Bulletin of Geography. Socio-economic Series, No. 53 (2021): 33–42
http://doi.org/10.2478/bog-2021-0021

ISSN 1732–4254 quarterly

BULLETIN OF GEOGRAPHY. SOCIO–ECONOMIC SERIES

journal homepages:
https://content.sciendo.com/view/journals/bog/bog-overview.xml
http://apcz.umk.pl/czasopisma/index.php/BGSS/index

The influence of transport offer on passenger traffic in the railway transport system in a post-socialist country: case study of Poland

Wojciech Jurkowski[1, CDFMR], Mateusz Smolarski[2, MR]

[1]*University of Wrocław*, Department of Spatial Management, Institute of Geography and Regional Development, Wrocław, Poland, e-mail: wojciech.jurkowski@uwr.edu.pl, ORCID: https://orcid.org/0000-0002-8926-3004; [2]*University of Opole,* Department of Geography and Landscape Management, Institute of Socio-Economic Geography and Spatial Management, Ozimska 46a, 45-058 Opole, Poland; e-mail: mateusz.smolarski@uni.opole.pl, ORCID: 0000-0003-0363-5039

How to cite:
Jurkowski, W. Smolarski, M. (2021). The influence of transport offer on passenger traffic in the railway transport system in a post-socialist country: case study of Poland. *Bulletin of Geography. Socio-economic Series*, 53(53): 33-42. DOI: http://doi.org/10.2478/bog-2021-0021

Abstract. The study examines factors influencing the number of rail passengers in Poland. The subjects of observation were 62 cities with poviat rights. The main factors influencing demand are the number of connections and the speed of trains. Therefore, we developed an original indicator – weighted number of connections, which takes into account the number of rail connections and the speed of trains. The article can be divided into two main parts: an assessment of the diversification of transport offer and transport demand in spatial terms, and an evaluation of the relationship between the variables. Poland has a large spatial diversity in terms of public rail transport offer and passenger traffic. There are three levels of city hierarchy according to the passenger number indicator: [1] Warsaw, [2] the largest agglomerations [3] other regional cities. Transport offer was found to have a statistically significant impact on transport demand.

Article details:
Received: 28 December 2020
Revised: 30 June 2021
Accepted: 27 August 2021

Key words:
railway transport,
transit offer,
transport demand,
passenger traffic,
Poland

Contents:

1. Introduction

The viability of each transport system is heavily dependent on transport demand. Therefore, analysing factors that influence the demand in public transport is vital from both a hypothesis-driven research and practical point of view. On the one hand, it clarifies the principles and mechanisms by which the transport system functions, and on the other, it facilitates the formulation of an effective transport policy.

Basically, the factors impacting the number of passengers can be divided into two groups: internal and external (Taylor et al., 2009; Thomson and Brown, 2006). It is important to stress that assigning a variable to the group of external or internal factors is often difficult and ambiguous (Taylor and Fink, 2003). The group of internal factors includes those aspects that depend on the rail operator and the entity that organises transport in the area. Internal variables of this type include, for example, the number of rail connections, ticket prices, safety level, or access to information (Lierop at al., 2018; Taylor and Fink, 2003). External factors include variables independent of the rail operator, such as the employment structure and age structure of the society, land use, population density, and the number of tourists. These factors relate primarily to the relationship between transport infrastructure development and spatial planning (Pan et al., 2017; Połom and Tarkowski, 2018).

These issues are part of the research on travel behaviour, which combines the questions of transport geography and social psychology (Van Acker et al., 2010). The vast majority of analyses focus on countries with a relatively developed public transport system: e.g. the United States (Buehler and Pucher, 2012; Le et al., 2020), China (Cheng et al., 2015) and Western Europe (Ingvardson and Nielsen, 2018). In these countries the role of internal factors (transport offer) is reduced, and external factors become the main determinants (Chakraborty and Mishra, 2013; Jun et al., 2013; Lindsey et al., 2010; Ratner and Goetz, 2013). However, there is still a lack of knowledge about the impact of particular factors on travel behaviour in countries where the public transport system is less developed. An interesting case is the post-socialist countries of Central and Eastern Europe (e.g. Poland), where far-reaching and chaotic changes took place during the economic and political transformation of 1989 and 1990 (Pucher, 1990; Pucher and Buehler, 2005). These changes are particularly conspicuous in the case of the Polish transport system, where there has been a marked decline in the popularity of public transport, especially in rail transport. In Poland, the transport offer is very spatially diversified, and the activities of railway companies are irregular and unstable (Król et al., 2018; 2019). The system of regional and intercity connections can be described as "still developing". As a result, internal factors may still play an important role in shaping the transport demand (Jurkowski and Smolarski, 2018). Previous research at the national level in Poland has usually been more general, and the main focus of interest has been general trends in transport behaviour (Bartosiewicz and Pielesiak, 2019; Marcińczak and Bartosiewicz, 2018). The above-mentioned studies did not analyse the impact of particular factors on passenger traffic, so in this article the authors attempt to complete the research gap in this area.

The aim of this study was to determine the relationship between transport offer and transit ridership in Poland, in both spatial and quantitative terms. The study was carried at national scale for 62 cities with poviat rights. Geographically, their spatial distribution is even; they play the role of main hubs; hence, we concluded that they represent all regions in Poland. It should be pointed out here that analysing a greater number of cities would barely affect the quality of the analysis performed. The time scope of this article was determined as 2019. In the empirical analysis, the authors used data on the daily number of passengers and rail for railway stations in Poland (published by the Office of Rail Transport in 2019) and the number of rail connections and commercial speed, obtained as data from archival timetables (published by PKP PLK in 2019). The high frequency of train departures allows departure times to be adjusted to current needs (commuting to work, school), whereas travel times (which depend on the commercial speed of the train on the route) allow competitiveness with cars to be increased. It is worth noting that only a few studies have taken into account both service frequency and travel time in their analyses (Chakour and Eluru, 2016; Curie and Deblose, 2011; Currie et al., 2011).

2. The railway transport system in Poland

The development of rail transport in Poland is strongly conditioned by historical factors (Lijewski, 1959; Taylor, 2007). First of all, it is worth noting the uneven development of the era of partitions (between Russia, Prussia and Austria) that resulted in infrastructural and economic diversification. In addition, periods can be identified in which the railroad network was expanded particularly intensively (e.g., up to 1914 and in the interwar period). In the years 1918–39 priority was given to consolidating the rail transport system, which varied greatly in density of rail network. The post-WWII period, in turn, was characterised by the reconstruction of railroad routes and the creation of new transport links, including the Skierniewice–Łuków route and the Centralna Magistrala Kolejowa (Lijewski and Koziarski, 1995; Koziarski, 1993).

There were significant changes in the Polish rail transport system after the economic and systemic transformation, which led to significant changes in the functioning of the monopoly operator Polish State Railways (PKP) (with an increasing importance of local-government regional railways). In terms of public transport, the 1989–90 period of transformation influenced, among others: an increase in economic freedom, a decrease in state subsidies and a decrease in supply of public transport (Pucher, 1995). These changes are particularly conspicuous in the case of the Polish transport system, where there was a marked decline in the popularity of public transport, especially in rail transport. This is related to the ineffective deregulation and privatisation of the Polish State Railways enterprise (PKP) (Taylor and Ciechański, 2011). Between 1989 and 2000, the number of journeys made by rail fell from 950 million passengers annually to 360 million. The lowest figures between 1989 and 2018 were recorded in 2005, when only 257 million journeys were made (Król and Taczanowski, 2016).

The functioning of rail transport in Central and Eastern European countries shows specific features in each country. At the beginning of the 1990s there was a decline in the importance of rail transport in Poland (Lijewski and Sujko, 2001; Taylor, 2006), Slovakia (Michniak, 2008) and the Czech Republic (Horňák et al., 2013). In addition, a very strong increase in the number and importance of private cars was observed in the context of transport behaviour of inhabitants of smaller towns and rural areas (Pucher, 1995; Pucher and Buehler, 2005). One of the factors that further influenced the decrease in the number of passengers and the deterioration of the transport offer was the closure of many industrial plants (Horňák et al., 2013). In the Czech Republic and Slovakia, the role of rail transport did not change significantly during the transition period (the process of closing rail routes was more intensive in Slovakia than in the Czech Republic). In Poland, Czech Republic and Slovakia, the phenomenon of liberalisation and regionalisation of the rail transport market has been identified (Górny, 2016; Taczanowski, 2015;). In the case of Slovakia, only one regional route was not operated by the national carrier (ZSSK). In the Czech system, too, some regional routes saw the participation of companies outside the ČD Cargo group.

The impetus for positive changes on the rail transport market in Poland was provided by the opportunity to use Structural Funds for development and modernisation of the transport infrastructure after accession to the European Union in 2004 (Połom et al., 2018). Furthermore, the organisation of regional transport in Poland was transferred to provincial governments, and the liberalisation process itself can be considered an important factor shaping the public transport system after 2000 (Taczanowski, 2015). Some voivodeships organised railroad transport by entrusting transport to voivodeship companies (e.g. Koleje Dolnośląskie, Koleje Małopolskie, Łódzka Kolej Aglomeracyjna). Since 2014 there has been a continuous upward trend in the number of railway passengers in Poland, which is evidence of the slow revival of this mode of transport.

3. Methods

Two indicators were used to illustrate and explore the relationship between transport offer and transport demand: weighted number of connections, and daily passenger volume, respectively. The first indicator – weighted number of connections – is the product of the number of pairs of connections in a given city during the day and the quotient of the speed to the most attractive destination and the maximum speed achieved on Polish rail routes:

$$\textit{The weighted number of connections} = \textit{the number of connections} \times \frac{\textit{speed to the most attractive city}}{\textit{maximum train speed in Poland}}$$

When constructing this indicator, we used information on the number of every connection (both regional and intercity) in a given city and the commercial speed of a train on the most important route. The authors tried examining a higher weighting for Intercity connections, but the results were the same as without the weighting process. For simplicity, the authors used the normal sum of every connection. The main issue to be resolved in this case is the choice of the most important route (the most attractive destination). The average speed on the railway lines departing from a railway hub cannot be taken into account, because the passengers' interest in transits on individual lines is unevenly distributed across particular routes. In order to determine the most important line, it is necessary to theoretically identify the most attractive travel destination for the city under study. In the case of the Polish settlement structure, these are usually centres of higher order in the settlement hierarchy that have the greatest socio-economic potential in the region and are the main centres of work, study and services. For sub-regional centres, these are voivodeship cities, while among voivodeship cities, it is the country's capital, Warsaw. It was difficult to establish a hierarchically higher centre for Warsaw, which has the highest rank in the settlement hierarchy in Poland. For the purposes of this study, it was assumed that the reference point for Warsaw must be the speed of travel to the nearest international centre with a higher rank in the settlement hierarchy, i.e. Berlin. Thus, theoretically, the greatest need for transit occurs on the route from the studied city to the most attractive destination. The value of commercial speed from the examined city to the most attractive destination is presented in a relative form, by dividing the obtained value of commercial speed expressed in km/h by 200 km/h, i.e. the highest speed possible on Polish tracks.

The second used indicator – daily passenger volume (as an element of transport demand) – was the sum of the number of passengers who get on and off during the day at all railway stations located in a given city. It was a modification of the daily station passenger volume indicator, which has been used by, among others, Pan et al. (2017). The point of reference was not individual railway stations, but the entire city. This is an alternative approach that has been used in air transport research (Wang et al., 2011). A transport hub was understood as the city as a whole, without distinguishing separate transportation stops. The data on the number of passengers in the largest railway stations was shown accurate to one passenger. In the case of smaller stations, the values were given in class ranges. Moreover, the data type determined the use of only a point approach in the study (there was no information on flows in a linear approach). It should be stressed that, in Poland, data related to travel demand in public transport, especially in the area of traffic flows or data from measurements of the filling of trains, are a trade secret of railway companies.

4. Results

4.1. The spatial distribution of transit ridership and transport offer in Poland

In the first part of the empirical analysis, an assessment was made of the diversification of transport offer and transport demand in spatial terms. There was a significant variation in the daily number of pairs of connections, from five pairs of trains in Krosno to 518 pairs in Warsaw. Units with a relatively small daily number of connections were undeniably predominant, as evidenced chiefly by the median value of 43 pairs of connections. For the analytical purposes of this study, the number of 14 pairs of connections per day was taken as the reference point as the absolute minimum threshold. Fourteen pairs of connections per day can be assumed as the necessary minimum number allowing for the regular use of a hub by passengers, which means that at least one train departs from the city every hour on average (excluding the time between 11:00 p.m. and 5:00 a.m.) (Jurkowski, 2019). It turns out that this threshold was not been exceeded in as many as ten cities, which should be treated as the main barrier to the development of rail transport in a given city. Such outcomes point to a very poorly developed transport offer (just a few pairs of connections per day). This is especially surprising when we look at the analysed set of cities, because some cities were already voivodeship capitals about 20 years ago (e.g. Ostrołęka, Krosno).

In spatial terms, the division into two groups, the largest agglomerations and all other cities, was most visible. Another, less obvious division into Western Poland and Eastern Poland can be seen (Fig. 1). In many cases, the number of pairs of connections in the largest agglomerations was several dozen times higher than in other cities, while the difference in the city size was not that significant. In addition, we must also distinguish Warsaw, which clearly stood out even from the other largest cities, in many cases surpassing them several times in the number of connections. The units with the lowest number of connections were mainly the towns in the east of Poland (Podkarpackie, Lubelskie and Podlaskie voivodeships) and peripheral areas of the Mazowieckie voivodeship far away from Warsaw.

In general, the conditions for the development of rail transport in these parts of Poland were less favourable: the railway infrastructure was less dense, the technical parameters of the infrastructure were inferior, and the stations were built away from city centres (such as Ostrołęka). In the study, cities located in the eastern part of Poland achieve better results only when they are located on main transport routes, such as Siedlce (the east–west main line).

The impact of historical conditions should be noted, as these areas were situated in the Russian and Austrian Partitions, where the railway network was much less extensive and its development was contingent on military factors. A negative feedback mechanism has emerged. Specifically, historical conditions translated into poor condition of infrastructure, low accessibility to railway and the isolation of railway infrastructure from settlement structure; this resulted in later restrictions on the transport offer on lines in the worst technical condition, which in turn had a negative impact on the number of passengers, who instead chose bus transport (especially more competitive mini-buses).

Large fluctuations were also noted for commercial speeds to a higher-order centre, from 41 km/h on the transit lines from Krosno to Rzeszów to 135 km/h on the lines from Katowice to Warsaw. When it comes to speed, however, the differentiation between regional and long-distance lines should be borne in mind, as results from the adopted methodology. For sub-regional cities, the speed to the regional centre (voivodeship capital city) of passenger trains was taken into account. For regional (voivodeship) cities, the connections with Warsaw were analysed for the fastest trains realised by PKP Intercity (which skip most stations on the route). The scale of the differences is quite unexpected, because it turns out that in Poland, competitive speeds are achieved only by trains on inter-agglomeration routes – mainly for transit lines to Warsaw. Typically, it was only on this type of connections that commercial speeds exceeded 100 km/h. It should be noted that speeds under 60 km/h are not a real alternative to travelling by passenger car on longer routes.

The speed distribution also shows a characteristic spatial structure of Warsaw, as it is better connected with other cities than with its surroundings. Of course, the agglomeration railway is booming and

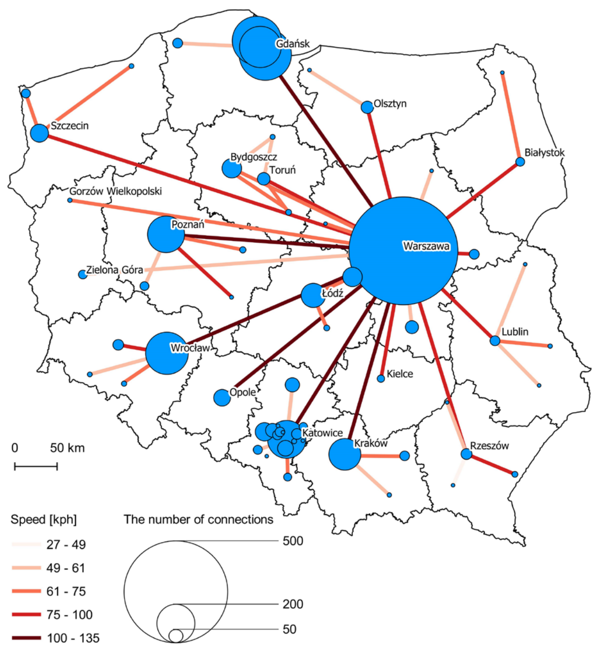

Fig. 1. Transport offer (number of connection pairs) and speed of fastest connection to a hierarchically higher centre
Source: authors' elaboration based on railway operators' data

the suburban zone is very well connected, which is also reflected in the high overall number of train connections (mainly as a result of the high frequency of agglomeration connections); however, important subregional centres such as Płock, Ostrołęka or even Radom do not achieve such favourable results.

The spatial dimension of the relationship between transport offer and transport demand is presented in Figure 2. Transport offer is shown in a synthetic approach as an indicator of the weighted number of connections, and the daily passenger volume is provided for comparison. First of all, it is visible that a high value of the transport offer translates into a large volume of passengers. There is almost no city that achieves high daily passenger volume values with a low transport offer. In general, the diversification of transport demand is even higher than the diversification of the transport offer, and ranges from 60 people in Krosno to 349,910 in Warsaw, with an average of 16,224 passengers. Once again, Warsaw stands out, achieving daily passenger volume values several times higher than those of other agglomerations. On the other hand, voivodeship cities show several dozen times higher values than other cities from a lower territorial level.

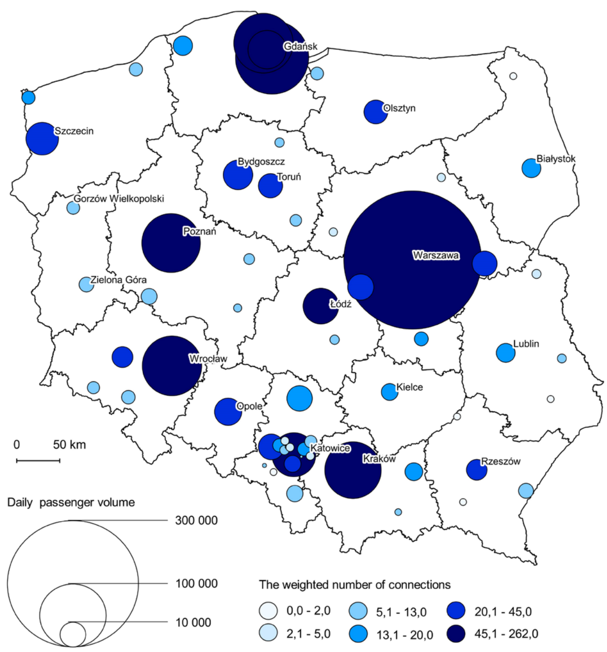

Fig. 2. Transport offer against demand for rail transport based on weighted number of connections and daily passenger volume indicators
Source: authors' elaboration based on railway operators' data

Regional city status does not always translate into a higher number of passengers. For example, the daily passenger volumes for Legnica or Skierniewice are twice as high as for Gorzów Wielkopolski or Kielce (which are voivodeship cities) and are comparable to the figures for Białystok and Olsztyn. The phenomenon of Legnica's high rank in terms of passengers can be explained by its proximity to the regional capital (daily shuttle services), and its very good transport offer, especially in terms of frequency and travel time.

Taking into consideration the number of passengers, three hierarchical levels can be defined: Warsaw (with several times larger figures than other centres); the largest agglomerations in Poland; and other cities. This refers to the Metropolitan European Growth Areas (MEGA) classification in ESPON Project 1.1.1. (2004). In this classification, Warsaw is the only city with category-three status; Wrocław, Poznań, Łódź, Kraków, Szczecin and the polycentric agglomerations of the Tri-City and Silesia are in category four according to MEGA, while the rest of the cities are not classified as Metropolitan European Growth Areas.

4.2. Transport offer impact on passenger volume (regression analysis)

Simple regression analysis was used to show the relationship between transport supply and transport demand. In this part, the authors focused exclusively on identifying the quantitative nature of the relationship between the variables. In this study, daily passenger volume was assumed as the dependent variable (Y) and the weighted number of connections as the independent variable (X). The authors proposed the following research hypothesis (alternative):

H.1 – the variable X has a statistically significant influence on the dependent variable Y.

In this case, the null hypothesis is:

H.0 – the variable X does not have a statistically significant influence on the dependent variable Y.

Regression analysis is based on quantitative variables. It is worth highlighting that there is a statistically significant linear relationship between the weighted number of connections and the daily passenger volume (Pearson's linear correlation coefficient at the level of 0.89). The independent variable, the weighted number of connections has an appropriate variability of 75%, as measured by the coefficient of variation of 75% (the minimum threshold was 10%). An important element of the regression analysis was the identification of outliers, which allowed for a more accurate fit of the model. Outliers were identified on the basis of statistical, graphical and substantive premises. As part of the statistical approach, two measures were used: Cook's distance and the quotient of covariance. Apart from the statistical analysis, outliers were identified on the basis of a graphical approach. The tool used was the scatter plot, where the outlier was the observations that were distant from the created point cloud, with a high absolute value of the residuals. These were usually observations with disproportionately high values of both the X and Y variables. On this basis, we decided to additionally remove 16 observations.

After the final determination of 46 units, the regression curve was estimated (classic least squares method). The resulting equation is Y=413X-974, which means that an increase in the weighted number of connections by one unit causes an increase in daily passenger volume by 413 people (Fig. 3). The value of the coefficient of determination was 0.93. This means that 93% of the variance of the dependent variable (daily passenger volume) was explained by the independent variable (the weighted number of passengers). The analysis of the statistical significance of the determination coefficient and the regression equation coefficients based on the appropriate tests has showed that each of these elements is statistically significant at the level of 0.01 (Table 1).

The tests confirmed that the resulting regression model has a normal distribution of residuals and homoscedasticity. The value of the test statistic for the normality of the distribution of residuals was 2.85 at the significance level of p=0.24 or, in other words, that there are no grounds for rejecting the null hypothesis of the normality of the distribution. To assess the heteroscedasticity of the random component variance, the Breusch–Pagan test was employed, the value of which was 2.51, with a significance level of 0.11. This means that there is no reason to reject the null hypothesis (the random component of the model is homoscedastic).

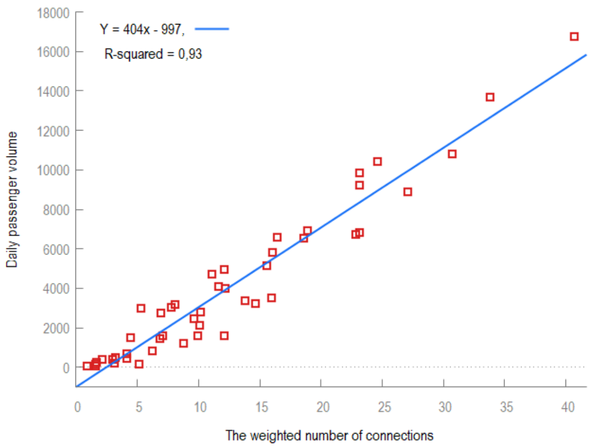

Fig. 3. Dependence between weighted number of connections and daily passenger volume
Source: authors' elaboration

Table 1. Assessment of fit of regression model

	Slope	Absolute term	R^2 coefficient of determination
Value	413	974	0.93
Student's t-test	-3.17	20.59	---
F-Test	---	---	611.82
Statistical significance	1.90×10^{-27}	0.0003	1.90×10^{-27}
Significance level α	0.01	0.01	0.01

Source: authors' elaboration

Finally, on the basis of the analysis performed, we can reject the null hypothesis that the variable X (weighted number of connections) does not have a significant impact on the variable Y (daily passenger volume) and adopt an alternative hypothesis about the significant influence of the variable X on the variable Y.

5. Conclusions

In the above article the authors identified the spatial and economic (quantitative) relations between the sphere of demand (passenger traffic) and the sphere of supply (transport offer). Upon analysis of the research results, the authors formulated several basic conclusions. First of all, Poland is characterised by a large spatial diversity in terms of transport offer and transport demand. Interestingly, in many cases, the spatial distribution of the transport offer and transport demand do not coincide with the demographic potential of individual cities and their position in the administrative hierarchy of Poland. This is especially visible in the case of smaller voivodeship cities, which are characterised by a relatively low number of connections and passenger traffic. The spatial differentiation of the transport offer and transport demand allows us to distinguish three hierarchical levels of cities in the context of passenger traffic: Warsaw; the largest agglomeration areas; and other cities. This division relates to the classification of the Metropolitan European Growth Areas.

The unevenness of the transport offer affects the unevenness of transport demand, as evidenced by a statistically significant relationship between these two variables. Thus, this research has shown that internal factors can significantly shape transport demand. This conclusion extends the current knowledge on the factors influencing transport. Typically, in the literature on the subject, external factors are viewed as more important determinants of passenger volume, which reduces the importance of internal factors (Pan et al., 2017; Walton and Sunseri, 2010; Yim et al., 2005) This study clearly indicates that in a country with a developing rail transport system (under conditions of a large variation in transport offer), internal factors may still be the main determinant of transport demand. This is corroborated by the fact that there are no universal factors influencing transport demand, and local conditions (mainly geographic and historical) should be taken into account. Taking into account the results of this study, the transport policy in Poland (and probably in other post-socialist countries of Central and Eastern Europe) should aim at maintaining high frequency and fast time of travel. A recommendation may be to raise the importance of comprehensive planning and organisation of transport at the local government level (Chaberko and Kretowicz, 2014) or specially established transport unions (Guzik, 2016).

References

Buehler, R. Pucher, J. (2012). Demand for public transport in Germany and the USA: An Analysis of Rider Charactterictis. *TransportReviews*, 32(5): 541-567. DOI: https://doi.org/10.1080/01441647.2012.707695

Chakour, V. Eluru, N. (2016). Examining the influence of stop level infrastructure and built environment on bus ridership in Montreal. *Journal of Transport Geography*, 51: 205-217. DOI: https://doi.org/10.1016/j.jtrangeo.2016.01.007

Chaberko, T. Kretowicz, P. (2014). Localpublic transport planning in Poland – geographical input. *Bulletin of Geography. Socio–economics Series*, 23: 7-24. DOI: http://dx.doi.org/10.2478/bog-2014-0001

Chakraborty, A. Mishra, S. (2013). Land use and transit ridership connections: Implications for state-level planning agencies. *Land Use Policy*, 30(1): 458-469. DOI: https://doi.org/10.1016/j.landusepol.2012.04.017

Cheng, Y. Loo, B.P.Y. Vickermann, R. (2015). High – speed rail networks, economic intergration and regional specialisation in China and Europe. *Travel Behaviour and Society*, 2: 1-14. DOI: https://doi.org/10.1016/j.tbs.2014.07.002

Currie, G. Ahern, A. Delbosc, A. (2011). Exploring the drivers of light rail ridership: An empirical route level analysis of selected Australian, North American and European systems. *Transportation*, 38(3): 545-560. DOI: 10.1007/s11116-010-9314-9

Currie, G. Delbosc, A. (2011). Understanding bus rapid transit route ridership drivers: An empirical study of Australian BRT systems. *Transport Policy*, 18(5): 755-764. DOI: https://doi.org/10.1016/j.tranpol.2011.03.003

Duhr, S. (2005). Potentials for polycentric development in Europe: The ESPON 1.1.1 project report. *Planning Practice & Research*. 20: 235-239. 10.1080/02697450500414728.

Górny, J. (2016). Voivodship self-government as the organizer of regional passenger rail transport (in Polish). P*race Komisji Geografii Komunikacji PTG*, 19 (4): 72-81.

Guzik, R. (2016). Public transport and accessibility in rural areas of Switzerland (in Polish). *Prace Komisji Geografii Komunikacji PTG*, 19(4): 49-61.

Horňák, M. Pšenka, T. Križan, F. (2013). The competitiveness of the long-distance public transportation system in Slovakia. *Moravian Geographical Reports*, 21(4): 64-75.

Ingvardson, J.B. Nielsen, O.A. (2018). How urban density, network topology and socio-economy influence public transport ridership: Empirical evidence from 48 European metropolitan areas. *Journal of Transport Geography*, 72: 50-63.

Jun, M.J. Kim, J.I. Kwon, J.H. Jeong, J.E. (2013). The effects of high-density suburban development on commuter mode choices in Seoul, Korea. *Cities*, 31: 230-238.

Jurkowski, W. Smolarski, M. (2018).The impact of transport supply on passenger volume characterising regional rail transport in Lower Silesia. *Europa XXI*, 34: 79-93. DOI: http://doi.org/10.7163/Eu21.2018.34.5

Jurkowski, W. (2019). Integration of residential development with railway infrastructure in suburban areas of Kraków, Łódź, Poznań and Wrocław (in Polish). Rozprawy Naukowe Instytutu Geografii I Rozwoju Regionalnego Uniwersytetu Wrocławskiego, Wrocław.

Kepaptsoglou, K. Stathopoulos, A. Karlaftis, M. G. (2017). Ridership estimation of a new LRT system: Direct demand model approach. *Journal of Transport Geography*, 58: 146-156. DOI: https://doi.org/10.1016/j.jtrangeo.2016.12.004

Koziarski, S. (1993). Sieć kolejowa Polski w latach 1842-1918. Państwowy Instytut Naukowy. Opole.

Król, M. Taczanowski, J. (2016). So close, so different – regional rail transport in Poland, the Czech Republic and Slovakia. *Yearbook of Antitrust and Regulatory Studies*, 9(14): 159-180.

Król, M. Taczanowski, J. Kołoś, A. (2018). The rise and fall of Interregio. Extensive open-access passenger rail competition in Poland. *Research in Transportation Economics*, 72, 37-48.

Król, M. Taczanowski, J. Jarecki, S. Kołoś, A. (2019). Publicly-owned operators can also challenge incumbents. New cases of open-access passenger rail competition in Poland. *Journal of Rail Transport Planning & Management*, 12: 100150.

Le, H.T.K. Carrel, A.L. Li, M. (2020). How much dissatisfaction is too much for transit? Linking transit user satisafaction and loyalty using panel data. *Travel Behaviour and Society*, 20: 144-154. DOI: https://doi.org/10.1016/j.tbs.2020.03.007

Lierop, V.D. Badami, M. El-Geneidy, A.M. (2018). What influences satisfaction and loyalty in public transport? A review of the literature. *Transport Review*, 38(1): 52-72. DOI: https://doi.org/10.1080/01441647.2017.1298683

Lijewski, T. (1959). Rozwój sieci kolejowej Polski. Dokumentacja Geograficzna, z. 5, PAN, Warszawa.

Lijewski, T. Koziarski, S. (1995). Rozwój sieci kolejowej w Polsce, KOW, Warszawa.

Lijewski, T. Sujko, E.S. (2001). Spatial regression of the railroad network in Poland (in Polish). *Prace Komisji Geografii Komunikacji PTG*, 7: 133-148.

Lindsey, M. Schofer, J.L. Durango-Cohen, P. Gray, K. A. (2010). Relationship between proximity to transit and ridership for journey-to-work trips in Chicago. *Transportation Research Part A: Policy and Practice*, 44(9): 697-709. DOI: https://doi.org/10.1016/j.tra.2010.07.003

Michniak, D. (2018). Changes, problems and challenges of passenger railway transport in Slovakia. *Geografický časopis*, 70(3): 217-230.

Pan, H. Shen, Q. Shi, C. (2017). What determines rail transit passenger volume? Implications for transit oriented development planning. *Transportation Research Part D: Transport and Environment*, 57: 52-63. DOI: https://doi.org/10.1016/j.trd.2017.09.016

Połom, M. Tarkowski, M. (2018). The role of the Pomeranian Metropolitan Railway in the shaping of the spatial and functional structure of Gdansk (in Polish). *Studia Miejskie*, 30: 39-55.

Połom, M. Tarkowski, M. Puzdrakiewicz, K. (2018). Urban transformation in the context of rail transport development: the case of a newly built railway line in Gdańsk (Poland). *Journal of Advanced Transportation*, 2018. DOI: https://doi.org/10.1155/2018/1218041

Pucher, J. (1990). Capitalism, socialism and urban transportation. *Journal of the American Planning Association*, 56: 278-297. DOI: https://doi.org/10.1080/01944369008975773

Pucher, J. (1995). The road to ruin?: Impacts of economic shock therapy on urban transport in Poland. *Transport Policy*, 2(1): 5-13. DOI: https://doi.org/10.1016/0967-070X(95)93241-P

Pucher, J. Buehler, R. (2005). Transport policies in central and Eastern Europe. Rutgers University, New Brunshwick NJ.

Ratner, K.A. Goetz, A.R. (2013). The reshaping of land use and urban form in Denver through transit-oriented development. *Cities*, 30: 31-46. DOI: https://doi.org/10.1016/j.cities.2012.08.007

Taczanowski, J. (2015). The effects of liberalisation of the passenger railway market on the situation of regional rail connections in Poland, Czech Republic, Slovakia and Austria. *Review of Economic Perspectives*, 15(3): 249-268.

Taylor, B.D. Fink, C.Y. (2003). The factors influencing transit ridership: A review and analysis of the ridership literature. University of California, Berkeley.

Taylor, B.D. Miller, D. Iseki, H. Fink, C. (2009). Nature and/or nurture? Analyzing the determinants of transit ridership across US urbanized areas. *Transportation Research Part A: Policy and Practice*, 431: 60-77. DOI: https://doi.org/10.1016/j.tra.2008.06.007

Taylor, Z. (2006). Railway closures to passenger traffic in Poland and their social consequences. *Journal of Transport Geography*, 14(2): 135-151. DOI: https://doi.org/10.1016/j.jtrangeo.2005.05.003

Taylor, Z. (2007). Rozwój i regres sieci kolejowej w Polsce. Monografie IGiPZ, Warszawa.

Taylor, Z. Ciechański, A. (2011). Recent organizational and ownership transformations of railroad transport enterprises in Poland - part II (in Polish). *Przegląd Geograficzny*, 83(2): 205-231.

Thomson, G.L. Brown, J.R. (2006). Explaining variation in transit ridership in U.S. metropolitan areas between 1990 and 2000. *Transportation Research Record*, 1: 172-181.

Van Acker, V. Van Vee, B. Witlox, F. (2010). When transport geography meets social psychology: toward a conceptual model of travel behaviour. *Transport Reviews*, 30(2): 219-240. DOI: https://doi.org/10.1080/01441640902943453

Walton, D. Sunseri, S. (2010). Factors influencing the decision to drive or walk short distances to public transport facilities. *International Journal of Sustainable Transportation*, 4(4): 212–226. DOI: https://doi.org/10.1080/15568310902927040

Wang, J. Mo, H. Wang, F. Jin, F. (2011). Exploring the network structure and nodal centrality of China's air transport network: A complex network approach. *Journal of Transport Geography*, 19(4): 712-721. DOI: https://doi.org/10.1016/j.jtrangeo.2010.08.012

Yim, K.K.W. Wong, S.C. Chen, A. Wong, C.L. Lam, W.H.K. (2005). A reliability-based land use and transportation optimization model. *Transportation Research Part C: Emerging Technologies*, 19(2): 351–362. DOI: https://doi.org/10.1016/j.trc.2010.05.019