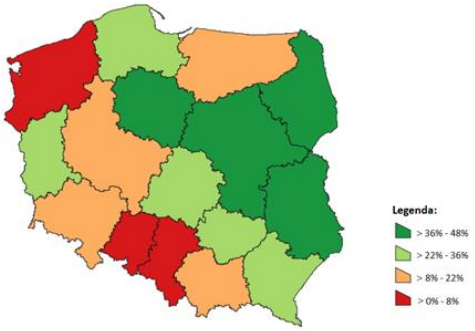
Figure 1. *Average weighted availability in 2000 and 2020.*



2000 2020

Source: *Prepared by the authors based on data from Table 2 and the ArcGIS software.*

Figure 2. *Change in transport accessibility indicator in 2000-2020 (in %).*



Source: *Prepared by the authors based on data from Table 2 and the ArcGIS software.*

As shown in Figure 1, a major improvement in transport accessibility took place in voivodships of central and eastern Poland. This is also confirmed by Figure 2 which illustrates the growth dynamics (in %) of the indicator for the sustainable level of

[2]*The weighted average density index takes account of spatial and demographic density. It is the quotient of the length of the network (e.g., road network) and the square root of the product of the surface and population of the studied area. This is discussed in more detail in W. Grzywacz, Infrastruktura transportu, WKiŁ, Warszawa 1982, p. 192.*

transport accessibility in individual regions of Poland. Given the weighted average indicator, it can be stated that the best availability of road transport infrastructure is found in rural areas in voivodships Świętokrzyskie, Małopolskie, and Łódzkie. Even worse results are reported in the Pomorskie, Zachodniopomorskie, and Mazurskie voivodeships.

5. Conclusions

Transport infrastructure with good qualitative and quantitative parameters betters the quality of life, including the mobility of citizens. Beyond the social aspect, transport infrastructure is also vital for the activities of economic entities. First of all, it has a favorable effect on their competitive ability. The quality of transport infrastructure also has an environmental impact.

In Poland, taking account of the infrastructural aspect, we can see an improvement in the transport accessibility of rural areas. However, we can see a spatial and demographic range of these transformations. This is influenced by the varying development of the length of rural roads in the analyzed systems and shifts in population. Improvement of the weighted average density indicator, and thus of transport accessibility, is noticeable in the regions of central (Mazowieckie, Kujawsko-Pomorskie voivodships) and eastern Poland.

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