Lecture Notes in Networks and Systems 117

Igor Kabashkin
Irina Yatskiv
Olegas Prentkovskis *Editors*

Reliability and Statistics in Transportation and Communication

Selected Papers from the 19th International Conference on Reliability and Statistics in Transportation and Communication, RelStat'19, 16–19 October 2019, Riga, Latvia

Springer

Igor Kabashkin · Irina Yatskiv ·
Olegas Prentkovskis
Editors

Reliability and Statistics in Transportation and Communication

Selected Papers from the 19th International Conference on Reliability and Statistics in Transportation and Communication, RelStat'19, 16–19 October 2019, Riga, Latvia

Springer

Editors
Igor Kabashkin
Telematics and Logistics
Transport and Telecommunication Institute
Riga, Latvia

Irina Yatskiv
Transport and Telecommunication Institute
Riga, Latvia

Olegas Prentkovskis
Vilnius Gediminas Technical University
Vilnius, Lithuania

ISSN 2367-3370 ISSN 2367-3389 (electronic)
Lecture Notes in Networks and Systems
ISBN 978-3-030-44609-3 ISBN 978-3-030-44610-9 (eBook)
https://doi.org/10.1007/978-3-030-44610-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Smart Solutions for Supply Chain Management

Logistics Service Quality of Dry Ports Within Land-Based Transport Corridors: A Case Study "Khorgos Gateways" 213
Aisulu Moldabekova, Anatoli Beifert, and Orazaly Sabden

The Impact of Proper Order Scheduling on Robotic Transportation System Efficiency 223
Alicja Dąbrowska, Robert Giel, and Marcin Plewa

Analysis of the Influence of Socio-Economic Factors on the Volume of Railway Passenger Transport in Łódź Region 233
Wojciech Kamiński and Aleksander Sładkowski

Complex Digital Model of Transport Logistic System Transformation . . . 244
Alexey Nekrasov and Anna Sinitsyna

Forming the Complex Model to Rate Transportation Indicators in Supply Chains 252
Valery Lukinskiy, Vladislav Lukinskiy, Elena Koroleva, and Darya Bazhina

The Application of Blockchain Technologies for Rail Transit Customs Procedures 260
Ainis Sturmanis, Justina Hudenko, and Maris Juruss

Risk Management in Sea Ports – Insights and Trends 268
Darius Bazaras and Ramūnas Palšaitis

Smart City

Estimating the Sustainability Impacts of an Urban Consolidation Center in a Medium-Sized City 277
Eftihia Nathanail, Thomas Terzakis, and Dimitris Zerzis

Shared-Use of Autonomous Transportation Solutions: How Ready Are We for Them? 287
Eftihia Nathanail, Giannis Adamos, Georgia Aggida, Vaia Drakouli, and Eleni Papapolykarpou

Improving the Branded Service of Vehicles with Intelligent Driver Assistance Systems 297
Irina Makarova, Ksenia Shubenkova, Eduard Tsybunov, Ilsur Giniyatullin, and Gleb Parsin

The Influence of Countdown Timers on Safety and Driver Reaction Time at Intersections with Traffic Lights 306
Monika Wengel and Natalia Okos

Analysis of the Influence of Socio-Economic Factors on the Volume of Railway Passenger Transport in Łódź Region

Wojciech Kamiński(✉) and Aleksander Sładkowski

Faculty of Transport, Department of Logistics and Transport Technologies, Silesian University of Technology, Krasińskiego 8, 40-019 Katowice, Poland
Wojciech.Kaminski@polsl.pl

Abstract. This article presents the determination of the weights of socio-economic factors affecting the volume of passenger transport on individual railway lines located in the Łódź region. Passenger transport on these lines is operated by the carrier Łódź Agglomeration Railway. The transport data containing the number of transported passengers and the transport work done in 2017 were used for the analysis. A partial correlation coefficient was used to obtain values of weights of the analyzed factors. During the calculation of correlation coefficients, transport gauges were used as explanatory variables (dependent variables). The socio-economic factors influencing the volume of rail passenger transport on individual lines were taken into account. To calculate the partial correlation coefficient, a correlation matrix, containing interrelations between all analyzed variables, was used. During calculating the weights of particular factors affecting the volume of rail passenger transport on individual lines located in the Łódź region for each socio-economic factor, the absolute value of partial correlation coefficients was summed for the number of trains and the number of transported passengers. Then the summed value was divided by the number of analyzed gauges describing the volume of transport. It allowed to determine the weights of individual factors affecting the volume of passenger transport on railway lines in the Łódź region. The obtained weights can be used in the future during the multi-criteria analysis of railway lines in the Łódź region. These weights allow to avoid the subjective assessments of experts, that have been often used in previous analyzes.

Keywords: Railway transport · Passenger transport · Correlation coefficient

1 Introduction

The Łódź Voivodeship is a medium-sized voivodeship located in the central part of Poland. It has an area of 18.22 thousand km^2 and the population of 2.49 million people. The length of railway lines in the Łódź Voivodeship is 1,080 km, which translates into a line density of 5.9 km/100 km^2. Transport availability of municipalities located in this voivodeship is diverse Apart from Łódź, the largest communication accessibility are in the municipalities: Łask, Pabianice, Zgierz, Poddębice, Stryków and Ozorków [1]. Regional passenger rail transport in the Łódź region is carried out by two

I. Kabashkin et al. (Eds.): RelStat 2019, LNNS 117, pp. 233–243, 2020.
https://doi.org/10.1007/978-3-030-44610-9_23

companies: Regional Transportation (Polregio brand) and Łódź Agglomeration Railway. In comparison with other regions of Poland, there are only a few railway lines closed in the passenger traffic in the Łódź Voivodship, they are: line from Piotrków Trybunalski to Rogowiec and line from Opoczno to Skarżysko Kamienna (Świętokrzyskie Voivodenship). The voivodship is crossed by the railway line connecting Chorzów Batory with Tczew (the so-called Carbon Road). On this line, only freight traffic and passenger long-distance traffic (mainly night trains) are operated. The line branching from the Chorzew Siemkowice and running to the Wyczerpy station (Silesian Voivodship) is also currently inactive in regional passenger traffic, and on this line passenger traffic was suspended on 9 December 2012 [17]. Before starting the modernization of the line, many analyzes should be carried out regarding profitability and scope of modernization. The appropriate variant should be chosen and technical parameters which are needed on analyzed railway line. In case of using an existing line, it is important to adjust it to current needs and maintain the technical condition, which has an impact on safety [2]. Therefore, studies should be carried out to determine the transport needs. An analysis of the correlation of transport volumes with the location of lines was carried out. During this analysis using graphs the stations were treated like nodes, and railway lines like the edges [3]. Analyzes are also performed to determine the capacity of the existing infrastructure. Factors related to the spatial structure of the region on which the analyzed line is located affect the volume of transport, and these in turn depend on technical limitations, such as maximum throughput of line [4]. If the results of the analyzes predict the exceeding of the current maximum capacity, in the case of single-track lines, calculations related to the profitability of the construction of the second track are made [5]. If it is using most of the transport capacity of existing railway lines, the impact of possible temporary closing of the line from use (for the modernization time), to transport streams is also studied [6]. During such analyzes, many socio-economic factors should be taken into account, which have an impact on the volume of both passenger and freight rail transport. Many various factors are taken into account in the analyzes performed so far, however, their weights are determined by decision making centers [7], or on the basis of expert assessments. Instead of using data from statistical offices, socio-economic factors in some analyzes are obtained during conducting surveys among passengers [8]. Such action carries the risk of disrupting the results. Except the impact of socio-economic factors on rail transport, there is also a reverse relationship. The influence of the arrangement of lines and volumes of transport on them on the economies of regions was also examined [9]. In this article the weights of individual socio-economic factors will be determined with the use of correlation coefficients. Taking into account the impact of individual factors on the volume of passenger transport will enable attribution to these factors the weights. The weights determined in this way using of previously calculated correlation coefficients will be able to be used in the future during conducting analyzes preceding the modernization of the line in the Łódź Voivodship. Calculations using correlation coefficients have already been carried out for individual voivodships in Poland, however, other socio-economic factors have been taken into account and other measures defining the volume of passenger transport have been used [16]. The data used in that analysis relate to entire regions, not to individual railway lines, and they do not take into account the local specificity of the Łódź region.

2 Scope of Analysis

The analysis was conducted for 4 railway lines operated by the Łódź Agglomeration Railway carrier, these are the following lines: Łódź Kaliska - Sieradz, Łódź Kaliska - Kutno, Łódź Kaliska - Łowicz Główny and Łódź Widzew - Skierniewice. Due to the fact that on these lines, the company Łódź Agglomeration Railway performs almost the whole volume of transport in regional traffic, the influence of running trains of other carriers were omitted. In Poland, the competition of rail passenger carriers occurs sporadically. It is different in Italy, where the carriers Nuovo Trasporto Viaggiatori and Trenitalia compete in the high-speed trains segment. This competition is focused on the price of the journey, the capacity of the used rolling stock and the frequency of running trains [10].

2.1 Łódź Agglomeration Railway

The first concepts of creation the agglomeration rail system in the Łódź region appeared in 2007–2008. At that time, preliminary analyzes related to the construction of the new railway system were made [11]. Under the Marshal's Office's agreement with the mayors of 12 towns located in the area of Łódź, in 2010 a decision to establish the Łódź Agglomeration Railway was made. The first construction works were commenced at the turn of 2012 and 2013. The company started operating in 2014. The connection between Łódź and Sieradz was launched on 15 June 2014, on 1 September of the same year ŁAR reached Zgierz, and on 14 December they reached Koluszki [12]. The trains to Kutno was launched on 14 June 2015, and to Skierniewice on 4 January 2016. From 8 December 2018, the trains of the Łódź Agglomeration Railway run between Skierniewice and Łowicz, and from 11 March 2019, between Łódź and Tomaszów Mazowiecki and Radomsko. Since the start of operations, this company has recorded an increase in operation work done and the number of transported passengers. The Łódź Agglomeration Railway carries out transport in the Łódź agglomeration, however, it mainly satisfies transport needs of neighboring cities. In connection with the course of railway lines mainly on the outskirts of Łódź, outside the area with the largest population, railway transport does not have a significant role in satisfying transport needs in this city [13]. In the case of suitable location of lines, railway transport has an important role in improving the quality of transport services. One of the cities where the railway lines influenced the increase in the population in areas neighboring with the railway station is Naples [14]. In addition to transports in the Łódź region, company Łódź Agglomeration Railway launches commercial trains from Łódź to Eastern Warsaw at weekends from on 13 March 2016. The map of the analyzed lines on which regional passenger traffic is operated by Łódź Agglomeration Railway is shown in Fig. 1. The green color indicates the line to Sieradz, the yellow line to Kutno, while the blue color shows the line to Łowicz and the red line to Skierniewice.

2.2 Data Used to Carry Out the Analysis

The transport data containing the number of transported passengers and the transport work done in 2017 were used for the analysis. The source of data for these gauges describing the volume of rail passenger transport is the annual report of the Łódź Agglomeration Railway carrier. During the calculation of correlation coefficients, these gauges were used as explanatory variables (dependent variables). Gauges describing the size of rail passenger transport on particular lines analyzed in the Lodz region is shown in Table 1. In addition, the length of the analyzed sections is shown there. In order to make it possible to compare railway lines of different lengths during the calculations of the operational work done its value was divided to the length of the line. In this way, instead of the value of the operation work done, the number of trains launched on an analyzed line during the year was received.

Table 1. Gauges describing the volume of rail passenger transport in individual lines.

Section	Operation work done [train, km]	Number of passengers [people]	Length of the line [km]
Łódź Kaliska – Sieradz	631,534.47	988,643	59
Łódź Kaliska – Łowicz Główny	565,539.37	813,449	61
Łódź Kaliska – Kutno	480,307.13	591,702	68
Łódź Widzew – Skierniewice	351,363.36	511,675	60

The volume of passenger transport on an individual railway line depends on the spatial structure of the area through which the railway line runs. The socio-economic factors influencing the volume of rail passenger transport on individual lines were taken into account, such as: the number of people in communes through which the analyzed railway line runs, the number of registered passenger vehicles per 1000 inhabitants in powiats on the route of a analyzed railway line, number of registered business entities in communes by the railway line, the value of fixed assets in business entities located in powiats near the railway line (this value reflects the size of business entities), the availability of inhabitants to the railway line, the number of people commuter for work and the number of accommodation facilities located in the communes by the railway line. The source of some data, such as: population, number of registered passenger vehicles, number of business entities and their value of fixed assets, number of accommodation facilities (included hotels, motels and guesthouses) are reports published by the Central Statistical Office. In order to be able to compare railway lines of different lengths, the themselves values are not given, but their ratio to the length of the lines. These data are presented in Table 2. The other values were calculated using the data from reports published by the Central Statistical Office.

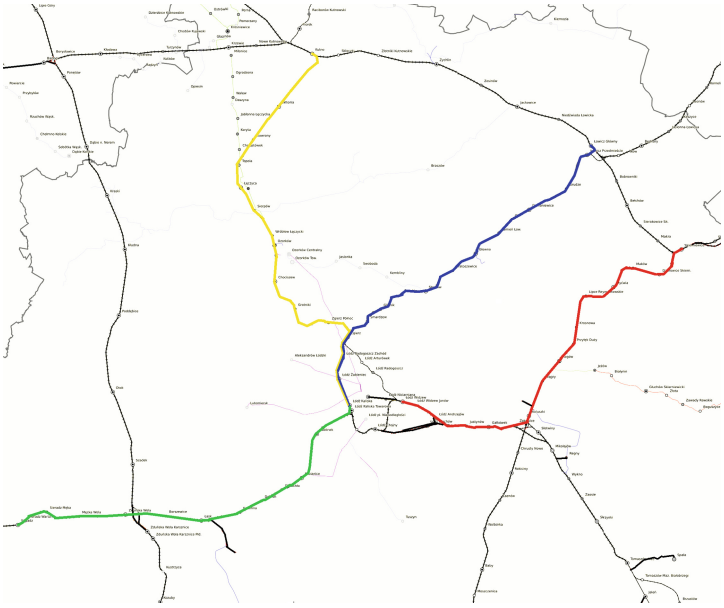

Fig. 1. Analyzed railway lines [17].

Table 2. Factors affecting the volume of transport on individual lines.

Section	Population/line length [people/km]	Number of vehicles/1000 people	Number of business ent./line length [entities/km]	Value of fixed assets/line length [millions PLN/km]	Number of accommod. facilities/line length [facilities/km]
Łódź Kaliska - Sieradz	15,367.25	728.76	1,957.00	831.76	1.68
Łódź Kaliska - Łowicz Główny	13,545.16	698.19	1,745.00	788.71	1.51
Łódź Kaliska - Kutno	12,825.16	718.48	1,622.16	774.83	1.46
Łódź Widzew - Skierniewice	13,381.37	703.17	1,732.48	745.00	1.23

3 Calculation of Factors Affecting the Volume of Transport

The possibility of using a railway line in passenger transport also depends on some socio-economic factors that cannot be directly read from reports of the Central Statistical Office. These factors are: the availability of inhabitants to the railway line and the number of commuters to work.

3.1 Availability to the Railway Line

Availability to the railway line for individual inhabitants, this is the value associated with the location of stations on the population centers. The availability parameter for an individual station is affected by the distance of the station from the city center, the condition of the network of roads leading to it, and the size of the population in which the station is located. The parameter related to the location of the station takes the value 1 if the station is located directly in the city center, while the value 0, when it takes 10 min or more to reach it by car from the city center. In other indirect cases, a proportional value is assumed, related to the time needed to reach the train station. Then, the size of the population in which the analyzed station is located is taken into account (the size of population in 2017 was used during analysis). The availability of an individual station is the product of its location and the size of the city (or village) where it is located. This calculation is represented by formula (1).

$$D_S = L_S \cdot W_M, \tag{1}$$

where D_S – availability of the stop/station; L_S – location of the stop (it takes a value from 0 to 1); W_M – the size of the city/village in which the stop is located.

In order to determine the availability to the whole railway line, the availability of all stops located on it is summed up. Next, the quotient of this sum and the length of the analyzed railway line is calculated. On this basis, the availability of the all railway line is determined, which is shown in the formula (2).

$$D_L = \frac{\sum D_S}{L_L}, \tag{2}$$

where D_L – availability to the railway line; D_S – availability of individual stations/stops; L_L – length of the analyzed railway line.

The calculated availability to the all analyzed lines is shown in Table 3.

Table 3. The ratio of the number of commuters to work and the length of the line.

Section	Availability of inhabitants to the railway line [people/km]	Number of commuters to work/line length [people/km]
Łódź Kaliska – Sieradz	10,622.35	153.85
Łódź Kaliska – Łowicz Główny	10,385.49	179.57
Łódź Kaliska – Kutno	11,181.26	152.25
Łódź Widzew – Skierniewice	8,985.12	105.55

3.2 The Number of Commuters to Work

To determine the number of only people who truly can use railway transport during travel from their place of residence to work, calculations were made. Only people living in the area through which the analyzed railway line runs, and at the same time commutes to work to the commune located on this line are taken into account. The data from the Central Statistical Office, coming from the detailed National Census of 2011 carried out every 10 years, were used for the calculations. After sum up the number of commuters to work, this value was divided by the length of individual railway lines, as shown in Table 3.

4 Correlation

During characterizing the correlation of two variables, its strength and direction should be given [15]. In the case of the analysis of the impact of socio-economic factors on the volume of passenger transport of individual railway lines more important than the direction is strength or the level of significance of correlation.

4.1 Partial Correlation Coefficient

The partial correlation between two variables is the relationship between these variables, excluding the influence of other variables on the analyzed variables. For calculation the partial correlation coefficient, a correlation matrix is used. This matrix contains the relationships between all analyzed variables. The individual element of the correlation matrix is the value of the Pearson correlation coefficient for the variables i and j. The partial correlation coefficient is calculated using the formula (3).

$$r_{ij.1..(i-1)(i+1)..(j-1)(j+1)..k} = -\frac{C_{ij}}{\sqrt{C_{ii} \cdot C_{jj}}}, \tag{3}$$

where C_{ij}, C_{ii}, C_{jj} – algebraic complements of the elements r_{ij}, r_{ii}, r_{jj} of matrix.

5 Analysis the Influence of Socio-Economic Factors on Transport

Calculations of the weights of each factor affecting the volume of rail passenger transport on individual railway lines located in the Łódź region were made using a partial correlation coefficient. To calculate this coefficient, a correlation matrix, containing interrelations between all analyzed variables, was used. Due to the size of this matrix (9 columns and 9 rows) to calculate the algebraic complement of individual matrix elements and determinants obtained from the correlation matrix by plotting the i-th row and the j-th column as shown in formula (3), the engineering calculation software Mathcad was used. The calculated values of partial correlation coefficients for socio-economic factors affecting the volume of transport on individual railway lines in

Łódź Voivodeship are presented in Table 4. The calculated partial correlation coefficients, after eliminating the influence of other factors on the analyzed one, allows to determine how much influence it has on the size of gauges such as the number of trains or the number of transported passengers. The number of inhabitants in area located near to the railway line has a greater impact on the number of transported passengers than on the number of trains. Another factor that has a major impact on the volume of rail passenger transport is the number of business entities located along the railway line, while the size of these entities (expressed by the value of fixed assets in entities) has a small impact on rail passenger transport. The availability of residents to the railway line and the number of people commuting to work are also very important factors affecting the volume of transport. In turn, the number of accommodation facilities located near the railway line has a very insignificant impact on the volume of transport. This is related to the fact that the analyzed area in the Łódź region has little tourist potential and is not a popular place for tourist trips.

Table 4. Calculated values of partial correlation coefficients.

Factor	Operation work done [train · km]	Number of passengers [people]
Population/line length [people/km]	0.36	0.80
Number of vehicles/1000 people	0.59	0.77
Number of business entities/line length [entities/km]	0.37	0.89
Value of fixed assets/line length [millions PLN/km]	−0.04	−0.19
Availability of inhabitants to the railway line [people/km]	0.56	0.91
Number of commuters to work/line length [people/km]	0.80	0.73
Number of accommod. facilities/line length [facilities/km]	0.01	0.13

6 Calculation of Weights of Individual Factors

During calculating the weights of particular factors affecting the volume of rail passenger transport on individual lines located in the Łódź region for each socio-economic factor, the absolute value of partial correlation coefficients was summed for the number of trains and the number of transported passengers. The use of the absolute value is related to the fact that to determine the weights of various factors is not important direction of their impact, but only the strength. Then the summed value was divided by two, which is related to the number of analyzed gauges describing the volume of transport. This operation is presented by formula (4).

$$I_F = \frac{\sum_{i=1}^{2} |C_{Ci}|}{2}, \tag{4}$$

where I_F – the impact of an individual factor on the volume of rail transport; C_{Ci} – calculated correlation coefficients between factors and gauges.

Using the formula (4) were obtained values for socio-economic factors corresponding their average impact on both gauges describing to the volume of transport. By dividing the received values I_F for each socio-economic factor by their sum, it is possible to determine the weights of individual factors affecting the volume of passenger transport on railway lines in the Łódź region. This operation is presented by formula (5).

$$W_F = \frac{I_F}{\sum_{i=1}^{7} I_{Fi}}, \tag{5}$$

where W_F – the weight of individual factor; I_F – the impact of an individual factor on the volume of rail transport; I_{Fi} – the sum of the impact of all factors affecting the volume of transport.

The impacts of an individual factors on the volume of rail transport calculated by the formula (4) and the weights calculated according to formula (5) are presented in Table 5.

Table 5. Calculated weights corresponding to the impact of individual factors on the volume of transport.

Factor	The impact of an individual factor on the volume of rail transport (I_F)	The weight of individual factor (W_F)
Population/line length [people/km]	0.58	0.16
Number of vehicles/1000 people	0.68	0.19
Number of business entities/line length [entities/km]	0.63	0.18
Value of fixed assets/line length [millions PLN/km]	0.12	0.03
Availability of inhabitants to the railway line [people/km]	0.74	0.21
Number of commuters to work/line length [people/km]	0.77	0.21
Number of accommod. facilities/line length [facilities/km]	0.07	0.02
Sum	3.59	1.00

7 Conclusions

The calculations made allowed for the determination of weights of socio-economic factors affecting the volume of passenger transport on individual railway lines located in the Łódź region. For this purpose, a partial correlation coefficient was used, taking into account the relationship between the factors and the number of trains a line during the year and the number of transported passengers. The obtained weights may be used in the future in multi-criteria analysis of railway lines in the Łódź region. These weights allow to avoid the subjective assessments of experts, that have been often used in previous analyzes. Additionally, during the analysis of socio-economic factors included the number of people who can truly use rail transport to get to work from their place of residence. These are only people living in the area through which the railway line runs and commute to work to the communes located near this line. Except to the use of data provided directly by the Central Statistical Office, a very important factor affecting the volume of transport is the accessibility to the railway line for individual inhabitants. This parameter has been determined for this analysis. It was defined as a factor related to the location of stations and stops located in the area of population centers. After the calculations, it was found that the number of commuters to work and the availability to the railway line have the greatest impact on the use of the railway line in passenger traffic (the weight of both factors is equal to 0.21).

References

1. Bartosiewicz, B.: Transport connections in the Łódź metropolian area. Studia KPZK **147**, 105–137 (2012). (in Polish)
2. Macchi, M., Garetti, M., Centrone, D., Fumagalli, L., Pavirani, G.P.: Maintenance management of railway infrastructures based on reliability analysis. Reliab. Eng. Syst. Saf. **104**, 71–83 (2012)
3. Ghosh, S., Banerjee, A., Sharma, N., Agarwal, S., Ganguly, N., Bhattacharya, S., Mukherjee, A.: Statistical analysis of the Indian railway network: a complex network approach. Acta Phys. Pol. B Proc. Suppl. **2**(4), 123–137 (2011)
4. Weik, N., Niebel, N., Nießen, N.: A rigorous discussion of the queuing based approach. J. Rail Transp. Plann. Manag. **6**, 99–115 (2016)
5. Sogin, S.L., Lai, Y.-C., Dick, C.T., Barkan, C.P.L.: Analyzing the incremental transition from single to double track railway lines. J. Rail Rapid Transit **230**(8), 1877–1889 (2016). CD
6. Wang, J., Li, Y., Liu, J., He, K., Wang, P.: Vulnerability analysis and passenger source prediction in urban rail transit networks. PLoS ONE **11**(8), e80178 (2013). CD
7. Jacyna, M., Wasiak, M.: Application of multicriteria assessment to the choice of a variant of modernization of railway infrastructure elements. Problemy Kolejnictwa **146**, 27–35 (2008). (in Polish)
8. Cascetta, E., Papola, A., Pagliara, F., Marzano, V.: Analysis of mobility impacts of the high speed Rome-Naples rail link using withinday dynamic mode service choice models. J. Transp. Geogr. **19**, 635–643 (2011)
9. Meng, D., Lu, Y.: Analysis of the inter-provincial accessibility and economic linkage spatial pattern based on the railway network. Geogr. Res. **1**(31), 107–122 (2012)

10. Bergantino, A.S., Capozza, C., Capurso, M.: The impact of open access on intra- and inter-model rail competition. A national level analysis in Italy. Transp. Policy **39**, 77–86 (2015)
11. Raczyński, J., Giedryś, A., Wesołowski, J.: Łódź Agglomeration Railway. TTS Technika Transportu Szynowego **10**, 14–22 (2012). (in Polish)
12. Giedryś, A., Raczyński, J.: Łódź Agglomeration Railway – the new railway system for the Łódź agglomeration. Technika Transportu Szynowego **6**, 30–32 (2014). (in Polish)
13. Bartosiewicz, B., Wiśniewski, S.: Agglomeration railway as a part of the public transport system in Łódź. Sp.-Soc.-Econ. **18**, 49–65 (2016)
14. Pagliara, F., Papa, E.: Urban rail systems investments: an analysis of the impacts on property values and residents' location. J. Transp. Geogr. **19**, 200–211 (2011)
15. Asuero, A.G., Sayago, A., Gonzalez, A.G.: The correlation coefficient: an overview. Crit. Rev. Anal. Chem. **1**(36), 41–59 (2006)
16. Kamiński, W., Sładkowski, A.: Determination the influence of socio-economic factors on the volume of railway passenger transport in different regions of Poland. In: Sładkowski, A. (ed.) Transport Problems 2019, pp. 308–319. Silesian University of Technology, Katowice (2019)
17. Nationwide Railway Base Homepage (in Polish). http://www.bazakolejowa.pl. Accessed 21 Apr 2019