

ANALYSIS OF TRANSPORT EFFICIENCY IN POLAND ON THE EXAMPLE OF PUBLIC TRANSPORT

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Purpose: The aim of the analysis was to demonstrate the level of public transport efficiency in Poland on the example of various modes of transport in selected years.

Methodology: Analysis of data from the library of the Central Statistical Office.

Findings: The evaluation results obtained from the analysis showed the advantage of road transport, which is systematically growing in the field of passenger transport, and the upward trend is also noticeable in air transport. The number of passengers using rail transport services is decreasing, but it still constitutes a significant part of the total transport traffic, and the investments made allow us to think about improving the current state of affairs. The share of sea transport and inland navigation in passenger traffic is small.

Originality/value: The publication discussed the topic public transport efficiency in Poland on the example of cargo transport in the years 1995-2022. Combining interdisciplinary research in the areas of management and quality sciences with economics and finance.

Keywords: public transport, transport efficiency.

Category of the paper: Research paper.

1. Introduction

Public transport plays a key role in the functioning of modern societies, being an important element of urban and regional infrastructure (Ceder, 2021; Divall, Hine, 2017; Miller et al., 2016; Saif et al., 2019). In Poland, the dynamic development of cities and the increase in the mobility of residents pose numerous challenges to the public transport system. The effectiveness of this system affects not only the comfort of travelers, but also the environment, economy and quality of life of local communities (Berg et al., 2017; Motowidlak, Tokarski, 2022).

An important problem from the point of view of logistics, apart from the transport of cargo, is also the transport of people by various means of transport. They are stimulated by social changes and the economic needs of both individuals and entire societies (Szczerbaciuk, 2014). People transport refers to the movement of people from one place to another, there are many different means of transporting people, depending on the distance, purpose of travel and availability of means of transport (Łuczak et al., 2023). The analysis of passenger transport can be carried out based on two types of statistical data, i.e. information on the number of passengers transported and information on transport performance expressed in passenger kilometers (Camargo Pérez 2015; Tajer, 2016).

2. Motivation and purpose

Public transport is an important element of the development of modern cities, directly influencing the quality of life of residents, the condition of the natural environment and the economic development of regions (Musiał-Malagó, 2013). In Poland, as in many other countries, ongoing urbanization, the growing number of cars on the road and the growing demand for fast and comfortable travel pose new challenges for the public transport system. The effectiveness of this system is crucial for the sustainable development of cities and reducing the negative impact of transport on the environment. Hence the need for a thorough analysis of the functioning of public transport, identification of its strengths and weaknesses and development of optimization strategies (Burchard-Dziubińska et al., 2014; Pawłowska, 2015).

Transport performs specific functions in the national economy, which are (Redding, Turner, 2015; Urbanyi-Popiołek, 2013):

- transport is an instrument for the exchange of goods and services and determines the flow of goods that are the subject of trade;
- is a factor in GDP growth and influences the development of other sectors of the national economy;
- determines the development of production and settlement locations - the existing and planned transport network and its level determine the location of the investment, and is also a city-forming factor;
- pursues social goals, such as meeting the communication needs of the population or increasing the accessibility of spheres of economic life, including: culture, education or sport.

The important role of transport in the processes of socio-economic development and its special place in social life and economy is obvious. However, the second decade of the 21st century brings widespread globalization of the world economy and advanced integration processes in many regions of the globe, which makes transport a key factor in the development

of modern societies (Fajczak-Kowalska, Tokarski, 2023; Quium, 2019). Developmental progressivity is the result of both expansive human activity in the social and economic sphere, as well as the modernization and expansion of transport infrastructure. Moreover, there is constant progress in the technical development of means of transport (Nowak et al., 2018; Porru, 2020).

3. Methodology

To confirm changes taking place in various modes of transport, it is necessary to conduct an analysis based on statistical data. In the presented study, they cover the period from 1995 to 2022 (GUS, 2022). This is a period in which very significant changes took place in individual modes of transport (i.e. rail, road, air, inland and sea shipping). Due to the systematic increase in the number of people transported, total transport was also taken into account, i.e. transport carried out by all mentioned modes of transport (Di Ciommo, Shiftan, 2017; Plawsky, 2020). For this purpose, transport data was used, mainly from the publications of the Central Statistical Office, regarding the number of people transported in the years 1995-2022.

4. Results

4.1. Passenger transport in thousands of people

Thanks to statistical data on passenger transport, it is possible to assess changes in transport services over the years. The above data broken down by means of transport in thousands of people in the years 1995-2022 are presented in Table 1, which shows that in the analyzed period 1995-2022 the number of passengers transported changed quite significantly. These changes occurred differently in different types of transport. This is especially visible in the case of road transport. Since 1995, there has been a gradual decline in the number of passengers transported by road. However, air transport has seen steady growth from 1995 to 2010 (except for 2020). This was largely due to the opening of the labor markets of European Union countries to Polish workers. This tendency was used by the so-called low-cost air carriers that have established a number of connections between Polish cities and centers of Polish economic emigration.

In 2020, there was a decline in passenger transport in all modes of transport. In total, 45.9% fewer passengers were transported than in the previous year. The largest decrease in transport was recorded in air transport (by 83.4%), followed by road transport (by 52.0%), rail transport (by 37.6%), sea transport (by 31.5%) and inland navigation (by 49.9%). Such a significant

decrease in the number of passengers transported was caused by restrictions on people traveling due to the state of the pandemic related to the spread of the SARS-CoV-2 virus.

In 2021, the number of passengers transported increased in all modes of transport. In 2022, compared to the previous year, the number of passengers transported by all types of transport increased, except for sea transport, which decreased slightly. In total, 35.5% more passengers were transported than in the previous year. The largest increase in transport was recorded in air transport (by 84.3%), followed by railway transport (by 39.5%), road transport (by 28.1%) and inland navigation (by 11.6%). Such a large increase in the number of transported passengers was caused by the abolition of restrictions on people's travel, introduced in connection with the pandemic related to the spread of the SARS-CoV-2 virus, as well as the introduction of martial law in Ukraine and the flow of refugees into Polish territory.

Changes taking place in passenger transport over time are illustrated by the single-base indicators included in Table 2, which show that the number of passengers transported by rail systematically decreased compared to 1995 and in 2020 was 45.2% lower, while in 2021 and 2022, an upward trend is noticeable. Road transport was similar, but the relative decline in transport was even greater and amounted to 85.9%. However, in air transport (outside 2020) and sea transport, the trend is increasing. In air transport, the number of passengers transported in 2022 increased sevenfold. Passenger transport by inland navigation shows quite large fluctuations. In total, passenger transport in 2020 shows a systematic decline of 23.3% compared to the volume of passenger transport in 1995. This decline was significantly influenced by the declines that occurred in rail and road transport. A detailed explanation of fluctuations in indicators regarding passenger transport by various means of transport would require additional research taking into account changes taking place, among others, in the number of means of transport available for individual modes of transport.

In order to verify changes in trends in passenger transport in the examined period for individual types of transport, the parameters of the trend model were estimated (Model 1):

$$Y_{tr} = \alpha_{0r} + \alpha_{1r}T_t + \varepsilon_{tr} \quad (1)$$

where:

Y_{tr} - volume of transport in persons in year t by transport r ,

T_t - time variable (trend) taking the following values: 1, 2, ..., 21,

ε_{tr} - random variable,

α_{0r}, α_{1r} - structural parameters of the model.

The calculation results presented in Table 3 indicate that certain regularities occurring in passenger transport can be observed in relation to rail, road, air and general transport. For the mentioned types of transport, a high coefficient of determination R^2 was obtained, ranging from 0.76 for rail transport to 0.98 for road transport. Analyzing the results obtained for rail transport, it can be concluded that the number of passengers transported shows a decreasing tendency. Similar results were obtained for road passenger transport. With each

year examined, the number of people transported also decreases. An upward trend was recorded in air transport. The results obtained for passenger transport in general indicate clear regularities.

The structure of passenger transport by mode of transport is presented in the calculation results presented in Table 4, which shows that despite the downward trend in passenger transport in the two dominant modes of transport: rail and road, the share of the former is clearly increasing, as the declines in the number of rail passengers were much weaker. than decline. number of passengers in public road transport. The results of rail transport would be even better, but due to the ongoing degradation of infrastructure, causing speed restrictions, some passengers stopped using the rail sector and focused on alternative means of transport - mainly private cars, air transport and buses. This situation has changed slightly since 2020 due to the completion of renovations of main sections of railway lines and the general improvement of passenger service standards (including new platforms and stations). Positive effects may also appear as a result of investing in rolling stock. Once again, the growing importance of air transport should be emphasized, conditioned by the above-mentioned tendency and related to Polish economic emigration.

4.2. Average passenger transport distance

The transport performance of individual means of transport is determined not only by the number of passengers transported, but also by the distances over which passengers are transported. Therefore, Table 5 contains data on the average transport distances of one passenger in kilometers, which shows that the average transport distance of 1 passenger is the largest - which is understandable for the dominant modes of transport: air and sea. The next places are taken by rail and road transport. However, in the case of inland navigation, the average passenger transport distance is the smallest. For all types of transport covered by the study, there were quite significant changes in the period under study, i.e. 1995-2022. It is worth noting that while in the case of road transport in the years 2005-2010 there was a slight increase in the average transport distance per passenger, in the following years there was a systematic increase. In the case of air transport, fluctuations can be noticed during the period under study. From 1995 to 2015, there was a clear decline in this level, while since 2020 there has been a slow increase. This can be explained by the increased flow of Polish employees working in England or Ireland, i.e. in countries not too far from Poland. A gradual decline can be observed in terms of average transport distance, which may be caused by the spread of the SARS-CoV-2 virus and the armed conflict in Ukraine.

The regularity of changes in the average transport volume of one passenger in the examined period is evidenced by the calculation results obtained for the development trend model, presented in Table 6, thanks to which it can be concluded that the most regular changes occurred in road transport, because the estimates of parameters a_0 and a_1 are statistically significant, the values Student's t-test exceeds the critical value many times, which in this case is 2.15.

The average transport distances for one passenger by rail were much less regular. In the case of other modes of transport, no clear regularities can be observed in the examined period.

Table 7 shows that the largest increase in the average transport distance of one passenger compared to the initial year (1995) occurred in: rail transport in 2005 and 2022 and amounted to 22.8%; road transport in 2022 and amounted to 80.0%; in air transport we observe slight fluctuations with a downward trend. The largest decrease compared to 1995 occurred in 2010 and amounted to 33.9%. In inland navigation there are significant fluctuations with a downward trend. Very large decreases in the dynamics of the average transport distance in the years 1995-2022 compared to 1995 occur in maritime shipping. The largest decline can be observed in 2021 and amounted to 66.3%.

4.3. Transport of people according to the transport work performed

The transport performance expressed in passenger kilometers is evidenced by the statistical data contained in Table 8, which shows that in the period under study there were quite significant changes in the transport performance expressed in passenger kilometers. The average transport volume is the highest in the case of road transport. This state of affairs is not surprising, because it is the road infrastructure that has been most intensively developed in recent years, which results in the above-mentioned primacy in terms of the level of transport. In second place is rail transport. This branch of transport still struggles with numerous problems, but efforts are being made to change this unfavorable state of affairs. Much less transport is carried out by air and inland navigation, but in the case of air transport an increasing trend can be observed. Passenger transport by sea remained relatively stable.

Table 9 shows that after 2022, the volume of rail transport systematically decreased. The volume of transport by this type of transport until 2021 decreased compared to the volume of transport in 1995. In road transport, we observe a systematic decline in the volume of transport. In the last analyzed year, transport decreased by 35.8%. There are quite large fluctuations in air transport. The value of the single-base index (1995 = 100) obtained for the year 2022 was 599.2%, which means that air transport increased by over 500% this year. There are also quite large differences in inland and sea navigation. A clear downward trend can be observed in inland navigation. Total transport expressed in passenger kilometers decreased in 2020 by 57.8% compared to the starting year, i.e. 1995.

Regularities occurring in transport carried out by various modes of transport are illustrated by the statistical characteristics presented in Table 10, which show that road transport is characterized by the greatest regularity, because the obtained estimates of parameters a_0 and a_1 are statistically significant, as evidenced by high values, many times exceeding the value critical, Student's t-test values. The coefficient of determination is also high, $R^2 = 0.85$. Slightly worse results were obtained for air transport, but also in this case the scores a_0 and a_1 are statistically significant. The coefficient of determination is much lower than the coefficient of determination obtained for road transport. The value of this coefficient is 0.27.

The structure of transport expressed in passenger kilometers is presented in the statistical data included in Table 11, which shows that road and rail transport played the dominant role in transport expressed in passenger kilometers. Air transport also had a significant share, from 7.1% (in 1995) to 25.7% (in 2015). Discussions about other rankings have already mentioned the reasons for the growing share of aviation in transport. The share of inland navigation was small and ranged in 2010 from 0.2% to 0.4%.

Table 12 shows that a quite clear pattern occurs only in the case of the structure of air transport, because the estimates a_0 and a_1 are statistically significant, and the value of the coefficient of determination is quite high and amounts to 0.92. In the case of other types of transport, changes in the structure do not show any clear regularities.

5. Conclusions

Analyzing data on the structure of passenger traffic in the years 1995-2022, the advantage of road transport is visible, which is systematically growing in terms of passenger transport. The upward trend in passenger traffic is also shared by air transport. The situation of the railway sector is completely different, as the presented data indicate a decreasing number of passengers using this means of transport. Nevertheless, rail transport still constitutes a significant part of total transport traffic, and the investments made give hope for improving the current state of affairs. The share of sea transport and inland navigation in passenger traffic is small.

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Appendix

Table 1.

Passenger transport in thousands of people by mode of transport in 1995-2022

Year	Type of transport					Total
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping	
1995	465901	1131593	1847	1208	458	1601007
2000	360687	954515	2880	1265	625	1319972
2005	258110	782025	4637	1144	714	1046930
2010	261314	569652	4990	1397	671	838024
2015	277321	416774	7288	1762	597	703742
2020	208651	159700	3629	682	1148	373810
2021	244874	168619	6996	986	1487	422962
2022	342139	214443	12893	1101	1472	572048

Source: own study based on Central Statistical Office data.

Table 2.

Passenger transport in percentage by mode of transport in the years 1995-2022 (1995 = 100)

Year	Type of transport					Total
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping	
1995	93.2	95.9	110.6	53.6	120.1	95.1
2000	77.4	84.4	155.9	104.7	136.5	82.4
2005	55.4	69.1	251.1	119.5	155.9	65.4
2010	56.1	50.3	270.2	115.6	146.5	52.3
2015	59.6	36.8	394.6	145.9	130.3	44.0
2020	44.8	14.1	196.5	56.5	250.7	23.3
2021	52.6	14.9	378.8	81.6	324.7	26.4
2022	73.4	18.9	698.1	91.1	321.4	37.7

Source: own study based on Central Statistical Office data.

Table 3.

Parameter estimates and statistical characteristics for Model 1

Rodzaj transportu	Model parameters					
	Rating a_0	$t(a_0)$	Rating a_1	$t(a_1)$	Se	R^2
Rail transport	42412	27.22	- 10072	7.44	34578	0.76
Road transport	1252314	66.22	- 375	26.78	42368	0.98
Air transport	1331.2	5.35	312.5	16.13	589.1	0.91
Inland shipping	586.79	18.01	5.22	1.90	67.07	0.17
Sea shipping	1485.4	2.04	24.023	0.38	1660	0.09
Total	1752412	59.79	- 38695	22.33	59244	0.97

Source: own study based on calculations.

Table 4.

Percentage structure of passenger transport in thousands people (according to the number of passengers) by mode of transport in the years 1995-2022

Year	Type of transport				
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping
1995	29.1	70.7	0.1	0.1	0.0
2000	27.3	72.3	0.2	0.1	0.1
2005	24.7	74.7	0.4	0.1	0.1
2010	31.1	68.0	0.6	0.2	0.1
2015	39.5	59.2	1.0	0.1	0.3
2020	55.8	42.7	1.0	0.2	0.3
2021	57.9	39.8	1.8	0.2	0.3
2022	59.8	37.5	2.2	0.2	0.3

Source: own study based on Central Statistical Office data.

Table 5.

Average distance in kilometers of transport of 1 passenger in the years 1995-2022

Year	Type of transport				
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping
1995	57	30	2509	21	330
2000	67	33	2095	20	207
2005	70	37	1834	14	263
2010	69	38	1658	17	250
2015	63	52	1851	12	233
2020	60	45	2127	14	121
2021	65	44	1874	13	108
2022	70	54	2153	12	113

Source: own study based on Central Statistical Office data.

Table 6.

Parameter estimates and statistical characteristics of the average transport distance of 1 passenger in kilometers in the years 1995-2022 for the trend model

Type of transport	Model parameters					
	Rating a_0	$t(a_0)$	Rating a_1	$t(a_1)$	Se	R ²
Rail transport	23.11	15.78	0.53	4.28	3.44	0.49
Road transport	76.45	58.75	0.56	5.16	2.87	0.62
Air transport	- 0.06	1.15	0.04	13.59	0.12	0.92
Inland shipping	0.04	14.00	0.002	17.83	0.004	0.94
Sea shipping	0.07	1.72	0.009	1.96	0.14	0.19

Source: own study based on calculations.

Table 7.

Dynamics of the average distance in kilometers of transport of 1 passenger in the years 1995-2022 (1995 = 100)

Year	Type of transport				
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping
2000	117.5	110.0	83.5	90.5	62.7
2005	122.8	123.3	73.1	66.7	80.0
2010	121.1	126.7	66.1	81.0	75.8
2015	110.5	173.3	73.8	57.1	70.6
2020	105.3	150.0	84.8	66.7	40.3
2021	114.0	146.7	74.7	61.9	32.7
2022	122.8	180.0	85.8	57.1	34.2

Source: own study based on Central Statistical Office data.

Table 8.*Passenger transport in passenger kilometers in millions by modes of transport in 1995-2022*

Year	Type of transport					Total
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping	
1995	26635	34024	4633	25	151	65468
2000	24093	31735	6034	26	129	62017
2005	18157	29314	8504	21	188	56184
2010	17921	21600	8273	23	168	47985
2015	17367	21570	13487	22	139	52584
2020	12557	7176	7720	10	139	27602
2021	15917	7448	13113	13	161	36652
2022	23827	11623	27762	13	167	63392

Source: own study based on Central Statistical Office data.

Table 9.*Passenger transport in passenger kilometers by mode of transport in 1995-2022 (1995 = 100)*

Year	Type of transport					Total
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping	
1995	99.8	99.9	95.1	52.0	103.3	99.5
2000	90.5	93.3	130.2	104.0	85.4	94.8
2005	68.2	86.2	183.6	84.0	124.5	85.8
2010	67.3	63.5	178.6	92.0	111.3	73.3
2015	65.2	63.4	291.1	88.0	92.1	80.3
2020	47.1	21.1	166.6	40.0	92.1	42.2
2021	59.7	21.9	283.0	52.0	106.6	56.0
2022	89.5	34.2	599.2	52.0	110.6	96.8

Source: own study based on Central Statistical Office data.

Table 10.*Parameter estimates and statistical characteristics of passenger transport in passenger kilometers for the trend model*

Type of transport	Model parameters					
	Rating a_0	$t(a_0)$	Rating a_1	$t(a_1)$	Se	R ²
Rail transport	58.69	37.55	0.16	0.82	4.2	0.05
Road transport	29.11	28.22	0.92	9.88	2.6	0.85
Air transport	2456.1	14.69	-30.21	2.78	367.1	0.27
Inland shipping	25.5	16.23	-0.57	3.56	3.45	0.40

Source: own study based on calculations.

Table 11.*Percentage structure of passenger transport work by mode of transport in 1995-2022*

Year	Type of transport				
	Rail transport	Road transport	Air transport	Inland shipping	Sea shipping
1995	40.7	52.0	7.1	0.0	0.2
2000	38.8	51.2	9.8	0.0	0.2
2005	32.3	52.3	15.1	0.0	0.3
2010	37.4	45.0	17.2	0.0	0.4
2015	33.1	41.0	25.6	0.0	0.3
2020	45.5	26.0	28.0	0.0	0.5
2021	43.4	20.4	35.8	0.0	0.4
2022	37.6	18.3	43.8	0.0	0.3

Source: own study based on Central Statistical Office data.

Table 12.

Parameter estimates and statistical characteristics of the passenger transport structure in passenger kilometers for the trend model

Type of transport	Model parameters					
	Rating a_0	$t(a_0)$	Rating a_1	$t(a_1)$	Se	R^2
Rail transport	40.17	41.64	- 0.37	4.79	2.13	0.55
Road transport	55.53	51.80	- 0.67	7.82	2.37	0.76
Air transport	4.06	4.52	1.03	14.38	1.98	0.92
Inland shipping	0.22	12.72	0.005	3.75	0.04	0.43

Source: own study based on calculations.