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ANALYSIS AND FORECAST OF PASSENGER FLOWS IN PUBLIC TRANSPORT – THE CASE OF POLAND

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A b s t r a c t

Public transportation provides its services to both urban centers and neighboring areas in the immediate vicinity of the city. The problem of urban transportation is evident, the number of people willing to use public transportation has decreased. Therefore, there is a need to delve into the issue and conduct an analysis of the demand for urban transportation in Poland in 2000-2030, this will allow us to assess in what direction urban transportation is heading, whether there is an increase in the number of people using it, or whether there is a downward trend (ZIELIŃSKA 2018).

Based on CSO statistics from 2009-2020 for the analysis of demand for public transportation in Poland, a forecast of people using public transportation was conducted using Statistica software for 2021-2030. Due to the situation with the COVID-19 pandemic, the study was conducted in 2 ways – with and without 2020.

Public transportation will make less and less profit and even losses for the next few years through rising gasoline and energy prices. Virtually in each of the provinces, and likewise throughout Poland, a decline in the number of people willing to use public transportation is evident. conclusions.

On the basis of the surveys carried out, there is a general trend that shows the current state of public transport. In most of the cases studied, a similar conclusion emerges, namely that public transport will experience a marked decline in the coming years. The number of people who want to use public transport will decrease, mainly due to the COVID-19 pandemic and people's fears for their own safety.

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Introduction

Transportation is an activity that aims to cover some area. Taking into account the economic aspect, this enterprise involves the profitable provision of services. The result of transportation activities is the movement of people and material goods, as well as the provision of additional ancillary services that are directly related to the primary services.

Public mass transportation is publicly available regular passenger transportation performed at specific intervals and along a specific line or transportation network. There are five basic subsystems of public transportation found in various cities in Poland, such as buses, trolleybuses, streetcars, subways and light rail.

Public transportation provides its services to both urban centers and neighboring areas in the immediate vicinity of the city. Public transportation in recent years has been trying to develop for the convenience of those who use its services. Despite the continuous and rapid development of transportation, some people have opted for transportation by private means. The problem of urban transportation is evident, the number of people willing to use public transportation has decreased. Therefore, there is a need to delve into the problem and conduct an analysis of the demand for urban transport in Poland in 2000-2030, this will allow to assess in what direction urban transport is heading, whether the number of people using it is increasing or there is a downward trend (Zielińska 2018).

The problem of forecasting is well known in the literature. It has been used, among other things, to forecast the number of traffic accidents. The vector autoregression model has also been used to forecast the number of traffic accidents, the disadvantage of which is the need to have a large number of observations of the variables in order to correctly estimate their parameters (Wójcik 2014), as well as the autoregression models of Monederoa et al. (2021) for analyzing the number of fatalities and Al-Madani (2018) curve-fit regression models. These, on the other hand, require only simple linear relationships (Mamczur 2022), and row autoregression (assuming the series is already stationary) (Piłatowska 2012) or exponential smoothing (Gorzelanczyk et al. 2022).

Chudy-Laskowska and Pisula (2015) in their work used the ANOVA method to predict the number of traffic collisions. The disadvantage of this method is that it makes additional assumptions, especially the assumption of sphericity, the violation of which can lead to erroneous conclusions (Gregorczyk, Swarcewicz 2012). Neural network models are also used to forecast the number of traffic accidents. The disadvantages of ANNs are the need for experience in the field (Chudy-Laskowska, Pisula 2014, Wróbel 2017) and the dependence of the final solution on the initial conditions of the network, as well as the inability to interpret in the traditional way, as ANNs are usually referred to as a black box, where the user provides input data and the model provides output data without knowledge of the analysis (*Techniki zgłębiania danych (Data mining)* 2022).

A new prediction method is the use of the Hadoop model by Kumar et al. (2019). The disadvantage of this method is the inability to work with small data files (*Top Advantages and Disadvantages of Hadoop 3* 2022). Karlaftis and Vlahogianni

(2009) used the Garch model for prediction. The disadvantage of this method is its complex form and complicated model (PERCZAK, FISZEDER 2014, FISZEDER 2009) On the other hand, McIlroy and his team used the ADF test (2009), which has the disadvantage of poor power in the case of autocorrelation of the random component (MUĆK 2022).

The authors of publications (SHETTY et al. 2017, LI et al. 2017) also used Data--Mining techniques for forecasting, which usually have the disadvantage of huge sets of general descriptions (MARCINKOWSKA 2015). One also encounters the combination of models proposed by SEBE et al. (2008) as a combination of different models. Parametric models are also proposed in the work of BLOOMFIELD (1973). On the other hand, the analysis of public transport costs was analyzed in the works (GORZELAŃCZYK, KOCZOROWSKI 2018a, 2018b). Given the diversity of forecasting methods, the authors used exponential smoothing methods in their work to get an opinion on how demand for urban transportation will develop in the following years in the analyzed provinces, so that measures can be introduced to encourage residents to use public transport instead of individual transport.

The forecasting methods presented can be successfully used to forecast not only road accidents, but also other events, such as forecasting passenger flows in public transport. Taking into account the above literature review, the authors carried out an analysis and forecast of passenger flows in public transport – the case of Poland.

Research

Methods and measures

The object of the research work is to conduct an analysis of the demand for public transportation of Polish society in 2000-2030. The results of the research will show the direction in which public transportation is heading. With the help of statistical research, the development or regression of public transportation will be determined.

The study was conducted in 2021 based on data collected by the Central Statistical Office in Poland. Due to the situation with the COVID-19 pandemic, the survey was conducted in 2 ways – with and without 2020 (i.e., excluding the pandemic year). Statistica program was used to conduct the survey.

The Statistica program offers access to a wide range of forecasting methods. One of the methods that was used in the study is the exponential smoothing method. The research method is considered the most accurate of all existing methods. The exponential smoothing method involves using the forecast for period t, which is equal to the forecast of that variable for period t-1, adjusted by the product of the smoothing parameter α, $0 \leq \alpha \leq$ and the value of its absolute error:

$$y^t = \alpha y_{(t-1)} + (1 - \alpha)\, y_{t-1}.$$

The parameter α is chosen using the smallest error criterion of expired forecasts (RABIEJ 2012). The exponential smoothing method is a method for forecasting time series with one-dimensional data. Forecasts made using exponential smoothing methods include a weighted average of preceding observations. The weights are distributed proportionally to the extinction of historical observations. Thus, the more recent the observation, the higher the weight (*Introduction to exponential smoothing* 2022).

Results

Surveys conducted by the Central Statistical Office (CSO) were used to analyze the research. The surveys conducted by the CSO were carried out from 2009 to 2020. In earlier years, surveys were not conducted by various types of institutions, as well as public transportation facilities were not required to keep relevant statistics showing the scale of people using public transportation in 2000-2008.

The results of the survey presented in Tables 1 and 2 are collected for the entire Polish population and for individual provinces in Poland. The data are presented in millions of passengers using public transportation in Poland. The data presented in the tables, come from CSO statistics from 2009-2020 by province. The tables also include information on forecasting the number of people using public transportation in 2021-2030 (with the pandemic) and 2020-2030 (without the pandemic).

Table 1

Passenger transportation by public transportation in 2009-2014

Passenger transport in millions	2009 [person]	2010 [person]	2011 [person]	2012 [person]	2013 [person]	2014 [person]
1	2	3	4	5	6	7
Poland	3,779.0	3,904.9	3,890.0	3,867.5	3,620.9	3,711.1
Lower Silesia	230.0	242.6	215.9	242.0	251.7	259.2
Kujawsko-Pomorskie	177.0	189.7	174.1	167.7	173.6	168.9
Lublin	100.0	98.9	98.0	126.1	133.3	140.6
Lubuskie	47.0	45.4	42.0	41.3	40.1	39.2
Lodz	192.0	189.9	215.9	255.4	250.1	254.6
Małopolska	371.0	389.7	396.7	408.4	416.6	484.9
Mazowieckie	1,065.0	1,117.0	1,111.0	1,021.2	919.1	908.7
Opole	30.0	28.7	28.2	25.5	25.5	21.5
Podkarpackie	62.0	58.2	54.0	48.2	54.7	53.4
Podlaskie	103.0	99.5	108.2	110.1	108.4	108.8
Pomeranian	291.0	303.1	292.7	279.1	284.7	287.8

cont. Table 1

1	2	3	4	5	6	7
Silesian	547.0	461.0	570.3	585.6	460.9	436.5
Świętokrzyskie	46.0	46.1	47.3	47.9	47.7	48.6
Warmińsko-Mazurskie	67.0	73.6	63.4	59.5	50.7	64.4
Wielkopolska	270.0	381.5	290.2	268.5	226.6	259.2
West Pomeranian	181.0	180.0	182.2	181.0	177.1	175.0

Source: based on *Transport pasażerów* (2021).

Table 2

Passenger transport by public transport from 2015 to 2020

Passenger transport in millions	2015 [person]	2016 [person]	2017 [person]	2018 [person]	2019 [person]	2020 [person]
Poland	3,672.2	3,766.3	3,739.4	3,774.1	3,864.9	2,270.8
Lower Silesia	264.1	271.1	281.2	274.8	260.5	162.8
Kujawsko-Pomorskie	181.8	182.9	172.0	172.4	174.2	113.8
Lublin	143.5	142.1	141.3	128.8	146.7	86.3
Lubuskie	43.1	42.9	43.5	43.4	43.5	32.3
Lodz	258.4	300.1	230.9	251.2	255.9	155.5
Małopolska	396.9	418.2	444.9	450.7	455.2	244.3
Mazowieckie	930.2	924.7	937.7	975.2	1,026.1	567.3
Opole	25.4	25.5	25.8	25.9	26.7	16.1
Podkarpackie	52.6	55.5	59.6	63.3	72.8	31.9
Podlaskie	108.9	108.5	106.3	101.8	96.6	41.4
Pomeranian	291.6	291.7	291.5	292.1	299.5	192.5
Silesian	416.7	413.7	406.1	403.8	375.3	203.6
Świętokrzyskie	48.5	46.8	46.2	45.2	46.3	32.9
Warmińsko-Mazurskie	53.8	63.2	66.3	65.1	65.4	44.4
Wielkopolska	279.8	299.8	306.2	313.4	309.2	200.2
West Pomeranian	176.7	179.5	180.1	166.9	210.9	145.7

Source: based on *Transport pasażerów* (2021).

The next step after collecting the relevant data is to create a graph of it, which will show whether the historical values are cyclical, seasonal, linear trend, constant or random. This procedure will allow the selection of an appropriate research method. Figure 1 shows a graph with collected data on demand for urban transportation in Poland. The graph shown for Poland indicates the random nature.

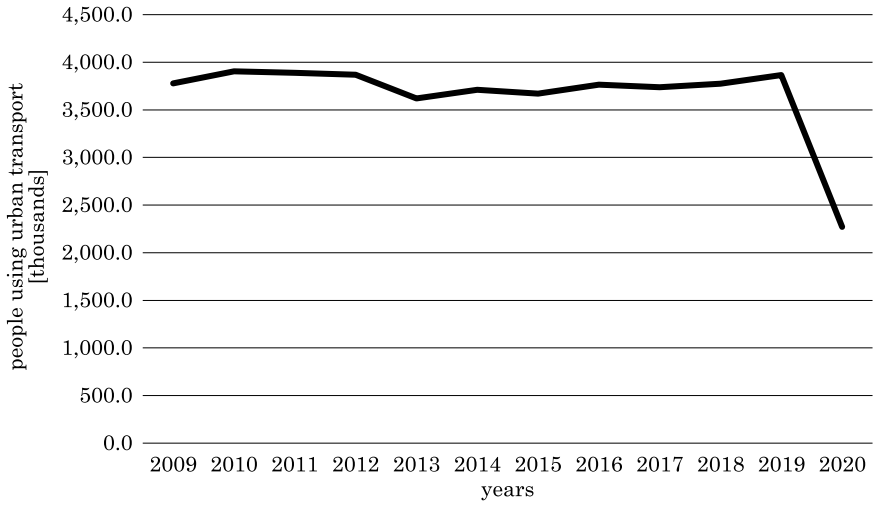

Fig. 1. Demand for urban transport in Poland from 2009 to 2020
Source: based on *Transport pasażerów* (2021).

Thus compiled, the author entered the data into Statistica software, which made it possible to develop a forecast for 2021-2030. The study was conducted in 2 ways. With 2020 and without 2020. The author conducted the analysis in this way, because 2020 is the year of the COVID-19 pandemic, in this way it is possible to predict how transportation demand would have developed without the pandemic year, and to see what effects the pandemic had on urban transportation.

The methodology of the study for each province will be presented in 1 of the examples. The same study will be conducted for the collected data of the entire country. The rest of the results will be presented in a summary table that will show the results for the other surveyed centers.

The various forecasting techniques used for the study are as follows:

– M1 – moving average method 2-points;
– M2 – moving average method 3-points;
– M3 – moving average method 4-points;
– M4 – exponential smoothing no trend seasonal component: none;
– M5 – exponential smoothing no trend seasonal component: additive;
– M6 – exponential smoothing no trend seasonal component: multiplicative;
– M7 – exponential smoothing linear trend seasonal component: none Holt;
– M8 – exponential smoothing linear trend seasonal component: additive;
– M9 – exponential smoothing linear trend seasonal component: multiplicative Winters;
– M10 – exponential smoothing exponential seasonal component: none;
– M11 – exponential smoothing exponential seasonal component: additive;

– M12 – exponential smoothing exponential seasonal component: multiplicative;

– M13 – exponential smoothing fading trend seasonal component: none;

– M14 – exponential smoothing fading trend seasonal component: additive;

– M15 – exponential smoothing fading trend seasonal component: multiplicative.

The essence of this method is that the time series of the forecast variable is smoothed using a weighted moving average, and the weights are determined according to the exponential function. The weights were optimally selected by the program, Statistica, in which the study was conducted. The forecast in this case is based on a weighted average of the current and historical values of the series. The result of the forecast using this method, depends on the choice of the model and its parameters.

The following errors of expired forecasts determined from equations were used to calculate measures of analytical forecasting perfection:

– ME – mean error

$$\mathrm{ME} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - Y_p\right) \tag{1}$$

– MAE – mean everage error

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - Y_p\right| \tag{2}$$

– MPE – mean percentage error

$$\mathrm{MPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{Y_i - Y_p}{Y_i} \tag{3}$$

– MAPE – mean absolute percentage error

$$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|Y_i - Y_p\right|}{Y_i} \tag{4}$$

– MSE – mean square error

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - Y_p\right)^2 \tag{5}$$

where:

n – the length of the forecast horizon,

Y – observed value of urban transportation demand,

Y_p – forecasted value of urban transportation demand.

On the basis of the exponential smoothing and forecasting error methods adopted, the forecasting method for which the value of the mean absolute percentage error was the smallest was selected and the results are shown in the figures below.

Then the same analysis was performed for the same example, but excluding the 2020 pandemic year. The methodology for the other models and subsequent provinces is the same as shown in the Figures above. The results of the analysis will be presented in Table 3 and Figures 2, 3, 4. Based on the analysis, it can be concluded that the results of the study are greatly influenced by the COVID-19 pandemic and thus the way of travel and developments in the next few years. On the other hand, the forecast with the pandemic year cut out in most cases is very optimistic. It even depicts a gentle increase in willing people using public transportation. This means an increase in demand for public transportation if pandemic years are not taken into account.

Table 3

Forecast for Poland, Lower Silesia and Kujawsko-Pomorskie with and without 2020

Years	Poland		Lower Silesia		Kujawsko-Pomorskie	
1	2		3		4	
2009	3,779.0		230.0		177.0	
2010	3,904.9		242.6		189.7	
2011	3,890.0		215.9		174.1	
2012	3,867.5		242.0		167.7	
2013	3,620.9		251.7		173.6	
2014	3,711.1		259.2		168.9	
2015	3,672.2		264.1		181.8	
2016	3,766.3		271.1		182.9	
2017	3,739.4		281.2		172.0	
2018	3,774.1		274.8		172.4	
2019	3,864.9		260.5		174.2	
Years	with 2020	without 2020	with 2020	without 2020	with 2020	without 2020
2020	2,270.800	3,925.317	162.8000	276.8642	113.8000	173.7780
2021	2,427.259	4,010.564	211.2293	279.1984	110.8273	173.6884
2022	2,206.354	4,097.663	200.8785	281.5522	100.1984	173.5989
2023	2,005.553	4,186.653	191.0350	283.9259	90.5889	173.5094
2024	1,823.027	4,277.576	181.6738	286.3195	81.9009	173.4200
2025	1,657.113	4,370.473	172.7714	288.7334	74.0462	173.3306
2026	1,506.299	4,465.388	164.3051	291.1676	66.9448	173.2412
2027	1,369.210	4,562.364	156.2538	293.6224	60.5245	173.1519

cont. Table 3

1	2		3		4	
2028	1,244.598	4,661.446	148.5970	296.0978	54.7199	173.0627
2029	1,131.327	4,762.680	141.3154	298.5941	49.4719	172.9735
2030	1,028.365	4,866.112	134.3906	301.1114	44.7273	172.8843

Source: based on *Transport pasażerów* (2021).

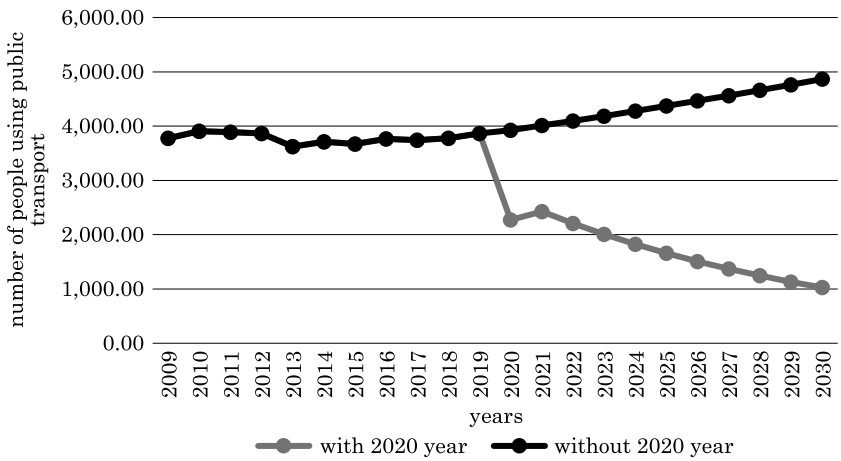

Fig. 2. Demand for urban transportation in Poland from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

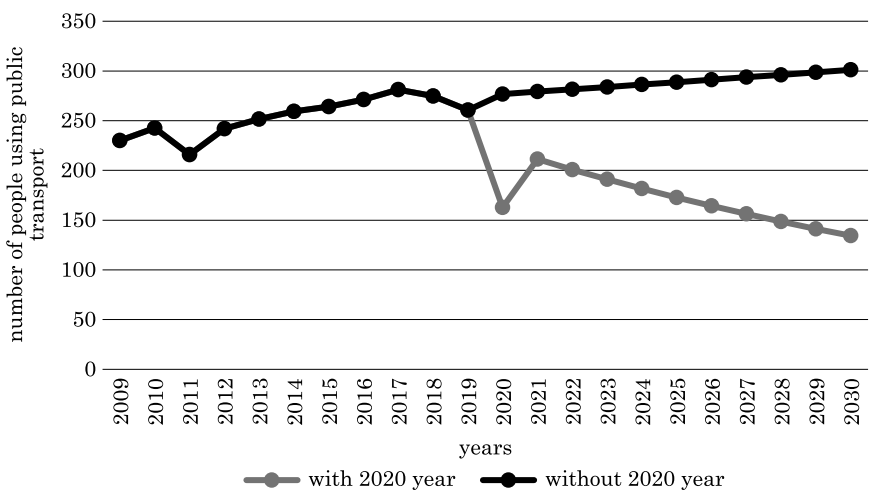

Fig. 3. Demand for urban transportation in the Lower Silesian province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

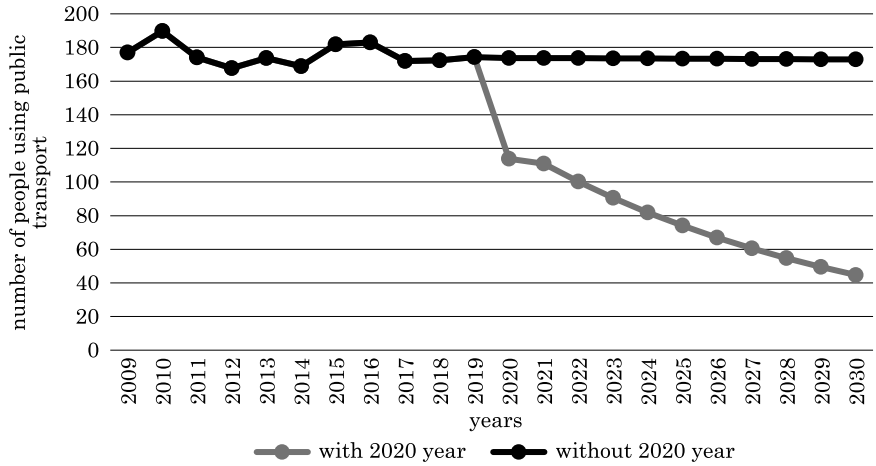

Fig. 4. Demand for urban transportation in the Kujawsko-Pomorskie region from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

Table 4 and Figures 5, 6, 7 show the forecast results for Lubelskie, Lubuskie and Łódzkie provinces. As in Table 3, a decrease in demand for public transportation is visible due to the COVID-19 pandemic. Taking into account the absence of the pandemic, a slight decrease is visible for Lubelskie Province. In contrast, a slight increase in demand is evident for Lubuskie and Lodz provinces.

Table 4

Forecast for Lubelskie, Lubuskie and Łódzkie provinces
with 2020 and without 2020

Years	Lubelskie	Lubuskie	Łódzkie
1	2	3	4
2009	100.0	47.0	192.0
2010	98.9	45.4	189.9
2011	98.0	42.0	215.9
2012	126.1	41.3	255.4
2013	133.3	40.1	250.1
2014	140.6	39.2	254.6
2015	143.5	43.1	258.4
2016	142.1	42.9	300.1
2017	141.3	43.5	230.9
2018	128.8	43.4	251.2
2019	146.7	43.5	255.9

cont. Table 4

1	2		3		4	
2020	with 2020	without 2020	with 2020	without 2020	with 2020	without 2020
	86.3000	145.6652	32.30000	43.58854	155.5000	258.3707
2021	86.1386	144.6377	32.17798	43.67714	153.7992	261.3718
2022	85.3306	143.6174	30.77527	43.76592	152.1170	264.4077
2023	84.5303	142.6043	29.43370	43.85487	150.4533	267.4789
2024	83.7374	141.5984	28.15061	43.94401	148.8077	270.5858
2025	82.9520	140.5996	26.92346	44.03333	147.1801	273.7288
2026	82.1739	139.6078	25.74980	44.12284	145.5703	276.9082
2027	81.4032	138.6230	24.62730	44.21252	143.9781	280.1246
2028	80.6396	137.6452	23.55374	44.30239	142.4034	283.3784
2029	79.8833	136.6742	22.52698	44.39244	140.8458	286.6699
2030	79.1340	135.7101	21.54497	44.48267	139.3053	289.9997

Source: based on *Transport pasażerów* (2021).

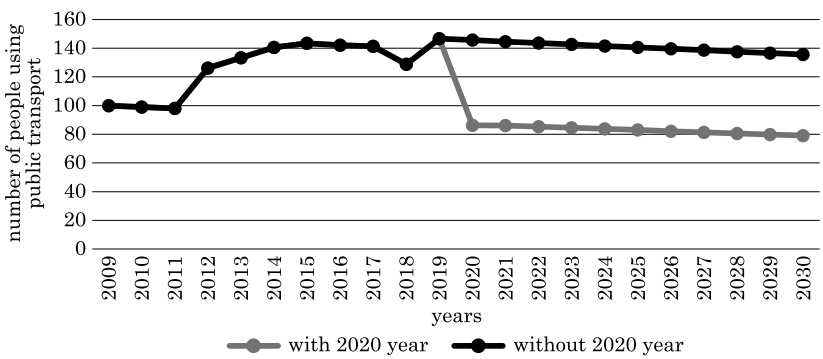

Fig. 5. Demand for urban transportation in Lublin province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

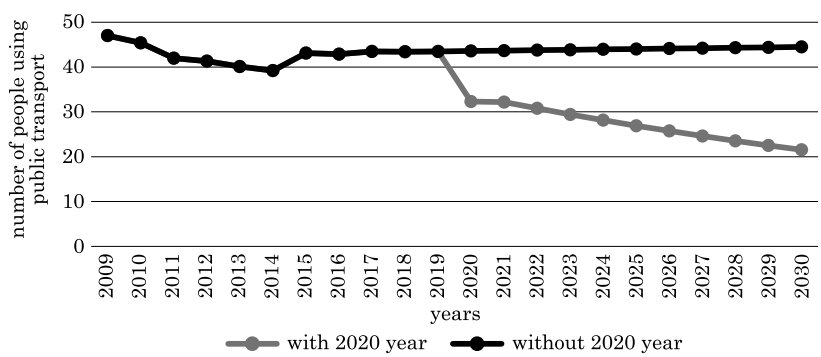

Fig. 6. Demand for urban transportation in Lubuskie province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

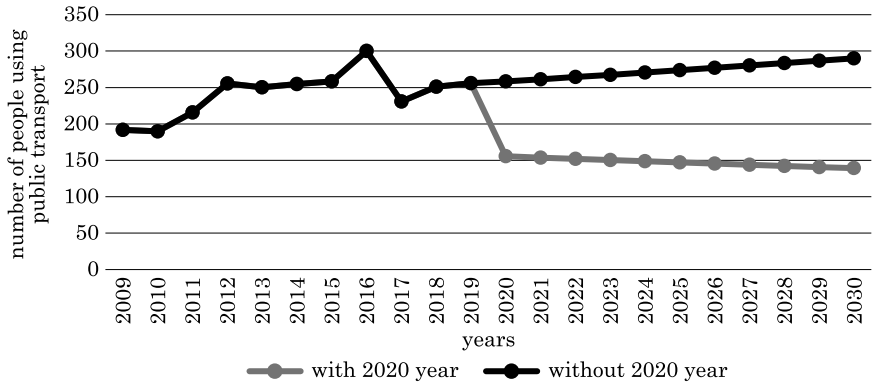

Fig. 7. Demand for urban transportation in Lodz province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

Table 5 and Figures 8, 9, 10 contain the forecast for the provinces of Lesser Poland, Mazovia and Opole. The results of the analysis indicate a decrease in the demand for public transport in the following years when 2020 is taken into account. However, the situation is reversed in the years when 2020 is not taken into account. In this case, the situation varies, however, a decrease is forecast for Małopolska province. In the case of the Mazowieckie and Opolskie provinces, a decrease is evident in the years with the pandemic year, while an increase in willingness to use public transportation can be observed without this year.

Table 5

Forecast for Małopolska, Mazowieckie and Opolskie provinces with 2020 and without 2020

Years	Małopolska	Mazowieckie	Opolskie
1	2	3	4
2009	371.0	1,065.0	30.0
2010	389.7	1,117.0	28.7
2011	396.7	1,111.0	28.2
2012	408.4	1,021.2	25.5
2013	416.6	919.1	25.5
2014	484.9	908.7	21.5
2015	396.9	930.2	25.4
2016	418.2	924.7	25.5
2017	444.9	937.7	25.8
2018	450.7	975.2	25.9
2019	455.2	1,026.1	26.7

cont. Table 5

1	2		3		4	
Years	with 2020	without 2020	with 2020	without 2020	with 2020	without 2020
2020	244.3000	451.8779	567.300	1,054.278	16.10000	27.09485
2021	386.4188	450.5581	565.499	1,083.229	21.41074	27.61077
2022	359.1361	449.2422	563.704	1,112.976	21.22902	28.13652
2023	333.7796	447.9301	561.915	1,143.539	21.04885	28.67227
2024	310.2134	446.9219	560.132	1,174.942	20.87020	29.21822
2025	288.3111	445.3175	558.354	1,207.207	20.69307	29.77457
2026	267.9552	444.0169	556.582	1,240.358	20.51744	30.34152
2027	249.0364	442.7200	554.815	1,274.419	20.34330	30.91926
2028	231.4535	441.4270	553.054	1,309.416	20.17065	31.50800
2029	315.1119	440.1378	551.299	1,346.374	19.99945	32.10795
2030	199.9241	438.4523	549.549	1,382.319	19.82971	32.71932

Source: based on *Transport pasażerów* (2021).

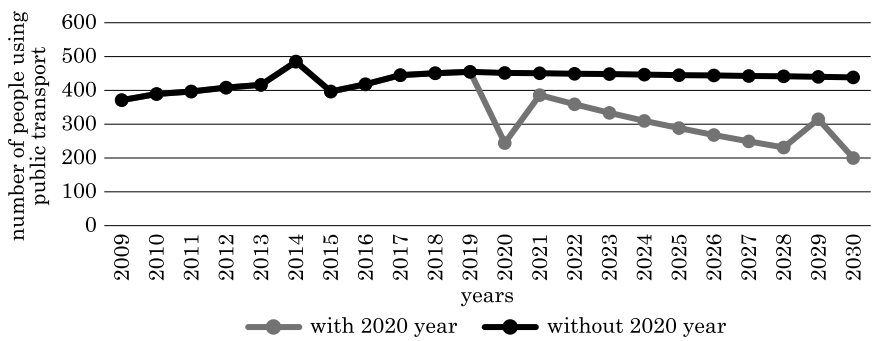

Fig. 8. Demand for urban transportation in Małopolska province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

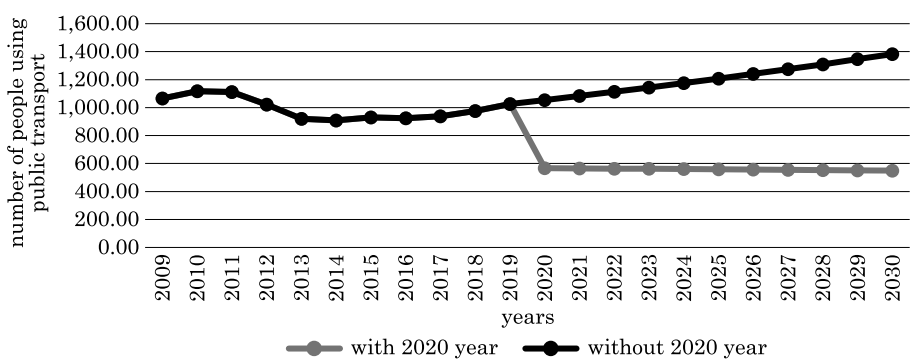

Fig. 9. Demand for urban transportation in the Mazowieckie Voivodeship from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

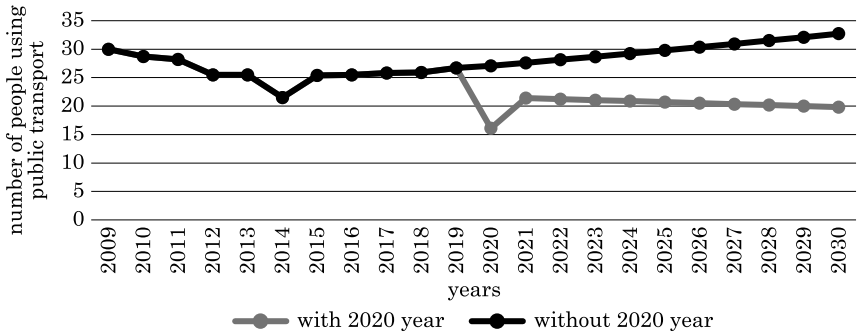

Fig. 10. Demand for urban transportation in Opole province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

With the help of Table 6 and Figures 11, 12, 13, the forecast for Podkarpackie, Podlaskie and Pomorskie provinces can be seen. It can be seen that for Podkarpackie and Pomorskie Voivodeship, an increase in public transport demand is visible excluding 2020 and with 2020. However, for Podlaskie Voivodeship, a decrease is visible for both analyses.

Table 6

Forecast for Podkarpackie, Podlaskie and Pomorskie Voivodeships with 2020 and without 2020

Years	Podkarpackie		Podlaskie		Pomorskie	
1	2		3		4	
2009	62.0		103.0		291.0	
2010	58.2		99.5		303.1	
2011	54.0		108.2		292.7	
2012	48.2		110.1		279.1	
2013	54.7		108.4		284.7	
2014	53.4		108.8		287.8	
2015	52.6		108.9		291.6	
2016	55.5		108.5		291.7	
2017	59.6		106.3		291.5	
2018	63.3		101.8		292.1	
2019	72.8		96.6		299.5	
Years	with 2020	without 2020	with 2020	without 2020	with 2020	without 2020
2020	31.9000	77.4660	41.4000	92.8559	192.5000	301.4678
2021	59.5565	86.6605	39.9932	88.9125	198.9839	304.1687
2022	62.07678	96.9463	38.6342	85.1366	187.806	306.8939
2023	64.70372	108.4529	37.3214	81.5210	177.2561	309.6435
2024	67.44181	121.3252	36.0532	78.0590	167.2988	312.4177

cont. Table 6

1	2		3		4	
2025	70.29578	135.7254	34.8281	74.7440	157.9008	315.2168
2026	73.27052	151.8347	33.6446	71.5697	149.0308	318.0410
2027	76.37114	169.856	32.5013	68.5303	140.6591	320.8904
2028	79.60298	190.0163	31.3969	65.6200	132.7576	323.7654
2029	82.97157	212.5695	30.3300	62.8332	125.3000	326.6662
2030	86.48272	237.7995	29.2994	60.1648	118.2613	329.5929

Source: based on *Transport pasażerów* (2021).

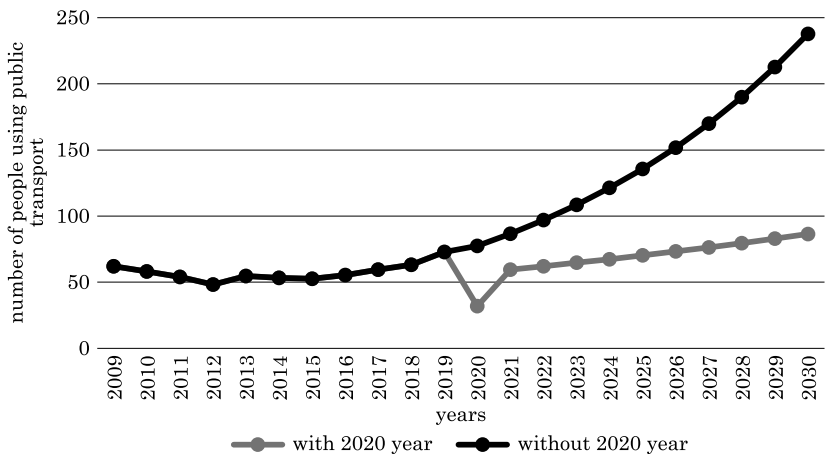

Fig. 11. Demand for urban transportation in the Subcarpathian region from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

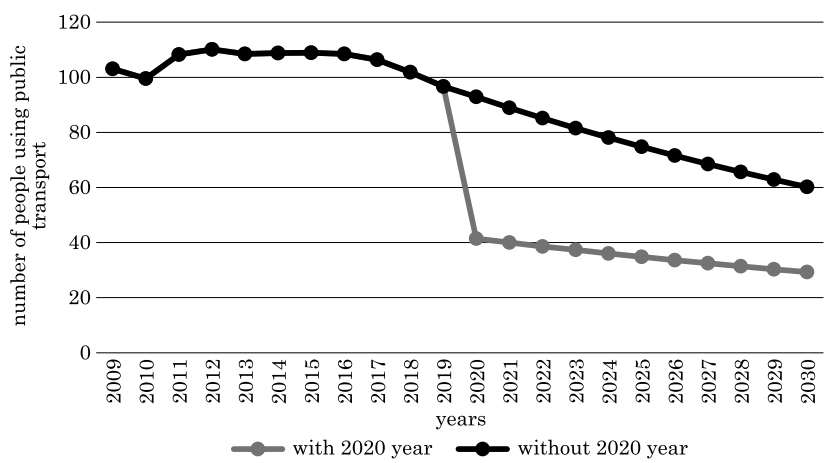

Fig. 12. Demand for urban transportation in Podlaskie province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

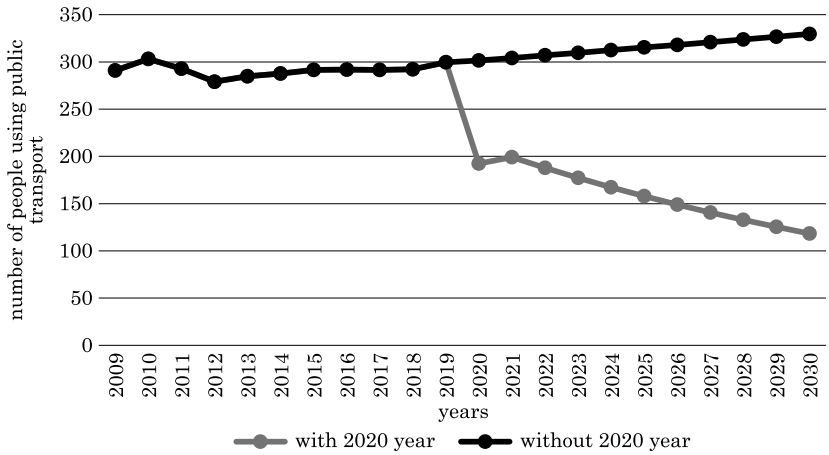

Fig. 13. Demand for urban transportation in the Pomeranian region from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

Table 7 and Figures 14, 15, 16 show the forecast results for Silesian, Świętokrzyskie and Warmian-Masurian provinces. The development of public transportation is predicted for the Warmian-Masurian Voivodeship, if the result of the forecast without 2020 is taken into account. Also minimal growth can be seen for the results of the forecast in the Świętokrzyskie province without 2020. The remaining results show a regression regardless of whether the results with or without 2020 are taken into account.

Table 7

Forecast for Silesian, Świętokrzyskie and Warmian-Masurian Voivodeships with 2020 and without 2020

Years	Śląskie		Świętokrzyskie		Warmińsko-Mazurskie	
1	2		3		4	
2009	547.0		46.0		67.0	
2010	461.0		46.1		73.6	
2011	570.3		47.3		63.4	
2012	585.6		47.9		59.5	
2013	460.9		47.7		50.7	
2014	436.5		48.6		64.4	
2015	416.7		48.5		53.8	
2016	413.7		46.8		63.2	
2017	406.1		46.2		66.3	
2018	403.8		45.2		65.1	
2019	375.3		46.3		65.4	
Years	with 2020	without 2020	with 2020	without 2020	with 2020	without 2020
2020	203.6000	362.6618	32.90000	47.69686	44.40000	73.6980
2021	202.3878	349.6768	32.97152	47.80055	59.24748	77.8187

cont. Table 7

1	2		3		4	
2022	181.4296	336.6918	33.04320	47.90446	54.73141	82.1698
2023	162.6417	323.7068	33.11503	48.00860	50.55956	86.7642
2024	145.7994	310.7218	33.18702	48.11297	46.70571	91.6154
2025	130.7012	297.7368	33.25917	48.21756	43.14562	96.7379
2026	117.1665	284.7518	33.33147	48.32238	39.85689	102.1468
2027	105.0333	271.7668	33.40393	48.42743	36.81884	107.8582
2028	94.1566	258.7818	33.47655	48.53271	34.01236	113.8888
2029	84.4063	245.7968	33.54932	48.63822	31.41981	120.2567
2030	75.6656	232.8118	33.62225	48.74395	29.02486	126.9806

Source: based on *Transport pasażerów* (2021).

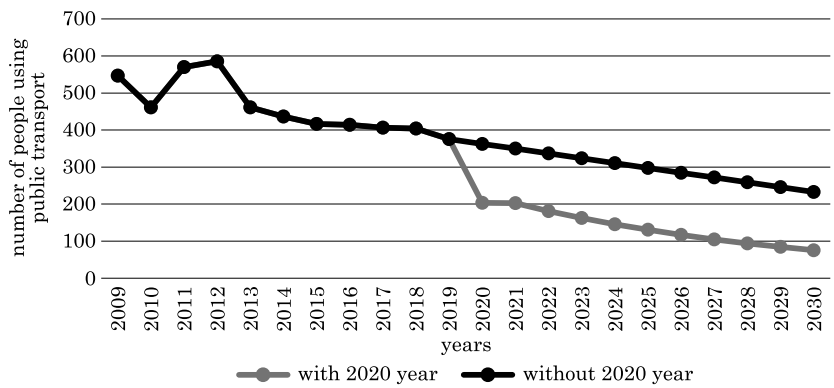

Fig. 14. Demand for urban transportation in the Silesian province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

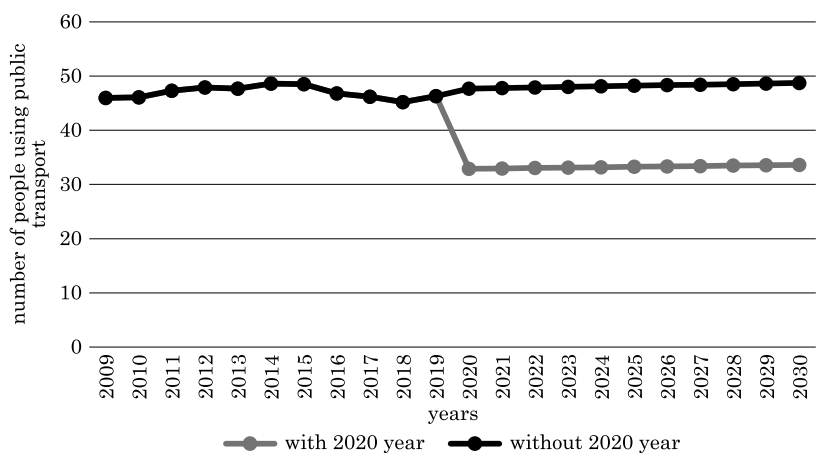

Fig. 15. Demand for urban transportation in the Świętokrzyskie province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

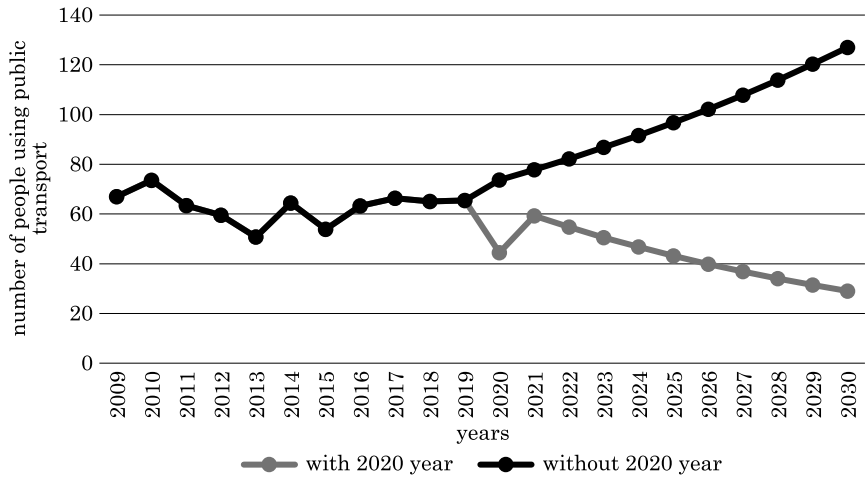

Fig. 16. Demand for urban transportation in the Warmian-Masurian province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

In the Wielkopolska and West Pomeranian Voivodeships, with the help of Table 8 and Figures 17, 18, it is apparent that there is a decrease in the need to use public transportation if the pandemic year 2020 is considered and there is also a decrease if 2020 is not considered, with the regression being smaller.

Table 8

Forecast for Greater Poland and West Pomeranian Voivodeship with 2020 and without 2020

Years	Wielkopolskie		West Pomerania	
1	2		3	
2009	270.0		181.0	
2010	381.5		180.0	
2011	290.2		182.2	
2012	268.5		181.0	
2013	226.6		177.1	
2014	259.2		175.0	
2015	279.8		176.7	
2016	299.8		179.5	
2017	306.2		180.1	
2018	313.4		166.9	
2019	309.2		210.9	
Years	with 2020	without 2020	with 2020	without 2020
2020	200.2000	308.6802	145.7000	176.3278
2021	296.6250	302.0638	168.4875	177.2372

cont. Table 8

1	2		3	
2022	277.1890	295.5892	167.5566	178.1514
2023	259.0266	289.2534	166.6309	179.9938
2024	242.0542	283.0534	165.7103	180.9222
2025	226.1939	276.9864	164.7947	181.8554
2026	211.3728	271.0493	163.8843	182.7933
2027	197.5229	265.2395	162.9788	183.7361
2028	184.5805	259.5543	162.0784	184.6838
2029	172.4861	253.9909	161.1829	185.6363
2030	161.1842	248.5467	160.2924	186.7840

Source: based on *Transport pasażerów* (2021).

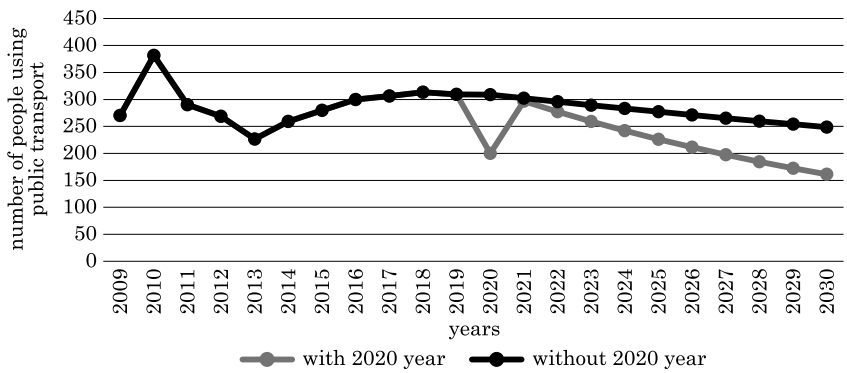

Fig. 17. Demand for urban transportation in Greater Poland province from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

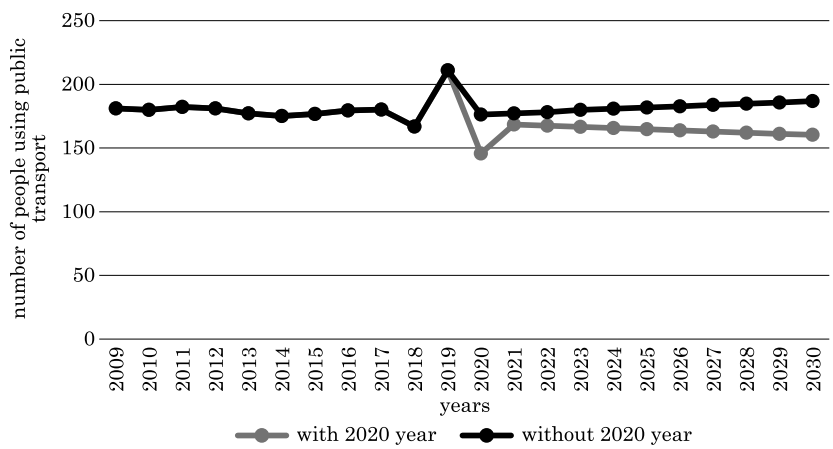

Fig. 18. Demand for urban transportation in the West Pomeranian region from 2020 to 2030
Source: based on *Transport pasażerów* (2021).

Discussion

Summarizing the results of the forecasting studies by province and for Poland with and without 2020 (the year of the pandemic), there is a general trend that shows the current state of urban transportation. In most of the cases studied, a similar conclusion is revealed, which is that public transportation will experience a marked regression in the coming years. There will be a decrease in the number of people who are willing to use public transportation.

Considering the pandemic year and comparing all provinces with each other, the survey results leave no illusions. Outside of the Podkarpackie province, a dramatic decline can be seen, by 2030 the number of people using public transportation will drop by more than half compared to 2020. However, if you cut out the pandemic year of 2020 from the forecast, you can see that the situation is changing. There is a noticeable increase in the number of people willing to use public transportation. This is true for individual provinces, but is also reflected in the results for Poland as a whole. However, despite the fact that the year 2020 is not taken into account, the Kuyavian-Pomeranian, Lublin, Podlasie, Silesian, Greater Poland and West Pomeranian provinces score a regression. Nevertheless, this is not as significant a difference as the decline in demand for public transportation in the 2020 forecast.

The reason for such a development when considering the 2020 forecast is the very small share of less developed provinces, namely Warmian-Masurian and Podlasie, as well as the area-small provinces of Lubuskie and Świętokrzyskie. The exception in this case is the Podkarpackie province, which, despite being called moderately developed, achieves high development scores compared to other provinces.

The decline in the number of demand for urban transportation is also the result of underdeveloped transportation to smaller towns. Especially those living in villages, are forced to have an individual means of transportation. In most families that live in rural areas, each person has his or her own means of transportation. Official errands, work or the desire to expand one's knowledge are the main factors by which people living in rural areas have to travel to larger cities.

Considering the results of the analysis, it can be concluded that the demand trend indicates a decline in the number of people willing to use public transportation in the coming years. A major influence on this situation is the COVID-19 pandemic, which has had a clear impact.

Referring to the research conducted by Piotr Gorzelańczyk *Change in the mobility of Polish residents during the COVID-19 pandemic*, it can be seen that the way Polish urban and rural residents move has changed. From the research conducted by Gorzelańczyk, it can be noted that during the pandemic,

people using public transportation in cities were forced to change their mode of transportation to cars, bicycles and walking. In smaller towns and villages, the situation during the pandemic did not change, because there access to public transportation is negligible, meaning that cars are mainly used for transportation. Gorzelańczyk's study and the research presented above show how much of an impact the COVID-19 pandemic had on the way people moved. One can also see a change in the purpose of movement, before the pandemic the main purposes of movement were work, shopping and then social life. During the pandemic, social life was replaced by school. On the other hand, doctor's appointments, rest or visits to parents were completely abandoned (GORZELANCZYK 2022). With the development of civilization, people's desire for individual means of transportation increased. Pandemic COVID-19 changed Polish society's perception of travel. This was due to the existing restrictions that the government put in place, such as a limit on the number of people who can travel by public transportation. In addition, measures were taken to lower fuel prices, making most people more willing to use individual transportation. This has had a clear effect, as can be seen in the available historical data.

If, on the other hand, the COVID-19 pandemic had not occurred historically, research shows that the Polish public, would increasingly use public transportation, but not in every province. However, the impact of the COVID-19 pandemic on the current demand for public transportation in Poland is significant. The result is a major regression that is unlikely to ever be restored to its pre-pandemic state. COVID-19 had an impact on reducing the number of people using road transport by an average of 10-15% depending on the province studied.

The survey, which was conducted, also helped show the transportation preferences of Polish society. Polish society is much more inclined to move by individual means of transportation, such as cars, than by public means, such as the city bus, streetcar or subway, according to the survey presented above. The Polish public uses public transportation in a small group. The survey was influenced by the epidemiological situation related to the infectious disease COVID-19. The population sought to protect itself from infection, so it opted for individual means of transportation. Before the outbreak of the pandemic, people were more likely to swap the personal car for public transportation.

In the current situation, it is virtually impossible to rebuild the position of public transportation. A large number of people who switched from public to individual transportation during this period will not return to use public transportation services again.

Conclusions

Road transport is a very important branch and the most important of all available modes of transportation. It plays an important role for the proper functioning of the country's economy. It is growing very rapidly and is the most popular available branch chosen for both passenger and cargo transportation. Individual transportation has begun to dominate as a form of transportation over mass transportation. The public wants to get from point *A* to point *B* as quickly as possible, and individual means of transportation help in this. People in Poland prefer to travel individually rather than adjusting their needs to current schedules. Road transport has a significant impact on the environment. Especially if one considers the amount of toxic gases escaping into the atmosphere. Today's vehicles are powered mainly by gasoline and diesel fuel, with marginal use of electricity to power cars. The greatest concentration of gases is caused by the use of passenger cars. The number of registered vehicles in Poland is increasing every year, resulting in increased road congestion caused by passenger transportation. Transportation also affects the daily life and health of the public. Increasing noise emissions from vehicles affect the physical as well as mental health of the public. In addition, chemicals that end up there during normal vehicle use, but also during collisions, enter the soils and air.

Urban transportation is in crisis, as evidenced by studies conducted by the author. They show that Urban transportation will lose willing users nationwide by at least half in the coming years. Taking into account the growing number of registered vehicles, one can see a greater willingness of the Polish public to travel by private means.

Considering the structure of Poland's population, one can see that Poland is dealing with an aging society. This is one opportunity for urban transportation to expand the willing group of people to use its services and rebuild. However, taken as a whole, public transportation has been in a yearly regression for many years, which is increasingly clear and visible.

Urban transportation will be less and less profitable for years to come. Studies conducted show a trend in the development of urban transportation. Virtually in each of the provinces, and equally in the whole country, there is a visible decline in the number of people willing to use urban transportation. However, the group that should be targeted to attract new takers are young urban without driving privileges, as well as older people who are willing to travel by urban transportation. The public's awareness of environmental issues should also increase, as it is apparent that despite ongoing studies, there are still visible problems in this topic.

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