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**Conference Paper** 

# Long-Term Impact Of Major Road Investments On The Transformation Of The Regional And Country Settlement Structure - A Case Study Of Lower Silesia

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## LONG-TERM IMPACT OF MAJOR ROAD INVESTMENTS ON THE TRANSFORMATION OF THE REGIONAL AND COUNTRY SETTLEMENT STRUCTURE - A case study of Lower Silesia

### Abstract:

The paper focuses on the analysis of relationships between the changes in the transport infrastructure and the development of subregions. The paper presents the measurement, spatial characteristics of the road infrastructure network and the delimitation of areas of different levels of transport accessibility. In particular the paper attempts to establish to what degree and for which regions the changes in the road network influence the development of particular regions.

The main results indicate that benefits from the development of road network are of a directional character, rather than area-related. This means that improvements in the infrastructure do not necessarily promote regions in which the improvements were made. Also, there is no simple principle of benefit resulting from improvements in connections between rich and poor regions. The beneficial influence is determined not only by the location of improvements but also the anisotrophy and dynamic character of the transportation system. Transportation improvements promote those subregions which achieved an improvement in communication efficiency in all connection distances and in more than one direction. The paper presents a typology of systems of changes in communication accessibility caused by the infrastructure changes and their role in the development of the subregion.

The studies implement a comprehensive cyclical model. This model is an extension of the spherical method as it implements the approach of mathematical analysis of network systems and statistical data.

The research covers the area of Lower subdivided into 154 calculation units. Detailed results are presented for four chosen areas.

**Keywords:** transportation network, spherical projection, communication accessibility, settlement structures.

JEL: 018; JEL: 02; JEL: P25; JEL: 50

### **INTRODUCTION**

Construction and modernization of the transport infrastructure network is beneficial to the economy. It is an endeavor which requires significant investments. At the same time an inappropriate structure of road network may cause losses resulting, for example, from additional costs of transporting people and products or it may cause unfavorable processes in land use.

Similar consequences may occur if network modernization is abandoned, which leads to the decapitalization of connections. At the same time the location of new or modernized sections may cause unintentional consequences for individual areas. The transport network is a dynamic system in which a change of one element influences the other elements. Many problems arise in the study of relationships between transport networks and socio-economic development of areas. The influence of transport investments on the economic development of regions may be identified using different methods<sup>1</sup>. The results of empirical studies into the nature of interactions between modernization of transport infrastructure and economic development of regions are both positive and negative. The contradictory results of studies are partly due to methodological differences<sup>2</sup>. Nevertheless this makes it difficult to objectively interpret the influence of transport on the inequalities of regions.

This can be determined by a certain duality related to transport functions. The first function is of a short-term character and is expressed in satisfying the flows between areas. The second function influences the changes in the accessibility of areas and is of a long-term character. This duality leads to the lack of unanimity in identifying the role of transport in the development of the region's economy<sup>3</sup>. The factor connecting both research trends is the movement through space in a network structure of connections. In this sense those research trends must have certain consistency in order to allow for verification of the degree to which individual descriptions of the studied phenomena correspond to each other.

The purpose of this paper is to analyze the influence of changes in the infrastructure on the diversification of development of areas.

The paper attempts to answer the following questions:

• Is there a relationship between transport improvement location and development areas?;

<sup>&</sup>lt;sup>1</sup> Cała C., 1978: Rola autostrad w zagospodarowaniu przestrzennym na podstawie doświadczeń włoskich. PWN. Warszawa.

Kim E., Hewings G.J.D., Hong C., 2002: An Application of Transport- Multiregional CGE Model I: A Framework for Economic Ananalysis of Highway Project. REAL Technical Paper No. 02-T-11. University of Illinois, Urbana, IL

Dall'eraba S., Hewings G.J.D., 2003: European Regional Development Policies: The Trade-off between Efficiency- Equity Revisited. REAL Technical Paper No. 03-T-2. University of Illinois, Urbana, IL.

Haddad E.A., Hewings G.J.D., 1999: Transportation costs and regional development: an interregional CGE analysis, In Anais do XXVII Encontro National de Economia, Belém. Pp. 1419-1437

Vickerman R., Spiekermann K., Wegener M., 1999: Accessibility and economic development in Europe, Regional Studies, 33,pp. 1-15

Buckley P.H., 1992: A transportation-oriented interregional computable general equilibrium model of United States, Annals of Regional Science, 26,pp. 331-348

Wigle R.M., 1992: Transportation costs in regional models of foreign trade: an application to Canada- U.S. trade, Journal of Regional Science, 32, pp. 185- 207.

<sup>&</sup>lt;sup>2</sup> De Almeida E.s., Haddad E.A., Hewings G.J.D., 2010: Transport- Regional Equity Issue Revisited. Regional Studies. Vol. 44, 10, pp. 1387-1400

<sup>&</sup>lt;sup>3</sup> Berry B.J.L., 1959: Recent studies concerning the role of transportation in the space economy. Annals of the Association of American Geographers, 49, pp. 328- 342.

• What are the long-term consequences of changes in the transport infrastructure on the development of a region and its units?

#### **RESEARCH METHOD**

In order to analyze the impact of the communication network on the development of subregions, an extended comprehensive cyclical model was used<sup>4</sup>. This systemic method of spatial analysis of correlating phenomena and processes implements elements of mathematical analysis, topology and taxonomy.

The approach is based on the method of spherical analysis by T. Zipser<sup>5</sup> in which spatial characteristics of the studied area are standardized by means of a single parameter. In the case of studies of linear systems this parameter is the standard deflection of the real distance between the source region and destination region from the model (air) distance (which is the straight-line distance between those two areas). Similarly we can calculate the deflection of areal density from the model value. The concept of concentric spheres, whose radiuses are equal to the values of calculated parameters, would enable the conjoint analysis of several phenomena occurring in one area. The shortening of the radius (parameter) would reflect the receding of the phenomenon from the model<sup>6</sup>. However, this approach could not be applied in spatial systems and did not satisfy the requirements of taxonomic standardization.

Network issues are characterized by its anisotropic nature. This is particularly significant in the analysis of spatial phenomena such as accessibility of various activities, zones of influence, etc. This feature is omitted in the study of spatial distribution models for various activities, which often causes interpretation problems and seemingly contradictory results. The distance aspect itself is not always the decisive factor<sup>7</sup>. What matters is the

<sup>&</sup>lt;sup>4</sup> Iwaszko- Niziałkowska K.., 1994: Sferyczna metoda oceny sieci komunikacyjnej w analizach układów przestrzennych. [w]: Planowanie przestrzenne. Zarys metod i technik badawczych, red. E. Bagiński., Wydawnictwo Politechniki Wrocławskiej. Wrocław, s. 67-80. <sup>5</sup> Zipser T. i inni, 1980: Analiza i ocena alternatywnych modeli docelowych systemu osadniczego, zagadnienia projekcji przestrzeni społeczno – ekonomicznej. Etap III. Raport Instytutu Architektury i Urbanistyki Politechniki Wrocławskiej, Wrocław.

<sup>&</sup>lt;sup>6</sup> Zipser T. i inni, 1980: Analiza i ocena alternatywnych modeli docelowych systemu osadniczego, zagadnienia projekcji przestrzeni społeczno – ekonomicznej. Etap III. Raport Instytutu Architektury i Urbanistyki Politechniki Wrocławskiej, Wrocław

<sup>&</sup>lt;sup>7</sup> Næss P., 2006: Accessibility, activity participation and location activities: Exploring the links between residential location and travel behaviour. Urban Studies, 43. pp. 627-652

direction of the interactions in space. This is especially important in the case of tours which connect different destinations<sup>8</sup> and in the classic problem of graph theory<sup>9</sup>. Such an approach was used to objectively assess network systems and define the efficiency of connections.

The method of calculating network efficiency and its degree of deformation can be implemented in various studies of network systems due to the following reasons:

• Any network in any configuration may be reduced to the division of a rectangle, i.e. it can be represented as orthogonal connections<sup>10</sup>.

• Implementation of a theoretical orthogonal network is the most objective assumption because such a network is the least susceptible to deformation<sup>11</sup>. The main assumptions of the method of measuring the efficiency of network connections are based on the assumption of a theoretical network in which the connections between units are made in the orthogonal structure of a directed graph.

Around the node which is considered the center of gravity of the source region a circle is assumed with a constant radius equal to 1, on which the center of the destination region travels.

When the directions (and orientations) of the real and ideal connection between the source an destination overlap, then the  $\beta$  angle between the directions of both connections equals 0 and the value of the real connection is equal to the value of the ideal connection. This reflects a situation when we can travel the real connection along a straight line.

Around the node which is considered the center of gravity of the source region a circle is assumed with a constant radius equal to 1, on which the center of the destination region travels.

Haugen K., 2011: The advantage of 'near': Which accessibilities matter to whom? European Journal of Transport and Infrastructure Research

<sup>&</sup>lt;sup>8</sup> Bowman J.L., Ben- Akiva M.E., 2001: Activity- based disaggregate travel demand model system with activity schedules. Transportation Research Part A, 35, pp. 1-28

Lee Y., Hickman M., Washington S., 2007: Household type and structure, time-use pattern, and trip- chaining behaviour. Transportation Research Part A, 41, pp. 1004-1020

<sup>&</sup>lt;sup>9</sup> Robin J. Wilson, 1998: Wprowadzenie do teorii grafów. z ang. tł. Wojciech Guzicki. PWN. Warszawa

Kenneth A. Ross, Charles R.B. Wright, 2005: *Matematyka dyskretna*. z ang. przeł. E. Sepko-Guzicka, W. Guzicki, P. Zakrzewski. PWN.Warszawa

<sup>&</sup>lt;sup>10</sup> Nievergelt J., Craig Farrar J., Reingold R. M., 1978: Informatyczne rozwiązywanie zadań matematycznych. Warszawa, s. 61-66.

<sup>&</sup>lt;sup>11</sup> Iwaszko- Niziałkowska K., 1990: Analiza układu komunikacyjnego Wrocławia przy użyciu wzbogaconej metody projekcji sferycznej z wizualizacją. Praca doktorska. Instytut Architektury i Urbanistyki Politechniki Wrocławskiej. Wrocław,.

Iwaszko- Niziałkowska K., 1994: Sferyczna metoda oceny sieci komunikacyjnej w analizach układów przestrzennych. [w]: Planowanie przestrzenne. Zarys metod i technik badawczych, red. E. Bagiński., Wydawnictwo Politechniki Wrocławskiej. Wrocław, s. 67-80.

When the direction of the real connection is not identical with the direction of the ideal connection, then the *r* parameter value of the real connection changes in accordance with the function  $\sin \beta + \cos \beta$ , where  $\beta$  is the angle between both directions. In practice this represents a situation in which we are forced to travel the connection along one-way "vertical" and "horizontal" segments of the orthogonal network.

The function  $r = \sin \beta + \cos \beta$  reaches its maximum value for angle  $\beta = 45^{\circ}$ , where rmax = 1.4142. Thus for  $\beta$  between  $0^{\circ}$  and  $45^{\circ}$  the value r increases from 1 to 1.4142 and further increase in the angle  $\beta$  does not result in an increase in the value of r due to the character of the sine and cosine functions. Theoretically r cannot exceed the maximum value of the function equal to 1.4142, and in practice larger r values reflect the occurrence of significant deformations in the network or reverse movements (i.e. movements in which there are turns in the same or similar direction as the ideal direction but of the opposite orientation).

The angular function reaches its maximum for r = 1.4142, which I proved to be the limit value of efficiency for all types of transport connections in spatial networks. The scope of connections of network efficiency for  $0^{\circ} \ll \beta \ll 45^{\circ}$  was divided into 6 classes equal in angle (every 7.5°) and for their  $\beta$  value the *r* values were calculated, which constitute the limits of classes:

1 <sup>st</sup> class of efficiency	for	$r \le 1.0001$
2 <sup>nd</sup> class of efficiency	for	1.0001 < r < 1.1220
3 <sup>rd</sup> class of efficiency	for	$1.1220 \le r < 1.2248$
4 <sup>th</sup> class of efficiency	for	$1.1248 \le r < 1.3066$
5 <sup>th</sup> class of efficiency	for	$1.3066 \le r < 1.3661$
6 <sup>th</sup> class of efficiency	for	$1.3661 \le r < 1.4021$
7 <sup>th</sup> class of efficiency	for	$1.4021 \le r < 1.4143$
8 <sup>th</sup> inefficiency	for	$r \ge 1.4143.$

The values of the *r* parameter for connections in each source units were subjected to such division and then the average sphere radiuses for every unit. In result conjoint characteristics of the communication levels of the area were obtained. When comparing transport networks, an average value may be set for each of them. This value is equal to the sum of average levels of the efficiency parameter for connections in all regions, divided by their number. These values may differ from the expected value of the parameter calculated for a theoretical system. The values may be directly compared, which is in accordance with the taxonomy assumptions (*city block* metric), where the distance between standardized numerical values of characteristics is equal to the difference between them<sup>12</sup>.

<sup>&</sup>lt;sup>12</sup> Jardine N., Sibson R., 1971: Mathematical taxonomy. London.

This does not include the traditional approach to taxonomic division into classes, which is proposed in regional studies by Haggett<sup>13</sup> and consists in choosing the relatively best number of classes.<sup>14</sup> However, it implements the proposed method of evaluating the level of diversification of characteristics of the area, in a similar manner to the one proposed in the comprehensive cyclical model. Hagget's methods are considered irrelevant to the study because they pertain to the geographic classification, which treats objects that are spatial in nature as an n – element set of objects. Thus the topographic characteristics of these objects in classes, such as size, shape and location, are not taken into account. Meanwhile they are of great significance for the interpretation due to the inclusion of the natural factor (influence of geography on the structure of the settlement network). In their explanation of differences between regions Krugman<sup>15</sup> and Cronon<sup>16</sup> distinguish the following factors: first nature (geographical) and second nature (man-made). Although Krugman focuses on second nature factors in spatial processes, according to Combes<sup>17</sup> natural factors must not be neglected if we wish to explain why certain regions form a group of "rich regions" while other regions are excluded from that group.

Apart from the adopted division into classes the categories of "type" and "effect" were introduced into the analysis of connection levels. The "type" category is related to the occurrence of inefficient connections on the following distances:

- Local (closes proximity to the source)<sup>18</sup>;
- Medium-distance trips;
- Long-distance trips<sup>19</sup>

The "type" category uses a three symbol notation where the symbol X represents inefficient connections and the symbol O represents the efficient ones. The position of the

<sup>&</sup>lt;sup>13</sup> Haggett P., 1977: Methods and new techniques of urban and regional research, W: Urban and regional research, New York, United Nation, p. 453

<sup>&</sup>lt;sup>14</sup> According to the maximum quotient criterion of inter-class and inner-class variances with respect to spatial classes and distributions as well as the maximum quotient of internal and external connections in the case of spatial classes.

<sup>&</sup>lt;sup>15</sup> Krugman P., 1991: Increasing returns and economic geography. Journal of Political Economi, 99, pp. 483 -499

Krugman P., 1993: First nature, second nature, and metropolitan location. Journal of Regional Science, 33, pp. 129-144.

<sup>&</sup>lt;sup>16</sup> Cronon W., 1991: Nature's Metropolis. Chicago and the Great West, London, W.W. Norton

<sup>&</sup>lt;sup>17</sup> Combes P.P., Mayer T., Thisse J.F.,2006: Economie geographique, l'integration des regions et des nations, Paris, Economica

<sup>&</sup>lt;sup>18</sup> The closest proximity is understood as the adjacency of the source region and the neighboring region, in accordance with the movements of a queen on the chessboard.

<sup>&</sup>lt;sup>19</sup> The boundary between medium-distance and long-distance movements was calculated as the radius length of the circle inscribed in the region area, which in this case is equal to 55 km.

symbol in the three-symbol notation refers to the local, medium-distance and long-distance trips respectively.

The "effect" category is a kind of typology of regions with inefficient connections – deformations. They create a characteristic, repeated system of regions inefficiently communicated with the source with respect to their shape, consistency and arrangement of directions. The following effects have been defined:

- Isolation effect
- Wing effect
- Sector effect
- Island effect
- Broken shadow effect

The introduction of notations for efficiency classes and the "type" and "effect" categories has significance in the interpretation of calculated states of communication accessibility on different tiers (stages) of analysis.

Only by analyzing a series of generated images of patterns in spatial levels of communication can we fully interpret the phenomena, which are separately indiscernible.

In the method of calculating the absolute efficiency of connections, the value  $\beta = 22.5^{\circ}$  constitutes the median of the angular scope of efficient connections. This value is assumed as the boundary between connections of high and low efficiency. On this basis, on any model-generated image of spatial distribution of phenomena, there are two areas of communication efficiency: high and low (apart from inefficient connections).

Similarly, the images of projections of various forms of development (generated by calculations of areal density for individual regions<sup>20</sup> contain two areas of phenomena intensity (in relation to the arithmetic mean):

- Those of high intensity;
- Those of low intensity.

The adoption of the division into two main areas of communication efficiency levels and into two areas of phenomenon intensity seems sufficient to analyze the various aspects of

<sup>&</sup>lt;sup>20</sup> Zipser T. i inni, 1980: Analiza i ocena alternatywnych modeli docelowych systemu osadniczego, zagadnienia projekcji przestrzeni społeczno – ekonomicznej. Etap III. Raport Instytutu Architektury i Urbanistyki Politechniki Wrocławskiej, Wrocław.

Zipser T., Iwaszko-Niziałkowska K., Kontrola i diagnoza procesów koncentracji w zagospodarowaniu przestrzennym przy użyciu zapisu sferycznego. Raport I-12 Politechniki Wrocławskiej, Wrocław, 1990.

Iwaszko- Niziałkowska K., 1994: Sferyczna metoda oceny sieci komunikacyjnej w analizach układów przestrzennych. [w]: Planowanie przestrzenne. Zarys metod i technik badawczych, red. E. Bagiński., Wydawnictwo Politechniki Wrocławskiej. Wrocław, s. 67-80.

communication accessibility for specific functions. This is because a high number of classes results in a decrease in the total number of cases assigned to those classes, which in consequence leads to a small representativeness of thus obtained classes<sup>21</sup>. Areas selected in this manner may be overlapped and compared if the condition of standardization of features according to the mean is satisfied<sup>22</sup>. With uniform classes it is also possible to compare them hierarchically<sup>23</sup>.

Adoption of thus established areas satisfies the study requirements<sup>24</sup> because:

- Common areas with any combination of characteristics are defined (established boundaries);
- There is a possibility to compare the obtained numbers of observations before various types of projections are overlapped;
- The number of elements in the area is other than zero;
- Two defined areas of phenomenon or function intensity enable us to quickly and accurately define communication levels for individual regions, which is not possible when applying direct projection comparison<sup>25</sup> [Zipser, 1980], because the basic zones in the spherical projection are assumed differently.

### **RESEARCH AND RESULTS**

Before World War 2 the Lower Silesian region had a well-developed road infrastructure. In 1937 a 106-km-long section of concrete motorway was opened to the west of Wrocław (part of today's A4 motorway). This motorway was to connect Berlin and Dresden with Silesia. After World War 2 Lower Silesia was annexed by Poland and for several decades the development of communication infrastructure stopped. This was mainly due to the lack of international transport resulting from political circumstances.

Before Poland's accession to the EU the following segments of the A4 motorway were built:

<sup>&</sup>lt;sup>21</sup> Brooks C.E.P., 1949: Metody stastystyczne w klimatologii. Przegląd Meteorologiczny, Warszawa, 1/49

<sup>&</sup>lt;sup>22</sup> Caliński T., Dyczkowski A., Kaczmarek Z., 1976: Testowanie hipotez w wielozmianowej analizie wariancji i kowariancji. Roczniki Akademii Rozlniczej, Poznań, pp. 77-114

<sup>&</sup>lt;sup>23</sup> Parysek J., 1982: Modele klasyfikacji w geografii. Seria Geografia, 31, Poznań.

<sup>&</sup>lt;sup>24</sup> Grigg D., 1967: Regios, models and classes, [w]: Models in geography, red. R. J. Chorley, P. Haggett. London, , s.461-509.

<sup>&</sup>lt;sup>25</sup> Zipser T. i inni, 1980: Analiza i ocena alternatywnych modeli docelowych systemu osadniczego, zagadnienia projekcji przestrzeni społeczno – ekonomicznej. Etap III. Raport Instytutu Architektury i Urbanistyki Politechniki Wrocławskiej, Wrocław.

- Częstlice Strzelce Opolskie (Opole province);
- Katowice Kraków (Silesian and Lesser Poland provinces).

In 2007 the National Program of Highway Development and Road Modernization was created which assumed the completion of the A4 and A18 motorways in areas connected to Lower Silesia, and the modernization and construction of S3, S5, and S8 expressways. As of mid-2012 the new sections of the expressways have not been finished.



Figure 1. Development plans for motorways and expressways, 2007 (source: GDDKiA).

After the political transformation in 1989 and later when Poland joined the EU, competition started between regions.

This paper focuses on the impact of the transport network on the efficiency of links between regions. Based on the current spatial distribution of regions and road connections a study was conducted to investigate which regions are located most favorably in a space characterized by diversified resources and accessibility. Regional resources in this case are measured by the population size. The inhabitants do not only use the potential of their place of residence. They also evaluate the attractiveness of resources in other regions, whose offer is more competitive<sup>26</sup>.

<sup>&</sup>lt;sup>26</sup> Zipser T., Sławski J., 1988: *Modele procesów urbanizacji*. Studia KPZK PAN, t. XCVII. Warszawa.

If regions are located in highly populated areas with good communication and numerous resources, their attractiveness increases.

Small peripheral regions which have few resources are usually incapable of finding buyers for all of the resources available. It is thus interesting to analyze the network connections efficiency with respect to the actual resources of individual regions - the population. To do this, the spatial distribution of population density was "filtered" through the dynamics of migration trends (Figure 3.) and the efficiency characteristics were calculated for the geometric transport infrastructure network of 1978<sup>27</sup> and 2012.

The results of the communication accessibility offered by the geometry of road infrastructure network showed only small changes in the analyzed period (Figure 2.).

What changed though was the distribution of population. Since 1998 there has been a constant trend for people to concentrate around big cities (Figure 3).

The results of the study show the centers of concentration and "declining" regions from which the population is "drained".



Figure 2. Spatial model of the distributions of accessibility/availability levels of the transport infrastructure network in 1967 and 2012. Geometric aspect. Symbols: 1<sup>st</sup> efficiency class, 2<sup>nd</sup> efficiency class, 3<sup>rd</sup> efficiency class, 4<sup>th</sup> efficiency class, 5<sup>th</sup> efficiency class, 6<sup>th</sup> efficiency class, 7<sup>th</sup> efficiency class, 8<sup>th</sup> inefficiency for r ≥ 1,4143. (own work).

<sup>&</sup>lt;sup>27</sup> Dörhöfer red., 1977: Reiseatlas DDR mit ČSSR, Polen, UDSSR, Ungarn, Rumänien, Bulgarien, Veb Tourist Verlag- 1978/79. Berlin/Leipzig, DDR



Figure 3. Conjoint analysis of the population density and migration trends.

1. areas with low population density and population outflow;

2. areas with low population density and population inflow; 3. areas with high population density and population outflow; 4. areas with high population density and population inflow.

However, this does not explain why some regions with medium-sized cities preserve their resources while others lose theirs. Apart from Wrocław – which is the natural capital of the region, three other cities constitute capitals of sub-regions: Jelenia Góra, Legnica and Wałbrzych. In 1967 [ed. Sojecki, 1969] the population of these cities was respectively: 54.9; 73.4 and 126.6 thousand inhabitants. At that time 487 thousand people lived in Wrocław. But in 2011 [GUS, 2012] the population of Wrocław was 632 996 inhabitants, while in Jelenia Góra, Legnica and Wałbrzych there was 84 thousand, 103.9 thousand and 120.2 thousand inhabitants respectively. While an increase in population may be easy to interpret for the regional capital, the situation with the other cities is not so straightforward. The population in Jelenia Góra and Legnica increased but in Wałbrzych the population dropped regardless of the general demographic trends.

According to many researchers the distance is the main factor influencing the organization of people's spatial activities and interactions [Miller 2004; Couclelis 1996 cited in Miller 2004]. But is this always the case?

According to Vilhelmson<sup>28</sup> factors such as changing land-use patterns cause an increase in the distances and travel times to many sources, which also decreases their accessibility. However, in economically developed regions travel is on the increase. According to the International Transport Forum<sup>29</sup> [2012] the total number of passengers on road networks in Poland, in the years 1970-2010, increased from 29,140 to 96,080. This increase is influenced by the relatively short times needed to reach the destination. It is thus interesting to analyze the influence of the time-accessibility aspect of the network on the changes in population distribution of the region.

Therefore four series of calculations were conducted of the spatial distribution of accessibility levels for the road infrastructure network in its shape in four periods:

- Up to 1990;
- Up to 1998;
- Up to 2004;
- Up to 2012.

Below is an illustration of the calculation results for four Lower Silesian cities: Wrocław (Figure 4.), Jelenia Góra (Fugure 5.) Legnica (Figure 6.) and Wałbrzych (Figure 7.). The screenshots generated by the model illustrate the distributions according to the average of parameter r for the source region.



Figure 4. Spatial distributions of levels of low and high communication accessibility (according to the average for the region) for Wrocław, on road infrastructure in the years 1990 -2011. Time aspect.

<sup>&</sup>lt;sup>28</sup> Vilhelmson B., 2005: Urbanisation and everyday mobility: Long – term changes of travel in urban areas of Sweden. European Journal of Geography, v.302

<sup>&</sup>lt;sup>29</sup> International Transport Forum; Trends in the transport sector: Inland passenger transport. URL: <u>http://www.internationaltransportforum.org/statistics/trends/index.html</u> (pobranie: 12.06.2012)



Figure 5. Spatial distributions of levels of low and high communication accessibility (according to the average for the region) for Jelenia Góra, on road infrastructure in the years 1990 – 2011. Time aspect.



Figure 6. Spatial distributions of levels of low and high communication accessibility (according to the average for the region) for Legnica, on road infrastructure in the years 1990 – 2011. Time aspect.



Figure 7. Spatial distributions of levels of low and high communication accessibility (according to the average for the region) for Wałbrzych, on road infrastructure in the years 1990 – 2011. Time aspect.

Based on the results obtained, the following conclusions are reached:

- The modernization of main connections (A4 motorway and sections of S5, S8 expressways near Wrocław, the S3 section to the north of Legnica and the section of the national road 35 near Wałbrzych) caused a decrease in communication time-accessibility. This results from higher traveling velocity and polarization of velocity standards offered by the Lower Silesian transport system;
- The changes in the technical standards for roads bring about changes in the scope of connections for sources. Only Wrocław and Jelenia Góra maintain constant time-efficient connections in all three distance ranges OOO type, but Wrocław maintains communication efficiency in almost all main directions (except for the sector shadow towards the north-west). However, Jelenia Góra is subject to the *flanking effect*. This means that the city's good accessibility is determined by one highly efficient road running from north-east through Wrocław to the south-west towards Prague. Legnica is inaccessible for short distances and is characterized by the XOO communication type and the *isolation effect*. In the case of Wałbrzych the only visible communication efficiency was for long-distance trips (type XXO) with a strong *isolation effect*.

The consequences of the generated communication situation are visible on conjoint projections for the abovementioned cities. The conjoint distribution of communication accessibility for Wałbrzych, as well as the following:

- per capita revenue of the commune (Figure 8.),
- migration trends (Figure 9.),

appear to confirm the described situation.



Figure 8. Conjoint analysis of the distribution of communication accessibility levels in 2004 and the density of per capita revenue of the commune for the source region of Wałbrzych. 1. Areas of high communication efficiency with the source and low level of revenue per capita; 2. Areas of high communication efficiency and high level of revenue; 3. Areas of low communication efficiency low level of revenue per capita; 4. Areas of low communication efficiency and high level of revenue per capita;



Figure 9. Conjoint analysis of the distribution of communication accessibility levels in 2004 and migration trends for the source region of Wałbrzych. 1. Areas of high communication efficiency with the source and high population outflow; 2. Areas of high communication efficiency and high population inflow; 3. Areas of low communication efficiency with the source and low population outflow; 4. Areas of low communication efficiency with the source and low population inflow;

The presented composite projections for Wałbrzych lead to the following conclusions:

The areas surrounding Wałbrzych are ineffectively communicated with it. Most of these areas exhibit a low level of per capita revenue of the commune and people from these areas migrate to other well accessible areas around Wrocław, which are characterized by high revenue of the commune. What is characteristic is that people migrate to areas adjacent to Wrocław, not to Wrocław itself. A probable cause of this situation is that industrial areas have been moved from Wrocław to the neighboring areas, which, as a result, offer better employment opportunities and a high diversity of services offered by the metropolis. The spatial distribution of areas with different transport accessibility levels indicates a decrease in the popularity of Wałbrzych among the inhabitants of neighboring areas. Therefore distance is not always the decisive factor and people may travel further than to the nearest city<sup>30</sup>.

#### CONCLUSIONS

The presented results (incomplete, due to editorial restrictions) appear to confirm the relationship between the communication accessibility of regions, the per capita revenue of areas and the migration trends.

Whereas the migration problem and relationships with areas of high per capita revenue is widely discussed in literature, the problem of influence of communication accessibility on such phenomena is quite problematic. There is still disagreement among the proponents of the importance of distance. The paper attempts to explore a completely different aspect of the role of changes in the transport infrastructure. This is the aspect of the direction of network impact – in the spatial sense – not analyzed in literature. The results of studies do not confirm the thesis on the impact of changes in transport infrastructure described, for instance, in the work of De Almeida et al<sup>31</sup>. This thesis states that the diversification of regions results from the fact that the studied impact depends mostly on where the changes in the infrastructure network occur.

As shown, the shape of areas of good accessibility is not determined by access isochrones. Regions do not constitute a circular space but a directional space. The studies on different sizes of areas, from the country area to the city area<sup>32</sup> appear to confirm this thesis.

<sup>&</sup>lt;sup>30</sup> Næss P., 2006: Accessibility, activity participation and location activities: Exploring the links between residential location and travel behaviour. Urban Studies, 43. pp. 627-652

<sup>&</sup>lt;sup>31</sup> De Almeida E.s., Haddad E.A., Hewings G.J.D., 2010: Transport- Regional Equity Issue Revisited. Regional Studies. Vol. 44, 10, pp. 1387-1400

<sup>&</sup>lt;sup>32</sup> Iwaszko- Niziałkowska K., Powiązania funkcjonalne i relacje z miastem; Migracje. [w:] Modele rozwoju dla terenów urbanizujących się w obrębie wielofunkcyjnych terenów wiejskich w regionie. "Analizy, badania i prognozy na rzecz Strategii Rozwoju Województwa Dolnośląskiego". Tom V. Wrocław. 2010. s.111-196.