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Comparative Analysis of Railway Transport to the Voivodship Centers of Eastern Poland—Cities of Białystok, Lublin, and Rzeszów

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Abstract

The article presents and compares railway transport to various voivodship centers of Eastern Poland which vary in terms of spatial resistance. Spatial resistance, which depends on many factors such as railway and stock infrastructure, has a major impact on the lengthening or shortening of travel time, distances and costs. Presentation of data and comparison of individual centers provides grounds for developing a strategy for further development. Availability of railway access is illustrated with several result maps. Maps depict the three most important elements related to covering distances by train. Factors analyzed include: travel time (isochrone), distance by rail and the cost of travel (isodapane) to the voivodship centers of Eastern Poland. Graphic studies provide data for the calculations presented in the charts subject to analysis. In summary, the article shows which voivodship centers of Eastern Poland feature better railway transport accessibility.

Keywords: railway availability, isochrone, railway distance, isodapane

Introduction

Access to railway transport, as opposed to individual access to transport, is a matter rarely touched upon in literature. Analysis of accessibility to railway transport is difficult because it requires considering many variables that influence accessibility (Warakomska 1992). One of the major variables posing a challenge is the ever changing timetable. Network connections on the other hand form the most stable component of railway accessibility, because of the small number of investments in infrastructure in the past two decades. The current situation of railway infrastructure is changing thanks to the support from European Union programs. Changes are expected to progress rapidly due to the growing financial resources spent on railway transport (Goliszek 2014a). The present state of the railway network in Poland is determined by historical factors (Koziarski 1993a, 1993b; Lijewski 1959). In terms of surface area, the regions that in the nineteenth century were located in Galicia and the Polish Kingdom featured the least dense railway network (Ratajczak 1992). According to Lijewski and Koziarski (1995), after World War II the density of the railway network in the east part of the country was not satisfactory, so efforts focused on electrification of existing tracks and building a second track along single-track routes. For a long period of time railways within the territory of Poland experienced an increase in length of railway tracks, as well as their regress, especially after political transformation in 1989 (Taylor 2007).

The main objective of the study is to compare railway accessibility of particular Eastern Polish voivodship centers using cartographic presentation methodology and GIS (Geographical Information Systems) tools (Sierpiński 2010).

1 Research methodology

This article refers to passenger transport. The gathered data embrace travel time, distance calculated along the railway network and the transport cost to the particular centers of Eastern Poland. It should be emphasized that the cost of transport is in most cases related to travel time. Raster maps were analized by interpolating approximately 500 measuring points distributed over Poland's territory at regular intervals (Brzuchowska 2010; Fortuna, Macukow, and Wąsowski 1993; Longley and Batty 1996). The values recorded at the measuring points were obtained from the online PKP timetable[1] and reflect the timetable in the period from 12th December 2011 to 29th February 2012. In situations where direct access required additional travel by bus or minibus, the right amount of time, distance and cost of travel was added. Average speed adopted by these modes of transport was 60 km/h. Adopted distance reflected the length of the road between the place of departure and the nearest railway station. Price ranged from PLN 2 for 10 km in the case of distances up to 20 km, and from PLN 1,5([2]) for 10 km when driving more than 20 km to the nearest railway station (Ratajczak 1999). Selection of the train category was associated with the speed of passage and best access to a railway station. In a situation when the travel time offered by more expensive carriers (Ex, EC, EIC) was less than 60 minutes for journeys exceeding 300 km, the analysis took into account cheaper carriers (TLK, fast trains). Prices were up to two times cheaper.

The analysis covered the area of the entire country, taking into account the number of inhabitants by statistical regions and census enumeration of GUS. The area of each analyzed raster

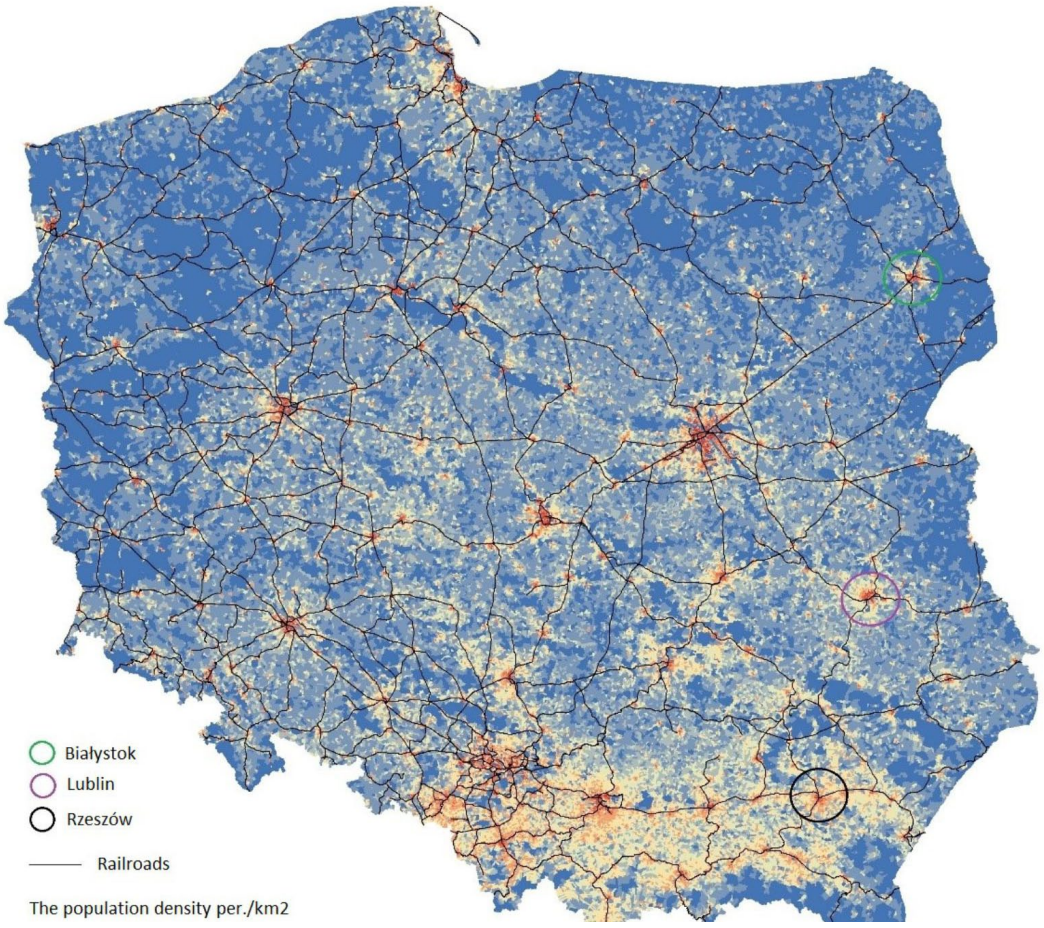

Fig. 1. Population density in the census circuits and location of the analyzed voivodship centers of Eastern Poland.
Source: Own study based on Central Statistical Office of Poland data

1. See: http://rozklad-pkp.pl/en#

2. [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

relevant for the phenomenon and the population was cut and converted in the ArcMap, providing statistical data for comparison. Analyzed rasters were classified and vectorized. Raster objects were cut by the tool "Ekstract by Mask." In contrast, vector objects were cut by the "Clip" tool. Both tools are used in the basic package Toolbox (Longley and Batty 1996). By using these tools, the population and surface area in different periods of isolinear maps were calculated (Ratajczak 1999). The sections depicting railway isochrones were set at 60 minutes from the beginning to 660 minutes or more. The distances on the railway network intervals shown on maps are set every 100 km, which can easily be interpreted as the tortuosity of the railway lines (Brzuchowska 2010; Fortuna, Macukow, and Wąsowski 1993). PLN 40 sections were identified for the maps presenting the cost of transport to the voivodship center.

In order to better illustrate the direct railway links maps showing isochrones were imposed with a simple ribbon cartodiagram. Width of cartodiagram lines corresponds to the number of direct railway connections (Ratajski 1989). Maps were prepared using kriging, a set of tools from Toolbox of the ArcGIS 10 software. In effect a raster layer was created (vertical-horizontal grid-colored pixels respectively) cut to the boundaries of the Polish territory (Brzuchowska 2010). The choice of voivodship centers of Eastern Poland was made on the basis of their location along the so-called the eastern wall in order to facilitate the comparison of spatial access times, distances and costs of the network. Cities are located in the immediate vicinity of the eastern Polish border and are considered to feature similar spatial and economic conditions.

2 Railway accessibility maps

2.1 Direct railway connections and isochrone maps

By analyzing the map presenting train network options to Białystok it is clearly visible that the main direct train connection is the route Białystok–Warszawa. Another important train route is a railway line to Olsztyn and further through Gdańsk to Szczecin. Less attended routes are those leading towards Belarus (Grodno) and Lithuania (Suwałki). In the south, trains lead to a border city of Czeremcha (border with Belarus). Inhabitants of Białystok can reach Warszawa by train within three hours, whilst a trip to Olsztyn takes much more time (fig. 3).

Analysis of direct railway connections to Lublin in the form of a simple ribbon cartodiagram shows areas with good accessibility. The main route is the train connection between Lublin and Warszawa. Another important railway line is the route to Chełm, which lies in the area of Rejowiec Fabryczny and splits into two routes, one leading to Zamość, and the other to Dorohusk (the border with Ukraine). In the south numerous trains lead to Kraśnik, and the less popular line runs to Rzeszów by Stalowa Wola. A relatively large number of trains from Lublin head toward Toruń and Poznań. Travel time from Lublin to these cities is more than six hours. The situation is much worse in the south and south-west, where travel time by train between Lublin and Wrocław exceeds eight hours. The main direction of railway routes from Rzeszów, in contrast to analyzed connections to/from Białystok and Lublin, is not Warszawa, but Kraków. Another important direction is the connection to Przemyśl and the railway border crossing in Medyka (the border with Ukraine). To the south, several direct trains run in the direction of Jasło and the main north direction runs directly to Lublin and Zamość. The main tracks from Kraków branch out to Gdańsk via Warszawa, along part of the Central Railway Route. One connection runs from Sosnowiec in the direction of Łódź through Częstochowa. Several connections head to Wrocław, where they split in the direction of Jelenia Góra and Zielona Góra. The greatest number of connections from Wrocław head to Szczecin via Poznań (fig. 2).

Direct train connections appear just like isochronea marked on the map. In most cases these are extended in places where there are trains going directly to the urban center. However, there are places more accessible on maps outside the direct network connections, which may be associated with indirect access by an express train. In some cases, direct connections are in a deteriorated condition, where trains do not exceed the appropriate speed (e.g., 80 km/h) (Goliszek 2014b).

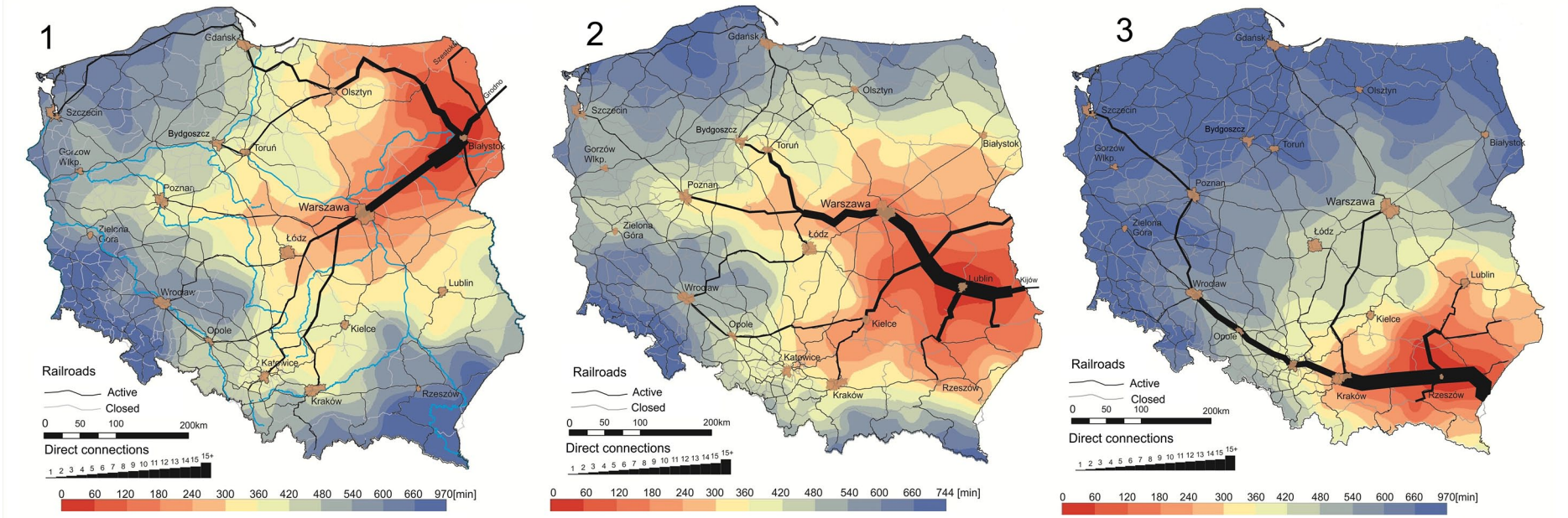

Fig. 2. Map of railway transport optiond to Białystok (left), Lublin (center), Rzeszów (right).

Source: Own study based on the PKP timetable

2.2 Equidistance of the railway network

The purpose of the equidistant method is to give a spatial representation of the distance by rail network and a comparison of availability to selected voivodship centers of Eastern Poland. In places where there is no railway line the road distance to the nearest railway station is added (Ratajski 1989; Warakomska 1967). On the map showing the length of the railway network in Białystok, in the range of up to 100 km, the isoline extends in the direction of Warszawa. Similarly arranged is the equidistance in the range of 100 km to 200 km distanced from Warszawa. At a distance of 200 km to 300 km Olsztyn is in range. All railway lines running from Warszawa to the east, south, west, north-west increase the equidistance in that direction. In the range of up to 400 km access to Łódź and Lublin are possible. In equidistant from 400 km to 500 km the distance to Poznań, Toruń, Bydgoszcz, Gdańsk and Kraków grows. It is worth noting that the 500 km to 600 km distance, though smaller than the the actual physical distance to Białystok, significantly extendes the equidistant. Places to/from which a transfer extends from/to Białystok sites are located to the south of Kielce and to the north of Opole. Voivodship cities located within 600 km of Białystok are Wrocław and Opole. The range of 600 km to 700 km is equidistant to the border with the Federal Republic of Germany, and then the Czech Republic and border crossing in Cieszyn. Voivodship cities within 700 km of the railway network include Szczecin, Gorzów Wielkopolski, Zielona Góra, and Rzeszów. The last isoline shows areas distanced 700 km from Białystok by railway, and characterizes border areas with the Czech Republic and Germany (fig. 3) (Goliszek 2015).

The railway isoline, ranging up to 100 km from Lublin, increases its reach along the main lines of rail transport to Warszawa, Rzeszów and towards the border with Ukraine. It is possible to reach Warszawa, Rzeszów and Kielce within 100 km to 200 km. There are several voivodship cities, including Kraków, Katowice, Łódź, Białystok distanced 300 km to 400 km in terms of railway tracks. The equidistance of 400 km to 500 km reaches Opole, Poznań, Toruń, Bydgoszcz, Gdańsk, and shows locations the access to which is greatly lengthened despite the proximity of good transport accessibility. A place worthy of attention is an area located to the east of Wrocław where passage to Lublin is longer in terms of distance, similarly as in the case of Iława and Toruń. The 500 km to 600 km isoline area increases to the west towards the border with Germany. The range of 600 km to 700 km reaches such cities as Szczecin, Gorzów Wielkopolski, and Zielona Góra. Places farthest distanced by rail are shown by the above equidistance of 700 km and are located in the Western Pomeranian voivodship.

The 100 km railway network isoline of Rzeszów spreads in two main directions — i.e., to the west and the east, and also extends short distances to the north and the south. The 100 km to 200 km equidistant railway network gives access to Kraków. Katowice and Kielce remain within 200 km to 300 km of rail tracks. The isoline 300 km to 400 km reaches Opole. At a distance of 400 km to 500 km there are three major voivodship cities, Warszawa, Łódź, and Wrocław. Zielona Góra is within 500 km to 600 km by rail. The 600 km to 700 km equidistant covers Poznań and Białystok. The range 700 km provides access by railway to the remaining voivodship cities such as Toruń, Gdańsk, Bydgoszcz, Olsztyn, Szczecin and Gorzów Wielkopolski (fig. 3) (Goliszek 2014b).

2.3 Maps of travel costs

Isodapane maps show various domestic destinations divided by PKP railway fee. Travel destinations (up to PLN 40) from Białystok are located close to the city and lengthen on the route to Warszawa. The price range from PLN 40 to PLN 80 was sufficient to reach most voivodship centers in Poland. Travel by train to Białystok at the price of PLN 80 to PLN 120 was possible from the south-western part of Poland and from areas near Bydgoszcz, in the western direction. The highest railway fee to Białystok is paid by travelers from Podkarpackie Voivodship and the areas to the west of Wrocław, where the price is more than PLN 120 (fig. 4).

Isodapane showing the cost of train travel to/from Lublin up to PLN 40 includes the area of the whole Lubuskie Voivodship, the northern part of the Podkarpackie Voivodship and parts of central and eastern Świętokrzyskie and Mazowieckie voivodships. Travellers paying for train services from PLN 40 to PLN 80 were able to travel to/from Lublin, from almost the entire country, with the exception of a relatively narrow strip along the western Polish border. Train tickets priced PLN 80 to

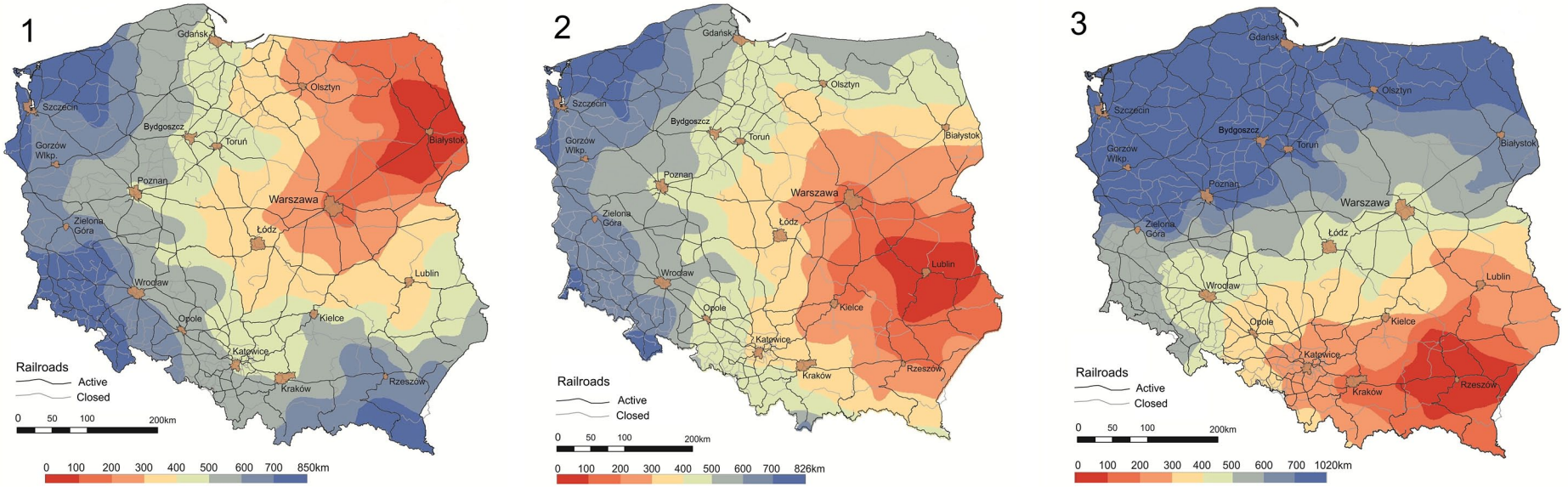

Fig. 3. Equidistance in the railway network of Białystok (left), Lublin (center), Rzeszów (right).

Source: Own calculations based on train timetable

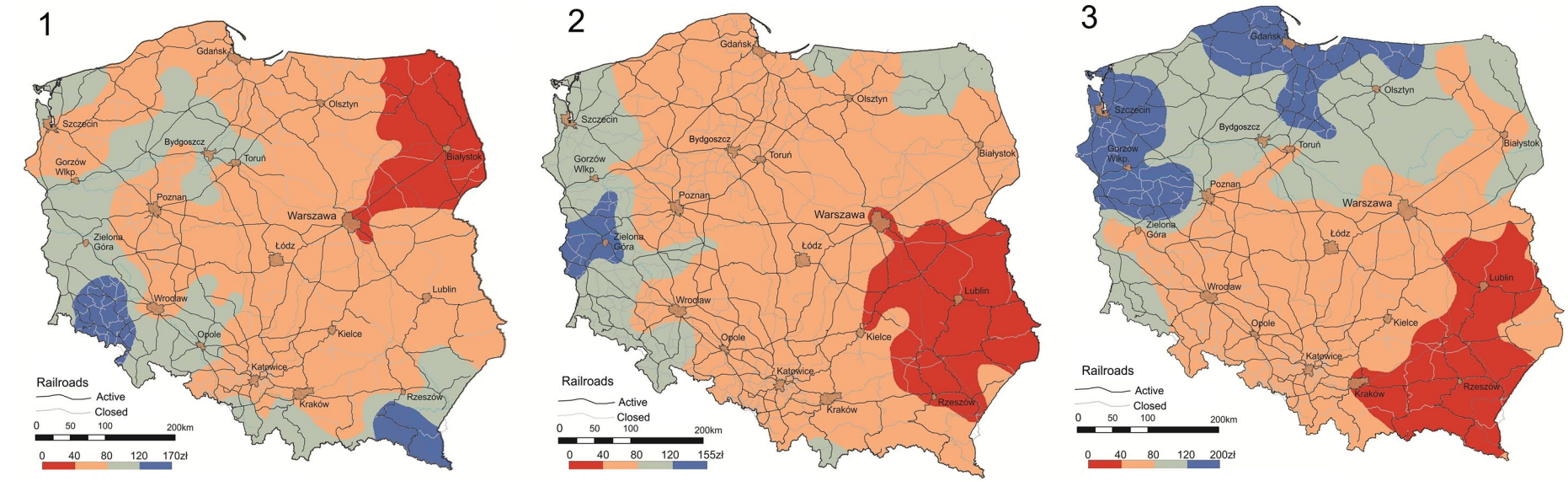

Fig. 4. The cost of train trips to Białystok (left), Lublin (center), Rzeszów (right)

Source: Own calculations based on train timetable

PLN 120 need to be bought to Zakopane, the region of Suwałki and Elbląg, as well as the western part of Poland. The most expensive tickets had to be paid in the area between Zielona Góra and the border with Germany (fig. 4).

Traveling by train with a ticket up to PLN 40 enabled access to Rzeszów from the central part of the Lubelskie Voivodship, the whole Podkarpackie Voivodship and the eastern part of the Małopolskie Voivodship. Paying for a ticket from PLN 40 to PLN 80 enabled access to Rzeszów from southern Poland, with the exception of the western part of Silesia Voivodship. In this range there are also two segments extending the availability of the railway network (i.e., Poznań–Toruń, Warszawa–Suwałki). Isodapane from PLN 80 to PLN 120 from/to Rzeszów shows destinations in the northern part of the country. The most expensive train tickets cost more than PLN 120 and are paid by residents of the northern and the north-western part of Poland and lead to Rzeszów (Goliszek 2015).

3 Comparison of time, distance and cost

The response to the basic research question of this study — i.e., which voivodship center of western Poland has better rail transport accessibility, lies in the analysis of the time required to travel from the voivodship cities to one of the centers of western voivodships. Configuration of the same spatial accessibility results will help answer the question. The time analysis presents the physical distance and the railway network as well as the cost of travel from the voivodship cities to one of the selected cities of Eastern Poland, the sum of all connections to voivodship cities and the average time of travel.

The total time travel of all railway links with the voivodship centers to/from Białystok is 6 823 minutes, giving an average of 401 minutes on a single rail connection. The sum of the physical distances is 6 900 km, giving the average distance of 405 km. The travelling distance from voivodship centers is 8 213 km, the average distance of one connection is 483 km and is about 19% longer than the average physical distance. In contrast, the total cost of travel from the voivodship centers is PLN 1 147, representing an average cost of travel on the level of PLN 67,50.

Travel from voivodship centers to/from Lublin took 6 158 minutes, an average of 362 minutes per connection. The physical distance from the voivodship centers is 6 062 km, giving 356 km for a single connection. The distance of the railway network in total is 7 193 km, with one connection accruing 423 km. The length of the railway network is 18,6% longer in comparison to the straight line on the map. The total cost of travel from voivodship centers to/from Lublin is PLN 1 080, the average partial ticket fare is PLN 63,50.

The sum of the travel times to/from Rzeszów from voivodship centers is 9 004 minutes and this is an average of 529 minutes per connection. The physical distance from the voivodship centers is 6 619 km, which in terms of one connection gives 389 km. The length of the network connections of voivodship centers is 8 273 km, which translates into a 486 km of one train connection. The railway track is up to 25% longer in relation to a straight line. And the sum of the travel cost from voivoiship centers is PLN 1 340, and so the price of a single trip is PLN 78,8.

Summing up travel times by rail in comparison to physical distances, the lowest travel cost was achieved on the route to/from voivodship centers to/from Lublin. Low travel times and distances between voivodship cities and chosen cities of Eastern Poland result from the central location in the voivodship and indicate better options of travel to Lublin, slightly worse to Białystok and much worse to Rzeszów. The situation of Rzeszów results from lack of direct connections to Warszawa, and the need to travel through Kraków and CMK, which extends the travel time, distance and cost of transport (Goliszek 2014b).

4 Statistics on railway transport accessibility

Analysis of the population in isochrone up to 300 minutes of travel time by train to the voivodship centers clearly shows that most people living in the isochrone have best access to Lublin (30,4), next to Białystok (21,2) and then to Rzeszów (17,4). Isochrone of 300 minutes travel time

is presented as the most optimal, and the more people live in this isochrone, the better. In contrast, the area of isochrones of 300 minute travel time is arranged in a similar manner as that of the number of people. For Lublin the figure is (28,7), for Białystok (23,1) and for Rzeszów (14,8). The population distribution is very interesting in the isochrone areas. In the case of Białystok and Lublin there is the peak, at the time of travel to Warszawa. However, the population densities are much higher for Lublin than for Białystok. The number of people commuting to Rzeszów is quite high in the 120 min range and drastically drops on longer distances and the travel time peak to the capital city appears in the range of 180 to 240 min (fig. 5)

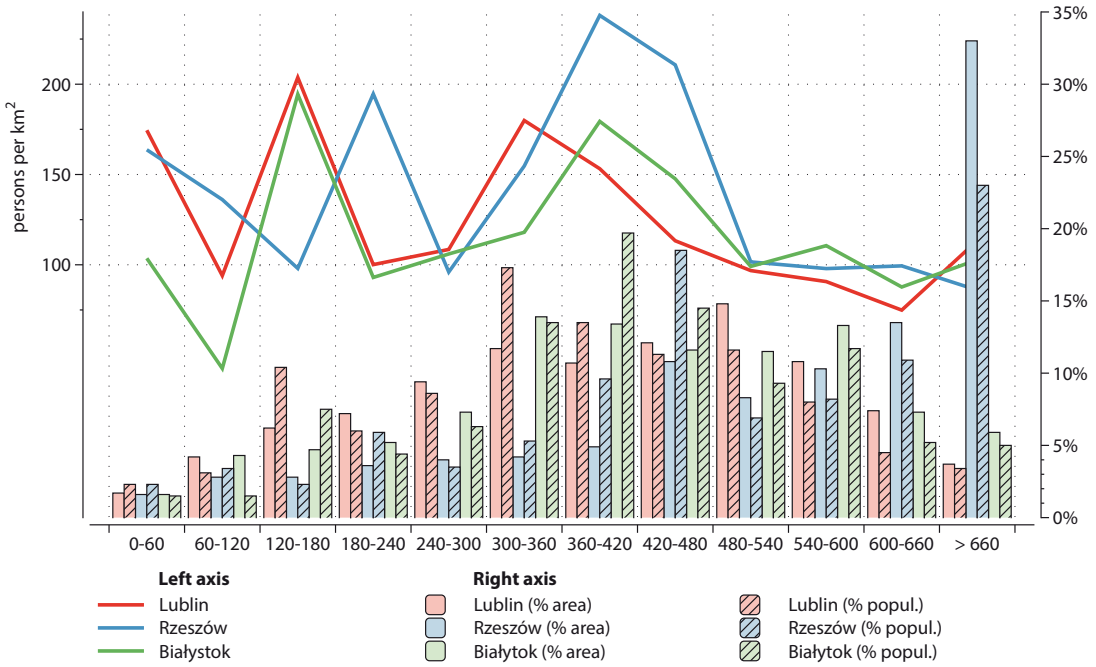

Fig. 5. The relation of population distribution to isochrones

Source: Own calculations based on train timetable

The analysis of the area that is equidistant to 400 km clearly indicates which of the cities are most easily reached by rail from the rest of the country and the number of inhabitants of the area. 53,6% of the population and 46,4% of the country's territory have access to the railway network in Lublin. Rzeszów ranks second in terms of spatial accessibility to the railway network. The area distanced 400 km by train from Rzeszów is inhabited by 42% of the population and covers 32,3% of the area of the whole country. In Białystok the number of people living in equidistance up to 400 km is inhabited by 33,3% of the population, which is less than in Rzeszów. In contrast, the area of a 400 km access from a railway network is bigger than in Rzeszów and covers 37,7% area of the country. Analyzing the population density equidistant to the railway network it is obvious that quite high population density is recorded in connections to Kraków, which is directly related to the high average population density in the Małopolskie Voivodship. Slightly lower population figures on the network were recorded in Lublin and Białystok. However, in combination these two cities almost always give higher figures than Lublin (fig. 6)

Linking travel prices to the size of the area and the number of people who could travel by train to the voivodship centers gives the economic dimension of train transport to the chosen urban centers. The voivodship city which has the cheapest connections and largest isodapane is Lublin. The quota of PLN 0 to PLN 80 to Lublin gives access to 82,3% of the country. On the other hand, the same distance is accessible to 87,8% of the population. In the cost range of up to PLN 80 to/from Białystok 76,8% area of the country is covered and 73,2% of the population of the country can be reached. However, the same cost range gives 71,9% of the population the possibility to travel to/from Rzeszów in 58,2% of the country.

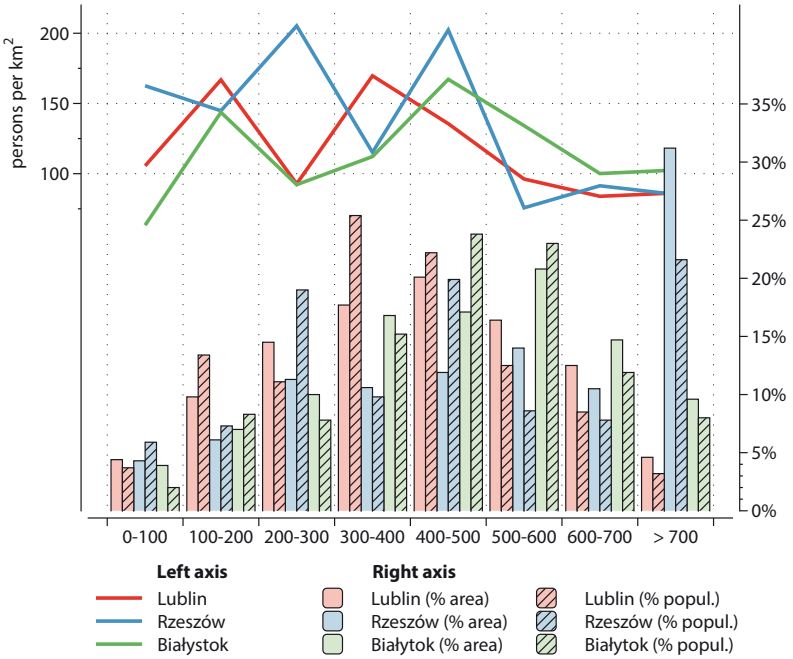

Fig. 6. Comparison of population distribution in area segments of the railway network

Source: Own calculations based on train timetable

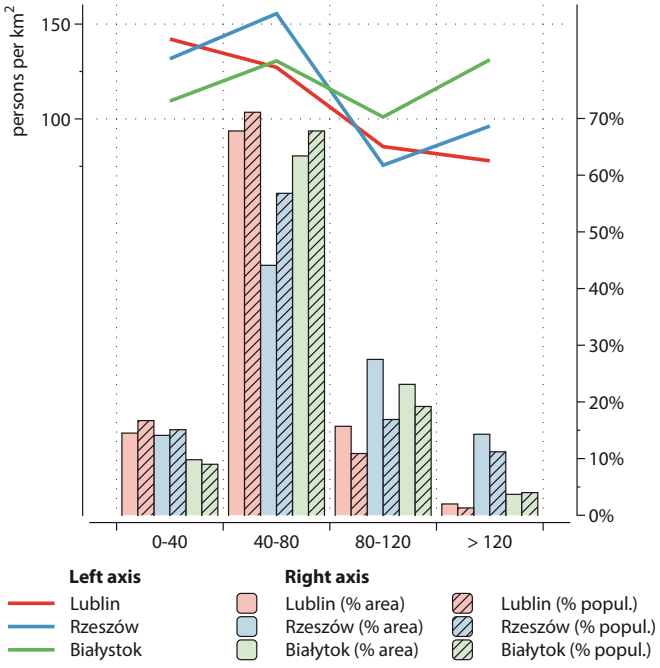

Fig. 7. Percentage of population in different price ranges in railway tickets

Source: Own calculations based on train timetable

The analysis of population density in specific ranges of travel costs in the case of Białystok and Rzeszów reveals an increase and then decrease of density with distance. However, a minimal decline was recorded in each subsequent isopadane in connections to Lublin. At the same time, it should be mentioned that areas located around Lublin feature the highest population density in the costs up to PLN 40 (fig. 7).

Summary (opportunities and threats)

Maps and statistical analysis of the phenomenon of railway network accessibility, helped answer the question of which eastern Poland city has the best accessibility in terms of time, space and cost. These three types of availability are important in making decisions about travel and choice of transport means. Comparing these centers Lublin has the best availability of railway transport in each measurement. Białystok has better spatial and temporal availability compared to Rzeszów. High population density shown by the isochrones around Rzeszów is caused by the densely distributed population in southern Poland (fig. 1).

Comparing railway transport accessibility and planned railway investments, it may be presumed that each analyzed city will definitely benefit from the planned investments (Goliszek 2014a). The area of isochrones in the future should be increased along the planned investments. However, the polarization of residents around the largest city centers in the country means growing importance of lines to Warszawa (for Lublin and Białystok) and Kraków (for Rzeszów). However, if in the future an investment in high-speed rail "Y" is completed, it will definitely favor such cities as Lublin and Białystok (Goliszek 2014b). Reactivation and faster connection to Warszawa would be a good investment in the case of Rzeszów.

The analysis presented in this paper provides a better understanding of the functioning of railway transport in accessing the major urban centers of Eastern Poland. The application purpose of this article is to demonstrate weak and strong aspects of rail networks and connections operating in the era of investments co-financed by the European Union. The methodology used in the analysis can also be applied in other areas in order to facilitate transport policy, in particular to identify areas that need improvement of infrastructure and the railway offer.

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