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ANALYSIS OF CAPACITY OF ROLLING STOCK USED IN REGIONAL PASSENGER TRANSPORT IN DIFFERENT REGIONS OF POLAND

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Abstract. This article assesses the impact of socio-economic factors and the amount of transport work done on the capacity of rolling stock used in passenger transport on selected railway lines located in various regions of Poland. The purpose of this article was to check the relationship between the capacity of rolling stock running on a railway line in regional passenger transport, and the socio-economic factors occurring in the area through which the analyzed railway line runs, and between volume of transport on this line. The analysis was carried out for 32 railway lines located in different voivodeships, with one main line and one local line selected from each voivodeship. The average number of seats in regional trains running on it was calculated for each of the analyzed lines. Then calculations of partial correlation coefficients were performed. During calculations, the average number of seats was used as a dependent variable, while socio-economic factors affecting the size of passenger flows and the amount of transport work done were used as independent values. The calculation used the transport data and socio-economic factors that occurred in 2018. The calculations showed that there is a clear relationship between the rolling stock capacity and the amount of transport work done. On lines where more transport work is done, more capacious rolling stock also runs. On the other hand, the dependence of rolling stock capacity on socio-economic factors affecting the size of passenger flows is small.

Keywords: railway transport, passenger transport, rolling stock, correlation coefficient, capacity, socio-economic factors, region

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1. Introduction

Many different socio-economic factors, such as the number of inhabitants, the number of business entities or the number of bus and tram connections enabling access from the city center to the railway station, affect the size of passenger flows. In turn, the size of passenger flows is related to the volume transport work done [1].

To transport more passengers, it is necessary to run more trains, while many passengers on an analyzed railway line is a signal for the organizer of transport to run more trains on this line. If there are large passenger flows on an analyzed line, there should also be used more capacious rolling stock on this line than on the lines on which passenger flows are smaller. Running an additional number of trains or, in the case of lower demand, limiting the transport offer can take place smoothly and can be implemented in a short period of time, one year with the introduction of a new timetable or quarterly in the case of a timetable correction. It can be implemented by changing the rolling stock circulation or by reducing the stop-ping time at return stations.

Of course, the launch of an additional number of trains requires the organizer of transport to provide additional funding, but its implementation can take place in a short period of time. However, it is practically impossible to quickly adapt the capacity of rolling stock to the current demand for transport. Rolling stock currently owned by the carrier is used to make connections. For the passenger carrier, the main problem is to provide sufficient seats for passengers, by using rolling stock with appropriate capacity while minimizing operating costs [2].

The condition of railway infrastructure in Poland has been systematically deteriorating from the late 1980s to the beginning of the 21st century. For about 10 years, due to numerous repairs and modernization of railway lines, the condition of infra-structure on many railway lines has been improving [3]. The situation is similar when it comes to rolling stock, where after many years of not purchasing new rolling stock for more than 10 years, there is an increase in the number of new vehicles owned by carriers.

Regional passenger transport in Poland is currently operated by many different carriers. The largest carrier is Polregio company, which services regional connections in 10 provinces. In the remaining 6 voivodeships, this traffic is served by companies owned by regional self-governments such as: Koleje Małopolskie, Koleje Dolnośląskie, Koleje Śląskie, Koleje Wielkopolskie, Koleje Mazowieckie, and the Łodzka Kolej Aglomeracyjna. In addition, the PKP Szybka Kolej Miejska w Trójmieście (co owned by the central government and regional and local self-governments), SKM Warszawa (owned by the City of Warsaw) and Warszawska Kolej Dojazdowa (owned by the conglomeration of self-governments) operate in large metropolitan areas such as the Trójmiasto (Gdańsk, Sopot, Gdynia) and Warsaw. Arriva RP is private operator.

In connection with the division of transport into so many operators, there is a problem of handling connections at the provinces border. Often, one operator's trains end at the last station in each province, thus not providing a proper connection to the neighboring province.

Some operators also have rolling stock problems. Most of the rolling stock used in regional passenger traffic, including all newly purchased electric units and rail buses, is owned by the provinces that lend it to operators. Only Regional Transportation has its own rolling stock, but they are mostly old vehicles. In Poland, many passenger carriers currently have problems with the appropriate amount of rolling stock needed to make connections. This problem occurs mainly in regional carriers, where there are many entities with a limited number of rolling stocks. This is usually associated with the decommissioning of old electric units and wagon depots and their replacement by an insufficient number of new vehicles. The number of vehicles in normal conditions is sufficient to carry out the intended transport.

However, due to the insufficient number of reserve vehicles in the event of breakdowns or inspections of individual vehicles, often transport is carried out with rolling stock of inadequate capacity or even in extreme cases replaced by bus communication.

Until now, the impact of various socio-economic factors occurring in the area crossed by the railway on the capacity of rolling stock running on this line has not been analyzed. These factors probably have a significant impact on the size of passenger flows, which in turn translates into the capacity of rolling stock running on the line.

This study assesses the impact of socio-economic factors and the amount of transport work done on the capacity of rolling stock used in passenger transport on selected railway lines located in various regions of Poland. These studies allow determining whether various social and economic factors occur-ring in the area through which a given railway line runs have an impact on the capacity of rolling stock running on that line. The relationship between the transport work done and the rolling stock capacity was also checked. Calculations were carried out using partial correlation coefficients. During these calculations, the average number of seats in vehicles was used as the dependent variable, while the socio-economic factors affecting the size of passenger flows and the amount of transport work done were used as independent values.

2. Analyzed railway lines

The analysis was carried out for 32 railway lines located in different voivodeships, on which regional passenger transport is carried out. A representative one main line and one local line were selected from each voivodeship. These lines are shown in **Fig. 1**. The main railway lines are marked in red and numbers 1-16, while the green color and numbers 17-32 represents local lines. Some of the analyzed railway lines are included in their entirety, while others only on limited sections located within one voivodeship.

Tab. 1 shows the analyzed railway lines divided into voivodeships in which they are located. In addition, **Tab. 1** shoves the length of these lines, the number of tracks on individual lines, their electrification, the maximum permissible speed, and average number of trains running on an individual line on a workday.

3. Rolling stock used on the analyzed railway lines

Currently, passenger rail rolling stock running in regional transport in individual voivodeships is truly diverse. This is because rolling stock manufacturers offer its adaptation to the needs of the customer. Most often they are vehicles from one family (e.g., Elf of Pesa, Impuls of Newag), but in different configurations. It is possible to adjust the length of the train by adding or reducing the number of its sections. Another possible modification is the interior design. It is possible to add additional seating or reduce their number which allows to obtain more space for passengers in standing places or adapting the vehicle to the needs of people with disabilities or with larger luggage (e.g., for transporting bicycles). Result of such changes in the creation of different series and varieties of rolling stock causing a huge variety in terms of their series.

Due to the large number of orders, the number of electric and diesel multiple units available to regional passenger carriers has increased in recent years. However, the number of passenger cars decreased significantly [5]. This is due to the replacement of classic trains by electric multiple units on electrified lines and by railbuses on non-electrified lines. Many used electric multiple units have been modernized. Also, during the modernization of the previously used rolling stock, it is possible to arrange the interior and adapt it to new needs.

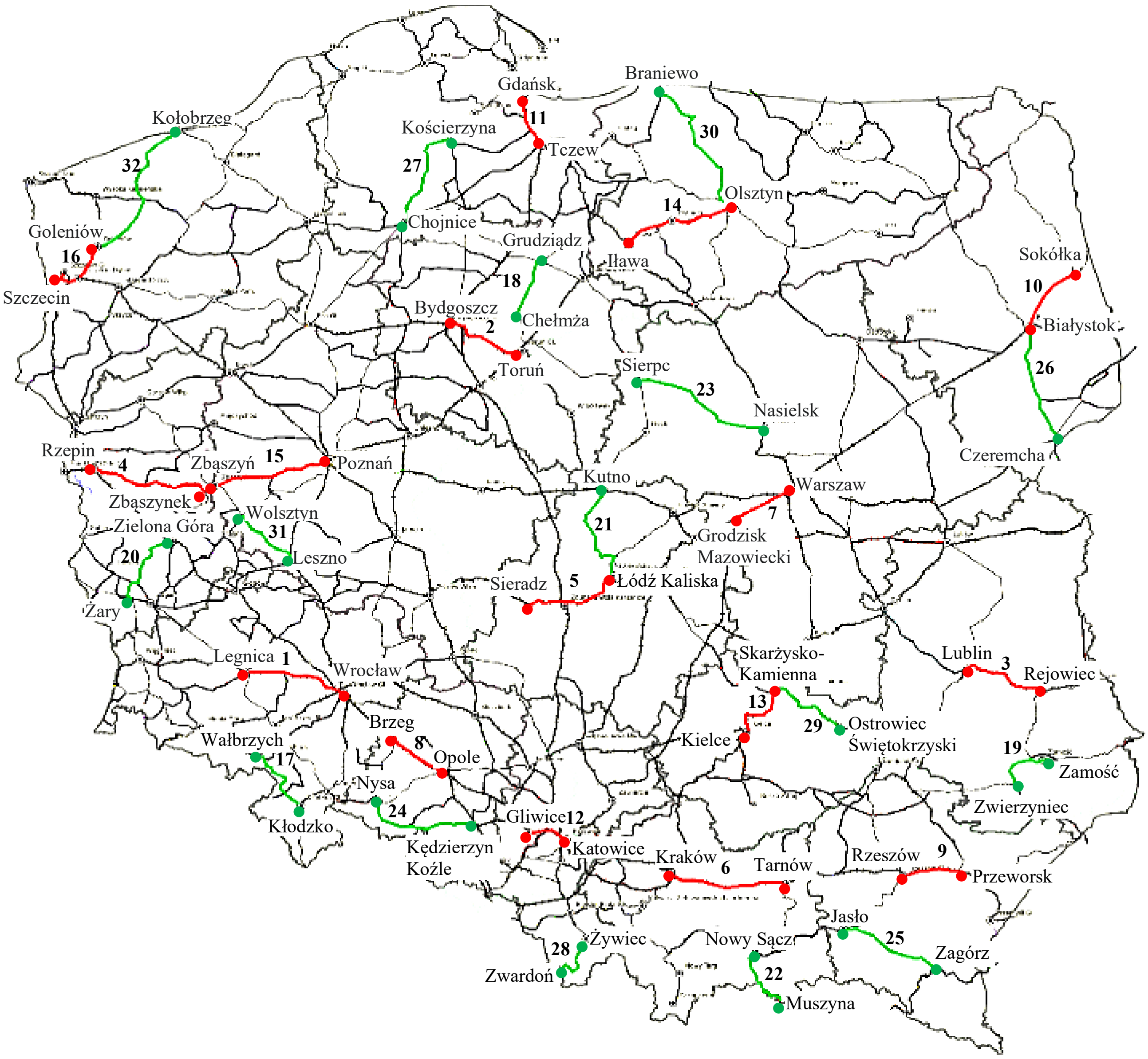

Fig. 1. Location of analyzed railway lines in Poland [4]

Table 1. Analyzed main and local lines

№	Voivodeship	Line or Section	Line length, km	Number of tracks	Electrifica-tion	Maximum speed, km/h	Average number of trains on a workday
			Main lines				
1	Lower Silesian	Wrocław Główny – Legnica	65	double	yes	160	34
2	Kuyavian-Pomeranian	Bydgoszcz Główny – Toruń Główny	51	double	yes	120	24
3	Lubelskie	Lublin – Rejowiec	55	double	yes	120	26
4	Lubuskie	Zbąszynek – Rzepin	75	double	yes	160	14
5	Łódzkie	Łódź Kaliska - Sieradz	59	double	yes	80	28
6	Lesser Poland	Kraków Główny – Tarnów	77	double	yes	160	36
7	Mazovian	Warszawa Zachodnia – Grodzisk Mazowiecki	27	double	yes	120	136
8	Opolskie	Opole Główny – Brzeg	40	double	yes	160	28
9	Podkarpackie	Rzeszów Główny – Prze-worsk	36	double	yes	120	30
10	Podlaskie	Białystok – Sokółka	42	single	yes	80	16
11	Pomeranian	Gdańsk Główny – Tczew	32	double	yes	160	24
12	Silesian	Katowice – Gliwice	27	double	yes	160	66
13	Świętokrzyskie	Kielce – Skarżysko-Kamienna	45	double	yes	120	16
14	Warmia-Masurian	Olsztyn Główny – Iława Główny	69	double	yes	100	20
15	Greater Poland	Poznań Główny – Zbąszyń	74	double	yes	160	30
16	West Pomeranian	Szczecin Główny – Go-leniów	38	double	yes	120	36
			Local lines				
17	Lower Silesian	Kłodzko Główny – Wałbrzych Główny	51	single / double	no	80	10
18	Kuyavian-Pomeranian	Grudziądx – Chełmża	38	single	no	90	16
19	Lubelskie	Zamość Wschód – Zwierzyniec	32	single	no	80	10
20	Lubuskie	Żary – Zielona Góra	53	single	no	80	8
21	Łódzkie	Łódź Kaliska - Kutno	68	double	no	70	20
22	Lesser Poland	Nowy Sącz – Muszyna	51	single	no	80	10
23	Mazovian	Nasielsk – Sierpc	88	single	no	80	10
24	Opolskie	Nysa – Kędzierzyn-Koźle	75	double	no	50	14
25	Podkarpackie	Jasło – Zagórz	69	single	no	80	4
26	Podlaskie	Białystok – Czeremcha	77	single	no	80	8
27	Pomeranian	Chojnice – Kościerzyna	69	single	no	80	8
28	Silesian	Żywiec – Zwardoń	37	single	yes	70	20
29	Świętokrzyskie	Skarżysko-Kamienna – Os-trowiec Świętokrzyski	46	double	yes	80	10
30	Warmia-Masurian	Olsztyn Główny – Braniewo	96	single	no	80	8
31	Greater Poland	Leszno – Wolsztyn	46	single	no	80	12
32	West Pomeranian	Kołobrzeg – Goleniów	100	single	no	80	14

On the one hand, it is possible to accurately adapt the rolling stock to the needs of the carrier or even a specific railway line. However, the purchase of new rolling stock is an investment, the implementation of which requires the involvement of significant financial resources and a long time of waiting for the finished product. If a carrier has shortage of rolling stock, it is necessary to prepare and perform a tender procedure, then for a specified period the vehicles are assembled at the manufacturer, after which it is possible to transfer them to the ordering carrier. Only sporadically there are cases such that the ready rolling stock is at the manufacturer's and its immediate collection is possible. In addition, they usually only apply to individual vehicles. If a carrier does not have the problem of having enough rolling stock necessary to carry out the ordered transport work most often, due to the remarkably high purchase cost, new rolling stock is not ordered. In this case, when rolling stock purchased many years ago is used to service the connections, it may be inadequately adapted to the current transport needs.

On railway lines where passenger flows have decreased, already existing rolling stock with too large capacity can run, generating high operating costs. On the other hand, on lines where the number of transported passengers has increased, there is a possibility to use on its insufficient capacious rolling stock, generating difficulties for passengers. This may be a reason for stopping the further increase in the number of passengers.

Another problem is the arrangement of appropriate circuits for owned rolling stock. The empty spread of rolling stock should be limited or avoided if possible [6]. Linear programming is used to reduce the number of kilometers of rolling stock carrying out empty mileage [7].

Another problem in arranging the correct rolling stock cycles is the diversity of passenger flows due to the time of day. If the same rolling stock with a fixed capacity is still running on a given railway line, its overflow may occur during the morning and afternoon peak, and during the off-peak hours it will run only slightly full. Therefore, the number of different types of vehicles needed to service the planned connections should be precisely determined. In the morning and afternoon rush hours, the multiple units can be coupled together to obtain the larger capacity needed to travel the increased number of passengers. In turn, during the off-peak hours, the multiple units can be decoupled to reduce the cost of running the train [8]. These activities generate the need for additional rolling stock maneuvers and track occupation at the return station by rolling stock out of service during off-peak periods [9]. The benefit of adapting the rolling stock capacity to the current demand on a specific railway line is the carrier's minimized operating costs [10].

Various complex methods are used to set up the appropriate rolling stock circulation, such as the heuristic Benders distribution [11]. Thanks to this distribution, the lower limit of rolling stock utilization can be calculated in a short time [12]. However, the key issue that allows the proper circulation of rolling stock to be arranged is that the carrier has sufficient rolling stock of the right capacity.

Another problem is the dispatcher's daily assignment of individual vehicles to a specific circuit. Vehicles assigned to a specific cycle can be done manually and using special software, which enables to shorten the time of performing this activity [13]. The use of appropriate software in addition to reducing the time needed to assign vehicles to circulation allows for a significant improvement in the provision of transport services, by better matching the capacity of rolling stock with passenger flows occurring at a given time [14]. In the case of rolling stock circulation planning over long distances, integrated algorithms based on graph theory can be used [15].

During planning circulation, it is necessary to consider exclusions the vehicles from use, both scheduled for inspections and random. Random factors excluding a vehicle from traffic may be both failures and participation in events such as accidents at level crossings or collisions with wild animals.

Vehicles running on the analyzed railway lines in 2018 are shown in **Tab. 2**, **3**.

Based on the data contained in **Tab. 2**, considering the capacity of individual types of rolling stock and the number of connections made with these vehicles on each of the analyzed railway lines, the average capacity of rolling stock was calculated. This value, calculated for a specific railway line, shows the average number of seats in regional passenger trains running on it. The results of the calculated average number of seats for the analyzed railway lines are presented in **Tab. 4**. In addition, this table includes transport work done in regional passenger transport on these lines in 2018.

4. Socio-economic factors affecting passenger flows

The size of passenger flows on a particular railway line depends on the spatial structure of the area through which an analyzed railway line runs. During the analysis, socio-economic factors were considered, such as:

- the number of people in cities and villages through which the railway line runs.
- the number of business entities registered in the communes at the railway line, divided into small, medium, and large entities (division expressed by the number of employees).
- number of commuters to work.
- the number of places in accommodation facilities (hotel, motels, etc.) located in communes at the railway line.
- number of bus and tram connections enabling access from the city center to the railway station [16].

These data are presented in **Tab. 5** for 2018. The data source are reports of the Central Statistical Office [17]. The last parameter, the availability of inhabitants to the line, was calculated based on data from the Central Statistical Office.

This parameter is affected by the distance of the station from the city center and the size of the population center in which the station is located [16]. To enable comparison of the analyzed railway lines having different lengths, the values of these factors were not used directly in the calculations, but their ratio to the length of the lines was used.

Table 2. Rolling stock used in regional passenger transport on the analyzed lines

Line or section	Used rolling stock
Main lines	
Wrocław Główny – Legnica	31WE, 45WE, SA134 · 2, 36WEa, SA139
Bydgoszcz Główny – Toruń Główny	EN76, EN57, ED72, EN71, EN96
Lublin – Rejowiec	EN57, SA134
Zbąszynek – Rzepin	EN57, ED78
Łódź Kaliska - Sieradz	E 4268 (FLIRT), EN57, EN57 · 2
Kraków Główny – Tarnów	EN64, EN79, EN57, EN78, EN78 · 2, EN64, EN77, EN63A
Warszawa Zachodnia – Grodzisk Mazowiecki	EN57 · 2, 45WE, 19WE, 35WE
Opole Główny – Brzeg	EN57, EN63A, ED72Ac
Rzeszów Główny – Przeworsk	EN64, EN76, EN71, EN57, EN62
Białystok – Sokółka	SA133, EN57, SA108
Gdańsk Główny – Tczew	EN57, EN76, EN56 · 2, EN90, EN71, SA137 · 2
Katowice – Gliwice	27WEb, 35WE, EN57, EN75, EN76, 34WEa, 22WE, 22WEd
Kielce – Skarżysko-Kamienna	EN63A, EN96, EN57 · 2, EN57, EN81, ED78
Olsztyn Główny – Iława Główny	EN57, ED72
Poznań Główny – Zbąszyń	EN76 · 2, EN76, EN57, ED78
Szczecin Główny – Goleniów	SA103, ED78, EN63A, SA136, EN57
Local Lines	
Kłodzko Główny – Wałbrzych Główny	SA134, SA135
Grudziądx – Chełmża	MR/MRD, SA133, SA106, SA106+SA123, 628.4
Zamość Wschód – Zwierzyniec	SA134
Żary – Zielona Góra	SA105, SA133, SA108
Łódź Kaliska - Kutno	E 4268 (FLIRT)
Nowy Sącz – Muszyna	EN99, EN79, EN57
Nasielsk – Sierpc	SA135, VT627
Nysa – Kędzierzyn-Koźle	SA134, SA103, SA137
Jasło – Zagórz	SA103, SA135, SA109
Białystok – Czeremcha	SA133, SA108
Chojnice – Kościerzyna	SA109
Żywiec – Zwardoń	EN76, EN71, EN75, 36WE, 27WEb
Skarżysko-Kamienna – Ostrowiec Świętokrzyski	EN63A, EN96, EN57, EN81, ED78
Olsztyn Główny – Braniewo	SA106
Leszno – Wolsztyn	SA108, Ol49 + 2 · 120A, SA134
Kołobrzeg – Goleniów	SA103, SA136

Table 3. Division of individual types of rolling stock

Rolling stock type	Sign
New electric unit	22WE, 22Wed, 27Web, 31WE, 34Wea, 35WE, 36WE, 36Wea, 45WE, E 4268 (FLIRT), EN56, EN62, EN63A, EN64, EN75, EN76, EN77, EN78, ED78, EN79, EN90, EN96, EN99
Old electric unit	EN57, EN71, ED72, ED72Ac
New railcar	SA105, SA106, SA108, SA133, SA134, SA135, SA137, SA139
Old railcar	MR/MRD, 628.4, VT627
Steam locomotive	Ol49

5. Determination of rolling stock capacity on the size of passenger flows

The analysis of the dependence of the rolling stock capacity on the size of passenger flows in regional transport was performed using correlation coefficients.

5.1 Assumptions of the used method

The analysis did not consider the long-distance traffic, which has completely different specificity. In this traffic, it is important to connect large urban centers and provide connections in popular directions, where large streams of travelers occur, but the socio-economic factors of the area through which the railway line runs are not that important.

Correlation coefficients are often used to analyze rail transport systems. They were used to analyze delays on 4 selected railway lines in Hungary, where the causes of delays were examined, focusing on the impact of weather conditions [18]. Correlation coefficients have already been used to check the relationship between line capacity, length of line sections and the timetable arranged [19].

The simplest correlation coefficient is the Pearson correlation coefficient. This coefficient determines the impact between 2 variables. The obtained value of Pearson's correlation coefficient may be disturbed due to the relationship of a pair of variables with other analyzed variables. Therefore, the partial correlation coefficient was used for this analysis. This coefficient allows to determine the relationship between two variables excluding the influence of other analyzed variables [20].

Correlation matrix is used for calculation the partial correlation coefficient. This matrix contains all relationships between 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

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

where Cij, Cii, Cjj – algebraic complements of the elements r_{ij}, r_{ii}, r_{jj} of matrix; k – number of analyzed variables.

Table 4. Average rolling stock capacity on individual railway lines

Line or section	Transport work done, trainkm	Average rolling stock capacity, seats
Main lines		
Wrocław Główny – Legnica	811200	221.2
Bydgoszcz Główny – Toruń Główny	441558	192.6
Lublin – Rejowiec	518210	157.0
Zbąszynek – Rzepin	352050	185.5
Łódź Kaliska - Sieradz	631534	150.0
Kraków Główny – Tarnów	1009008	194.6
Warszawa Zachodnia – Grodzisk Mazowiecki	1349136	381.1
Opole Główny – Brzeg	404800	181.7
Rzeszów Główny – Przeworsk	398016	169.9
Białystok – Sokółka	236544	137.3
Gdańsk Główny – Tczew	277056	229.0
Katowice – Gliwice	647892	216.1
Kielce – Skarżysko-Kamienna	244080	172.8
Olsztyn Główny – Iława Główny	489348	206.0
Poznań Główny – Zbąszyń	808240	248.7
Szczecin Główny – Goleniów	499472	164.7
Local lines		
Kłodzko Główny – Wałbrzych Główny	179826	73.5
Grudziądz – Chełmża	218044	112.5
Zamość Wschód – Zwierzyniec	105920	134.0
Żary – Zielona Góra	143736	95.2
Łódź Kaliska - Kutno	480307	120.0
Nowy Sącz – Muszyna	186150	166.8
Nasielsk – Sierpc	321200	60.7
Nysa – Kędzierzyn-Koźle	352050	88.5
Jasło – Zagórz	102120	64.9
Białystok – Czeremcha	224840	116.0
Chojnice – Kościerzyna	237102	73.0
Żywiec – Zwardoń	282312	235.3
Skarżysko-Kamienna – Ostrowiec Świętokrzyski	167900	148.6
Olsztyn Główny – Braniewo	290496	60.0
Leszno – Wolsztyn	211140	130.7
Kołobrzeg – Goleniów	542400	105.5

The partial correlation coefficient allows to determine only the linear relationship between the examined variables. Therefore, after its calculation, in the case of obtaining no relationship between variables, it is necessary to analyze scatter plots to check whether there is no non-linear relationship between the analyzed variables. Another problem associated with the use of partial correlation is the considerable complexity of calculations performed using this method.

5.2 The use of partial correlation coefficient

Because calculations of partial correlation coefficients are complex, STATISTICA software was used to determine the partial correlation coefficients in this analysis. During calculations, individual socio-economic factors affecting the size of passenger flows, presented in **Tab. 5**, were used as independent variables. In turn, the average rolling stock capacity was used as a dependent variable (**Tab. 6**, test 1). Then, the examined independent variables were expanded by the quotient of transport work done by the length of the line (**Tab. 6**, test 2). This quotient shows the number of regional passenger trains launched on individual railway lines during the year. The results of calculating the partial correlation coefficients of the average rolling stock capacity both for socio-economic factors affecting the size of passenger flows and after extending the independent variables by the number of regional passenger trains launched during the year are presented in **Tab. 6**. In this table, the correlation coefficient value with a significance level of 0.05 bilaterally has been bolded [21].

Calculations of partial correlation coefficients show that socio-economic factors affecting the size of passenger flows on a specific railway line do not have a significant impact on the average capacity of rolling stock running on this line in regional passenger transport. Most of these factors have no impact on rolling stock capacity at all.

An example of a factor that does not have impact for the average capacity of rolling stock running on a railway line is the availability of residents to this line, determined based on the size and location of population centers. **Fig. 2** presents the scatter chart of average rolling stock capacity and residents' availability to the railway line. From this graph, it can be noticing not only the lack of a linear relationship, which was studied using the partial correlation coefficient, but the lack of any relationship between these quantities.

The highest value of the partial correlation coefficient among the socio-economic factors affecting the size of passenger flows was achieved by the factor showing the average number of bus and tram connections in a day enabling access to the railway station from the city center. **Fig. 3** shows a scatter chart for these quantities.

In this chart, the relationship between these quantities is small, but clearly visible. This is because people having easy access from their places of residence to the railway station more often decide to use this mode of transport. In addition, the number of bus and tram connections is higher in densely populated and economically developed regions of Poland. There is a greater need for population movement, which causes an increase in passenger flows. In turn, regional rail carriers operating in densely populated areas have greater financial resources at their disposal, which allows the purchase of capacious rolling stock.

Table 5. Socio-economic factors affecting the size of passenger flows

№	Line or section	Numb. of people, pe.	Number of entities			Availability inhabitants to line, pe./km	Number of accommodations places, pe.	Number of commuters, pe.	Bus and tram connections
			up to 9 people	10-49 people	from 50 people				
	Main lines								
1	Wrocław Główny – Legnica	758013	135152	3641	985	3591.72	13296	73076	285.62
2	Bydgoszcz Główny – Toruń Główny	572163	68354	2330	698	3516.38	8115	43327	210.00
3	Lublin – Rejowiec	388645	48982	1514	418	2735.39	4526	41053	34.86
4	Zbąszynek – Rzepin	40853	6528	227	54	356.75	2566	6295	2.64
5	Łódź Kaliska - Sieradz	863521	107563	4303	925	10267.10	9521	57623	74.15
6	Kraków Główny – Tarnów	948204	163658	6068	1421	5268.79	35440	123357	80.00
7	Warszawa Zachodnia – Grodzisk Mazowiecki	2025760	442698	14809	3939	20361.57	34149	283173	402.50
8	Opole Główny – Brzeg	174910	27909	882	237	2478.87	1839	24582	71.63
9	Rzeszów Główny – Przeworsk	241271	31858	1018	318	3633.26	4469	52132	45.90
10	Białystok – Sokółka	337044	38361	1134	386	3542.62	3094	17521	59.78
11	Gdańsk Główny – Tczew	564995	85415	2824	670	8287.99	18557	49672	178.00
12	Katowice – Gliwice	948112	107774	4971	1281	20223.53	8960	174321	327.50
13	Kielce – Skarżysko-Kamienna	254824	36147	1317	372	2843.10	5726	29370	40.27
14	Olsztyn Główny – Iława Główny	244163	29237	997	291	1914.11	8099	21784	84.23
15	Poznań Główny – Zbąszyń	584872	121611	4568	977	2842.12	10617	98209	197.87
16	Szczecin Główny – Goleniów	428136	71782	2207	459	5199.20	7624	26800	110.00
	Local lines								
17	Kłodzko Główny – Wałbrzych Główny	184290	20654	577	141	1185.58	2601	12719	8.33
18	Grudziądx – Chełmża	111431	9684	369	115	1954.70	1425	3813	31.33
19	Zamość Wschód – Zwierzyniec	76677	8541	279	90	1919.04	2544	7084	23.89
20	Żary – Zielona Góra	185775	26129	897	208	1514.98	1534	21145	28.10
21	Łódź Kaliska – Kutno	828287	102150	3985	903	10864.94	8965	53155	86.56
22	Nowy Sącz – Muszyna	104896	13308	527	143	987.71	4755	11364	69.13
23	Nasielsk – Sierpc	64274	7012	270	65	456.27	611	3274	2.86
24	Nysa – Kędzierzyn-Koźle	132923	19273	654	159	1462.31	5057	9562	25.46
25	Jasło – Zagórz	145984	17548	667	221	1821.32	2831	32628	26.91
26	Białystok – Czeremcha	328781	38718	1155	399	1837.33	2863	17894	46.86
27	Chojnice – Kościerzyna	80769	7976	305	92	609.45	905	5758	21.79
28	Żywiec – Zwardoń	60542	7308	306	74	1032.82	1682	9718	32.33
29	Skarżysko-Kamienna – Ostrowiec Świętokrzyski	176108	18966	639	195	2677.22	1379	13415	11.00
30	Olsztyn Główny – Braniewo	214861	28478	983	249	1258.51	6091	19930	62.33
31	Leszno – Wolsztyn	88347	15812	725	167	1125.74	3706	13128	9.15
32	Kołobrzeg – Goleniów	120852	20622	627	160	872.65	23929	8174	19.94

Table 6. Calculated values of partial correlation coefficient

Factor	Average rolling stock capacity, seats	
	test 1	test 2
Number of people / line length, pe./km	-0.036	-0.123
Number of entities up to 9 pe. / line length, ent./km	-0.076	-0.189
Number of entities 10-49 pe. / line length, ent./km	0.078	0.116
Number of entities from 50 pe. / line length, ent./km	0.029	0.109
Availability inhabitants to line, pe./km	-0.081	0.022
Number of accommodations places / line length, pe./km	0.073	0.104
Number of commuters / line length, pe./km	0.178	-0.019
Bus and tram connections	0.286	0.303
Number of running trains	-	**0.481**

However, the largest correlation exists between the average rolling stock capacity and the number of running trains during the year. The scatter chart for these quantities is shown in **Fig. 4**.

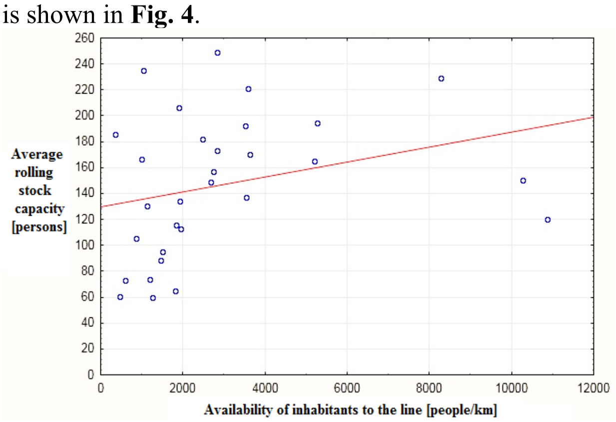

Fig. 2. Scatter chart of average rolling stock capacity and residents' availability to the railway line

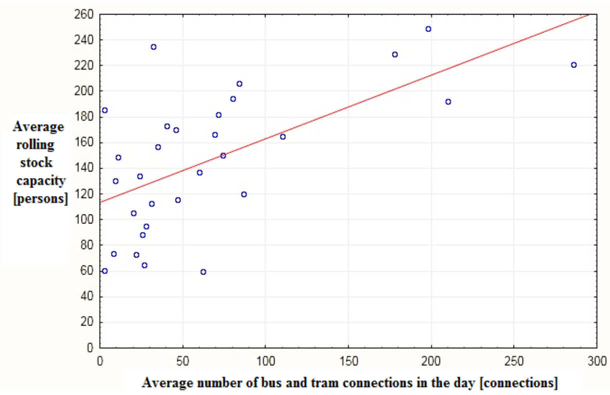

Fig. 3. Scatter chart of average rolling stock capacity and average number of bus and tram connections

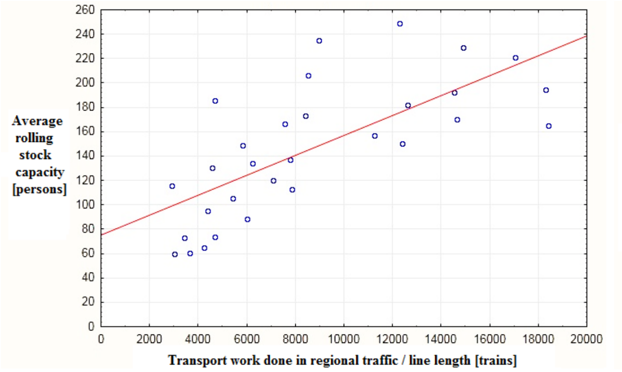

Fig. 4. Scatter chart of average rolling stock capacity and number of running trains during the year

This graph shows a clear linear relationship between these quantities. On railway lines with exceptionally large passenger flows, in addition to the fact that the number of running trains is large, the average capacity of rolling stock operating there is also higher than for lines with smaller passenger flows.

6. Conclusion

Earlier, no calculations were made of the impact of socio-economic factors in the area crossed by the railway line and the volume of transport on the rolling stock capacity on the given railway line. The calculations showed that the average number of seats in the rolling stock used for regional passenger transport on the analyzed railway lines does not depend on socio-economic factors affecting the size of passenger flows. There is no dependence of the rolling stock capacity on factors such as: the number of inhabitants in the area crossed by the railway line, the number of business entities, the availability of inhabitants to the railway line and the number of beds in accommodation facilities. The reason for the lack of this relationship may be the fact that the capacity of the rolling stock is not adapted to the passenger flows. Particularly in economically less developed areas (e.g., Podkarpackie and Podlaskie Voivodesips) due to the shortages of rolling stock at carriers, the number of seats on regional passenger trains may be insufficient.

Only a small relationship exists between the rolling stock capacity and the average number of bus and tram connections enabling access from the city center to the railway station. This is because people having easier access from their place of residence to the railway station more often decide to use rail transport. In addition, the number of bus and tram connections is generally higher in more economically developed regions of the country. In such regions (e.g., Silesian, Mazovian voivod-ships), regional rail carriers have the financial means to purchase the appropriate rolling stock.

The largest relationship can be seen between the average rolling stock capacity and the number of running trains during the year. On railway lines, with many running trains, also the average capacity of rolling stock operating there is large. It is related, as in the case of the average number of bus and tram connections, to the fact that lines with many trains are in more developed regions of Poland.

Based on the obtained results, it can be concluded that an adequate rolling stock capacity adapted to transport needs is ensured in more economically developed regions of Poland, mainly in the south and west of the country. However, in less developed economically areas, therefore in the eastern regions of Poland, the capacity of rolling stock operating in regional passenger transport on some lines is insufficient. Also, a larger number of running trains generate larger passenger transport. Passengers who have a small number of rail connections at their disposal can choose another mode of transport more suited to their needs (often a car), while many trains encourage the use of rail transport services. This may be important in urban planning, as it increases the frequency of trains and increasing the number of passengers trans-ported in this way. This, in turn, can help reduce traffic problems, such as peak traffic jams that occur in many cities, not just the major ones.

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