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Analysis of the Impact of the Effects of Modernisation of the Railway Line on the Quality of Travel on the Section Piła – Poznań

Miłosz Gast[1], Piotr Piątkowski[2], Piotr Gorzelańczyk[1*]

[1] Department of Transport, Stanisław Staszic State University of Applied Sciences in Piła, Podchorazych 10 Street, 64-920 Pila, Poland
[2] Department of Transportation Engineering, Faculty of Mechanical Engineering, Koszalin University of Technology, Raclawicka 15-17, 75-620 Koszalin, Poland
[*] Corresponding author, e-mail: piotr.gorzelanczyk@ans.pila.pl

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Abstract

The article's purpose is to show the impact of the modernisation of the section Piła – Poznań of railway route No. 354 on the quality of travel. The detailed characteristics of the railway infrastructure in Poland and the elements included in it are presented.
Modernisation of railway line No. 354 on the route Piła – Poznań was included in the Program of the Wielkopolska Regional Operational Program for 2014–2020. As a result, 134 km of track were replaced, translating into a reduced travel time. The modernisation allowed for the reconstruction of the traffic control system equipment. The entire railway line is controlled remotely from Poznań station.
The punctuality level at Pila station when running trains between Pila and Poznań for November and December 2021 was 92.68%. The punctuality level at Poznań station when running trains from Piła to Poznań station for November and December 2021 was 89.61%. In December at Pila station, rolling stock breakdowns caused as much as 40% of all delays.
53.8% of respondents travelled most often, several times a year. According to the respondents, the comfort of travel has significantly increased, as well as punctuality. After the analysis, it was concluded that modernisation positively impacted the quality of travel.

Keywords

railway, Poland, modernisation

1 Introduction

"Wielkopolska Regional Operational Program 2014–2020" includes modernising railway line No. 354 between Pila and Poznań stations (Serwis Wielkopolskie). The program aims to achieve the European Union's economic, social and territorial cohesion by striving for sustainable development of, among others, northern Wielkopolska.

The work carried out on this line aims to increase train throughput by improving the technical condition of the entire railway line. Increase the maximum speed of travel by replacing the track and its substrate with new ones, and at the same time, reduce travel time while increasing the maximum speed at which the trains can travel. The rules for using infrastructure, development, maintenance and modernisation of rail routes are years in the making, resulting in laws. This makes it possible to clarify the rights and obligations of those who use railway services, constantly trying to avoid risks and attempting to eliminate them after constant updating.

Two types of regulations can be distinguished in rail transportation: National and international. National law is created through laws, regulations and resolutions – the acts of International law include conventions, international agreements and EU directives (Railroad Transport Office, 2021a).

Railway law in Poland is supervised by the Office of Railway Transport (ORT). ORT's main goals include managing the safety and regulation of the rail market and passenger rights. ORT controls railway managers over infrastructure quality and railways' modernisation by national and international standards.

One of the most essential infrastructure elements in the rail transportation field is electrical equipment and telematics. Telematics can be understood as modern solutions in telecommunications, information technology, information transmission and automatic traffic control in the case of rail transportation (Dąbrowa-Bajon, 2007).

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In rail transportation, we distinguish the intelligent transport system, i.e. the European Railway Transport Management System (ERTMS), which is divided into two groups: the European Traffic Control System (ETCS) and the GSM Railway Network (GSM-R).

One of the most important factors in passenger comfort is punctuality. The punctuality of trains was also discussed in the Railway Transport Authority's report "Evaluation of the Railway Transport Market Performance and the Status of Railway Traffic Safety in 2012," where transportation during the EURO 2012 tournament, transporting fans to matches or the airport, was considered (Railroad Transport Authority, 2021).

The punctuality of public transport was also discussed in foreign articles. One is Public Transport: Punctuality Index for Bus Operation by Yaakub and Napiah (2011), published by the World Academy of Science, Engineering and Technology (WASET). The publication presents methods for studying punctuality using public bus transportation. This topic was also repeated in the article "Bus Punctuality-Towards a Structure That Can Deliver (2021)" (PTEG, 2014), which focused on presenting public transportation directions.

The topic of punctuality in mass rail transportation was also included in the article "Aspects of Improving Punctuality From Data to Decision in Railway Maintenance" by Nyström (2008). It presents issues related to rail punctuality, a methodology for reporting the phenomenon of delays, and suggestions to improve the punctuality of mass rail transportation. The study of train punctuality has also been included in works (Olsson and Haugland 2004; Zakeri and Olsson, 2018). It is one of the main quality factors in rail transport (Palmqvist et al. 2017; Parbo et al., 2013). For years, efforts have been made to make trains punctual, but systematic work in this area is still required. Passengers rate the punctuality of rail services highly (Coulombel and De Palma, 2014) and are willing to pay more for punctual trains (Beirão and Cabral, 2007; Li et al., 2010). Hansen (2001) believes that punctuality is the percentage of trains arriving at or departing from a certain point at a certain time.

One such point is creating dynamic schedules considering train delays (Högdahl et al., 2019; Lee et al., 2017; Sels et al., 2016). Various ways and methods are used to improve train punctuality. An analysis of railway improvements in the UK is included in the work (McTavish and Maidment, 1989), and in Sweden (Fahlén and Jonsson, 2005) and Norway, a method for improving punctuality has been proposed (Veiseth et al., 2011) using quality management principles such as TQM, Lean and Six Sigma (Aquilani at el., 2017; Sreedharan at el., 2018).

Various authors have also addressed the topic under discussion. For example, Stopka et al. (2015) evaluated integrated transportation systems by passengers – Gašparik et al. (2015) assessed the quality of regional passenger rail transportation. Abramović (2017) analysed passenger satisfaction with long-distance terminals using Zagreb as an example.

2 The organisation of rail transport in Poland

PKP passenger trains can be divided into two groups. Domestic trains run only within the country's borders, and International trains, whose routes lead across national borders and are compatible with carriers from neighbouring countries. In the family of domestic trains, we can distinguish the following types: InterCity (IC) trains – trains composed of a locomotive and a set of modern Z2-type passenger cars, divided into compartment cars (6- or 8-seaters) and cars without compartments, forming a line of double seats arranged behind each other. The carriages have air-conditioning and are adapted for disabled passengers. InterCity trains run long-distance routes within the country as well as abroad. Express trains (EC) – movement of trainsets between the largest cities of provinces. Fast trains are a category of passenger trains; they consist of cars with 1st and 2nd class seats or mixed cars, as well as bicycle cars. Overnight trains also run sleeping cars and cars with berths. Fast trains usually run with passenger and multipurpose locomotives. Agglomeration railways are passenger railways operating in urban agglomerations. Systems of this type are characterised by a high frequency of line service, a large number of stopping places, the use of cyclic timetables, an uneven distribution of the traveller stream during the day and a decreasing size of the traveller stream as one moves away from the agglomeration centre (Markusik, 2013).

Polskie Linie Kolejowe is a company in the Polish State Railways (PKP) group and is the main manager of railway lines in the Polish State. According to data from Polskie Linie Kolejowe (PLK), as of December 31, 2020, there are 18,566 km of railway lines in operation in Poland. These lines include 13,689 level crossings. The railways have 39,389 railway switches, 24,792 engineering structures such as bridges, tunnels and 5,269 technical stations and 14,502 structures such as shelters and platforms with noise barriers (Polish Railways, 2021).

2.1 Modernisation of the infrastructure of railway line No. 354 on the route Piła – Poznań

Modernisation of railway line No. 354 (Table 1) on the route Pila Glowna - Poznan Glowna was planned under the Wielkopolska Regional Operational Program 2014–2020 program. The project's full name was "Modernisation of Railway line No. 354 Poznan Glowna PoD- Chodzież- Pila Glowna within the framework of the Wielkopolska Regional Operational Program 2014–2020". The main beneficiary of the entire project is the Joint Stock Company PKP Polskie Linie Kolejowe. The value of the entire project amounted to PLN 614,877,000.00. The subsidy from the European Union amounted to PLN 424,915,000.00. The investment is being implemented in the Wielkopolska province. Its scope includes five counties. These are the county of Chodzież, the city of Poznań, the county of Oborniki, the county of Pilski, and the county of Poznań. The project envisaged primarily the construction of railway stops. This includes railway stations Poznań Podolany, Osiedle Grzybowo, Złotkowo, and Golaszyn (Bogdanowo). The other changes are the correction of the geometry of track curves, the replacement and work on the routes to improve the railway surface, the reconstruction of track systems at stations, and the modernisation or reconstruction of line and station drains. The platforms included in the modernisation have primarily received infrastructure upgrades. Sheds and small architecture were built, equipped with visual and audio information devices for travellers.

Table 1 Characteristics of railway line No. 354 Piła – Poznań (Polish Railroads, 2021)

Points/Railway Station	km
Poznań – starting station	0.001
Poznań Podolany	3.261
Poznań Strzeszyn	5.000
Suchy Las	6.300
Złotniki Grzybowe	8,157
Złotniki	9,525
Złotkowo	11,250
Golęczewo	13,907
Chludowo	16,747
Wargowo	19,424
Bogdanowo	24,597
Oborniki Most	25,395
Oborniki Wielkopolskie Miasto	26,331
Oborniki Wielkopolskie	27,788
Rożnowo	31,540
Parkowo	35,887
Rogoźno Wielkopolskie	42,514
Tarnowo Rogozińskie	48,047
Sokołowo Budzyńskie	51,912
Budzyń	58,169
Ostrówki k/ Chodzieży	63,337
Chodzież	70,439
Milcz	77,356
Dziembówko	82,098
Piła Kalina	85,802
Piła Leszków	88,580
Piła	92,538

Pavement upgrades, new crossing plates and crossing accesses covered level crossings. Most significant was the reconstruction of engineering structures. The railway lived to see the modernisation of traffic control devices along the entire section of this route through a remote-controlled system of computerised equipment. The modernisation of SRKs at level crossings was also related to changing the category of level crossings and adapting these facilities to the increased speed of train traffic. It was necessary to rebuild the scope of the LPN line, which was related to changes in track layouts. New power connections were established to supply power to traffic control equipment and lighting. In terms of lighting, platforms, crossings and track layouts were rebuilt. Security was improved by constructing new monitoring and access control devices for electrical turnout heating equipment. Railway infrastructure facilities have been equipped with new power supplies.

The total length of the railway is 92.538 km, with 28 stops. The maximum technical speed is 120 km/h. The line along its entire length is electrified. The gauge is standard (1435 mm) and designed for passenger and freight train traffic.

One of the main goals of modernising railway line No. 354 Pila Glowna - Poznan Glowna was to improve the platform infrastructure. Four new train stops were built for travellers: Poznań Podolany, Złotniki Grzybowe, Złotkowo and Bogdanowo. The following stations were rebuilt: Złotniki, Wargowo, Oborniki Wielkopolskie, Rogoźno Wielkopolskie, Budzyń, Chodzież, Dziembówko, Piła and stops: Poznań Strzeszyn, Golęczewo, Chludowo, Oborniki Miasto, Rożnowo, Parkowo, Tarnowo Rogozińskie, Sokołowo Budzyńskie, Ostrówki near Chodzież, Milcz, Piła Kalina. Constructing or reconstructing 34 platforms and modernising the stations' track systems significantly improved passenger travel comfort. New shelters, lighting and a passenger information system adapted to the needs of people with limited mobility, were built on the platforms (Polish national Railways, 2021).

At Pila station, trains travelling on this line stop at two platforms. Platform No. 3 was included in the modernisation project; the platform surface was replaced, and the platform shelters were renovated. This platform was adapted to the needs of people with disabilities, and an elevator and paths for blind people were created. New benches for travellers waiting for trains, information boards equipped with timetables and information signs were installed. The platform shelter was renovated, preserving its historical value. The length of the platform is 400 m, which allows long-distance trains to stop. The platform surface includes platform boards and "*L*" type platform walls. They form a set for constructing a platform with a height of H = 0.78 m. They have a grooved surface with a designated safety strip. On the platform board, there are tactile strips (concrete mouldings) 400 mm wide from the platform's edge at 1500 mm and a yellow visual strip 200 mm wide away from the edge at 1300 mm.

Railway line No. 354 at Pila station also serves platform No. 4. It was not included in the modernisation project. It has not undergone any changes. The infrastructure is designed to handle only short-distance trains, such as the Wielkopolska Railway. This platform is not adapted for travellers with disabilities. There is no canopy, and the platform surface is dilapidated.

Very big changes related to modernisation occurred at the "Pila Kalina" train stop. Before modernisation, there were no facilities for travellers at this stop. The infrastructure was not up to the standards of other railway stations. Initially, there was talk about the complete liquidation of this stop. It was to disappear from the railway map. The reason was the technical condition and low level of daily passenger service. Their number ranged from 0 to 9 people (Railroad Transport Office, 2021c)

After completing the entire project to modernise railway line No. 354, the Pila Kalina stop gained a new face. First and foremost, the platform gained a concrete surface of platform slabs. A ramp was built to allow people with physical disabilities to get to the stop. The station's infrastructure included shelters along with benches. It was equipped with signs and information boards. Most of all, safety was improved.

3 Impact of modernisation on travel time

After the modernisation, railway No. 354 was classified as a Class I railway. Passenger trains can run at V_{max} = 120 km/h, while freight trainsets can run at V_{max} = 80 km/h.

The line has a class C3 rating from 0.00 km to 79.450 km. This means the maximum axle load on the tracks is 196 kN/axle (20 *t*/axle), and the maximum linear load is 71 kN/axle (7.2 *t*/axle). On the other hand, in the section 79.450 km – 92.788 km, the line has been assigned to class D3. This entails a maximum axle load of 221 kN/axle (22.5 *t*/axle) and a maximum linear load of 71 kN/axle (7.2 *t*/axle).

Thanks to the modernisation of railway line No. 354 between Pila Glowna and Poznan Glowna stations, train travel time has been shortened in the first place. After the completion of all renovation work, the travel times of PKP InterCity's long-distance trains have shortened. In the case of the IC Malczewski train, travel time was shortened by 21 minutes (Table 2). The reduced travel time was due, among other things, to an increase in the maximum speed at which trains travel along the various sections of the rail route (PKP, 2021) (Table 3).

As one can see, a top speed of 100 km/h was only available on 11.158 km of the 92.788 km on odd sections and 2.077 km on even sections. With a maximum speed of 90 km/h on the odd section, trains can only travel on 2.18 km of the 92.788 km, while on 6.425 km on the even section, they can travel at the above speed.

Table 2 Travel time of IC 8304 Malczewski train before and after modernisation (PKP, 2021)

Modernization	Train number	Train name	Time of departure from Pila	Time of entry To Poznań	Travel time [h]
Before	IC 8304	Malczewski	8:30	10:08	1:38
After	IC 8304	Malczewski	15:37	16:30	1:07

Table 3 List of speeds from 2016 on railway line No. 354 Piła – Poznań (PKP, 2021)

Line no.	Line name	Track	Km of the beginning point	Km of the ending point	Maximum speed [km/h]
354	Poznań – Piła	N	–0.197	28,691	70
354	Poznań – Piła	N	28,691	36,220	60
354	Poznań – Piła	N	36,220	79,450	70
354	Poznań – Piła	N	79,450	81,630	90
354	Poznań – Piła	N	81,630	82,788	100
354	Poznań – Piła	P	–0.160	25,408	70
354	Poznań – Piła	P	81,536	82,550	100
354	Poznań – Piła	P	82,550	85,300	60
354	Poznań – Piła	P	85,300	91,725	90
354	Poznań – Piła	P	81,725	92,788	100

The most common speed on this route was 70 km/h. It is as high as 25.568 km on the sections with an even track and 72.118 km on the odd track. On the odd-numbered track, trains can travel at 60 km/h for 7.529 km, while on the even-numbered track, they can travel for 2.75 km. After upgrading the entire railway line, the maximum speed on the entire route section increased to 120 km/h. Assuming that after upgrading the 92.788 km route, the trains travel at a constant speed of 120 km/h, they will cover the route in 46 minutes and 40 seconds. Before modernising the entire route, trains travelling at a constant speed of 70 km/h covered it in 1 hour and 19 minutes. The difference is significant at 33 minutes. In the course of the entire route, it is also necessary to consider the stopping of trainsets at railway stations, starting time and braking time (Table 4):

Modern level crossings help reduce the vibrations generated when trains pass, positively impacting the environment. Thanks to the modernisation of this area, speed limits are cancelled, and travel time is reduced as a result. Modernised level crossings improve safety both on the road and on the railway. The risk of road vehicles getting stuck at the crossing is reduced. Dangers to rail and road traffic resulting from the technical condition of the road surface, access roads to the crossings and the high failure rate of outdated equipment are eliminated. Self-acting crossing signals have been installed at all class A, B or C level crossings (Table 5).

4 Punctuality of trains on railway line No. 354 Piła - Poznań

Train punctuality is an important factor in a successful trip. If it fails for passengers, exposing them to unpleasant consequences, they will not want to use rail services again.

Data from infrastructure managers show areas affecting passenger punctuality. Particularly noteworthy are the interrelationships between the causes of delays at different carriers. For example, the failure of one carrier's locomotive can negatively affect others in remote parts of the network. Even a single event can translate into the performance of carriers throughout the province.

Table 4 List of maximum speed for 2022 (PKP, 2021)

Line no.	Line name	Track	Km of the beginning point	Km of the ending point	Maximum speed [km/h]
354	Poznań – Piła	N	–0.197	79.450	120
354	Poznań – Piła	N	79.450	92.788	120
354	Poznań – Piła	P	–0.160	25.408	120
354	Poznań – Piła	P	81.536	92.788	120

The basic parameters by which we determine the percentage of delayed trains at destination stations are the number of passenger trains in operation and the number of delayed trains since a designated period. The Railway Transport Authority counts delays from 6 minutes after the train arrives at the destination station.

The most common causes affecting train delays include rolling stock causes:

- Resulting from defects in railway vehicles, which are often associated with delays of up to several tens of minutes and, in extreme cases, even more than 2 hours, infrastructure causes
- related to the modernisation of, for example, the tracks and resulting from poor organisation of the work, commercial causes - generate the largest number of delays, the most significant of which are causes related to the location of travellers and late notification of readiness for train departure, external causes
- including primarily accidents involving other vehicles, people or animals, acts of hooliganism or events related to weather conditions.

In Table 6, we see data on the punctuality of passenger service on railway line No. 354 Pila – Poznań by month. In 2019, the average value of delays was 92.48%, but only in October did the value fall below 90%. Thus, we can conclude that most trains reached their destination station according to schedule.

Table 7 shows the basic parameters of train punctuality nationwide from 2010 to 2020. Until 2018, a train was considered delayed from 5 minutes after the scheduled arrival time, and this value increased to 6 minutes. We can see a significant improvement in the punctuality of passenger trainsets at railway stations. From the beginning of 2010 to the end of 2020, punctuality increased by 9.53%.

5 Survey methodology

The study of the punctuality of trainsets was conducted in November and December 2021. Each day, the delays of trains on rail route No. 354 Piła – Poznań were checked via. The punctuality of trains is defined as the arrival of a train set according to the schedule at a designated railway station. The punctuality and the reasons for the delays were recorded in an Excel sheet each day. The study

Table 5 List of parameters of the overhead line 2021/2022 (PKP, 2021)

Line no.	Line name	Track	Km of the beginning point	Km of the ending point	Network type	Maximum speed [km/h]	Current carrying capacity [A]
354	Poznań – Piła	N	–0.197	–0.160	C120-2C	110	1725
354	Poznań – Piła	N	–0.160	25.408	YC120-2C	120	1725
354	Poznań – Piła	N	25.408	79.450	YC120-2C	120	1725
354	Poznań – Piła	N	79.450	92.788	C120-2C	110	1725
354	Poznań – Piła	P	–0.160	25.408	YC120-2C	120	1725
354	Poznań – Piła	P	81.536	92.788	C120-2C	110	1725

Table 6 Data on punctuality of passenger services by month (Railroad Transport Office, 2021b)

month	2019	2020	2021	change 2021/2020 [%]
January	91.42%	93.95%	90.09%	–3.86
February	94.34%	94.28%	87.77%	–6.51
March	93.55%	95.94%	93.27%	–2.67
April	94.00%	98.00%	94.01%	–3.99
May	93.54%	97.70%	92.62%	–5.08
June	90.92%	94.56%	89.48%	–5.08
July	92.18%	94.33%	86.73%	–7.6
August	92.47%	93.64%	89.08%	–4.56
September	91.98%	93.83%	90.37%	–3.46
October	89.46%	93.35%	89.97%	–3.38
November	92.76%	94.68%	89.30%	–5.38
December	93.12%	93.25%	88.74%	–4.51

Table 7 Basic parameters about punctuality in 2010–2020 (Railroad Transport Office, 2021b)

Year	Punctuality rate on arrival	Number of trains in operation	Number of trains delayed 6 min or more
2010	85.09%	1 468 008	370 901
2011	89.83%	1 477 990	420 612
2012	92.08%	1 553 649	405 670
2013	91.61%	1 506 984	392 005
2014	91.08%	1 504 098	385 883
2015	92.36%	1 593 972	364 896
2016	91.22%	1 691 888	330 237
2017	90.17%	1 715 587	359 384
2018	88.54%	1 783 210	419 074
2019	92.46%	1 716 044	370 796
2020	94.62%	1 581 087	280 584

included 18 trains from Pila station to Poznań station and 18 trains from Poznań station to Pila station.

In the November period, 540 passenger trains ran on the section between Piła station and Poznań station, of which 493 trains entered Poznań station on time, and 47 trains were delayed, i.e. entered the station later than scheduled in the timetables. In the November period, 540 passenger trains ran on the section between Poznań station and Piła station, of which 492 trains entered Poznań station punctually, and 48 were delayed, i.e. entered the station later than scheduled in the timetables. In December 2021, 558 passenger trains travelled on the Pila Poznań route. A total of 504 arrived at Poznań station on time, while 54 were delayed. In December, 588 trains ran on the Poznań - Piła railway route. Five hundred fifty-three trains arrived on schedule, while 35 arrived late (Table 8).

Considering the punctuality of trains at Poznań station in November 2021 on railway line No. 354 Piła – Poznań,

Table 8 Punctuality of all trains at Poznań, Piła railway stations in November and December

Month / Railway Station	Total of all trains	Punctual	Delayed	Percentage of on-time trains	Percentage of delayed trains
November Poznań	540	493	47	91.30%	8.70%
November Piła	540	492	48	88.89%	11.11%
December Poznań	558	504	54	90.32%	9.68%
December Piła	558	523	35	94.05%	6.33%

the total number of train delays in November 2021 at Poznań station when running trains between Piła and Poznań was 769 minutes. Train No. 87216 is the only train that had 100% punctuality during this period. The most delayed trains, as many as six times during the month, had train No. 84101 with a total time of 127 minutes of delay due to secondary difficulties, which were a consequence of traffic disruptions occurring on the route and affected the current train delay. Train No. 3806 recorded the highest number of minutes of delay in November, with a total of 252 minutes. On 08/11/2021, most trains did not arrive punctually at Poznań station. The total number of delays on that day was 233 minutes. The main reason for the delays was the failure of traffic control or supervision equipment. In addition, the delay caused by the failure of the rolling stock of train number 8306 amounted to 70 minutes.

Considering the punctuality of trains at Pila station in November 2021 on railway line No. 354 Pila – Poznań, the punctuality of trains to Pila station on the Poznań – Pila railway line was 88.89%. The total time of delays was 717 minutes. Throughout the month, as many as three trains, numbered 78173, 78215, and 78145, arrived punctually at Pila station daily. On 8/11/2021, there was a train control or supervision equipment failure, which caused the biggest delay in November. It amounted to 334 minutes, and 10 of 18 trains did not arrive on schedule at Pila station that day. Train number 3807 arrived late at Pila station 7 times throughout the month and was 169 minutes late.

Considering the punctuality of trains at Poznań station in December 2021 on railway line No. 354 Piła – Poznań, the punctuality of trains at Poznań station running on the railway line between Piła and Poznań stations was 90.32%. The total amount of delays was 2123 minutes. In December, each train had at least one day in which it did not arrive punctually at Poznań station. As of 18/12/2021, there began to be difficulties in the operation of trains. Very low air temperatures, reaching as low as –20 degrees Celsius, caused many failures, including failures of railway traffic control systems. These failures caused a total of 471 minutes of delays. The second major cause was rolling stock failures, with 853 minutes of delays. In December, train set 87340 had the highest total delay, at 270 minutes.

Considering the punctuality of trains at Pila station in December 2021 on railway line No. 354 Pila – Poznań, the punctuality of trains at Pila station was 94.05%. The total amount of delays was 1462 minutes. Most of the delays were due to rolling stock breakdowns caused by the low temperatures experienced in December. The largest delays occurred on 27/12/2021. They reached a total of 516 minutes. In contrast, as many as five trains arrived without delays throughout the month. These were trains with 68101, 78461, 78341, 78463, 78145.

6 Research

The survey was conducted in December 2021 and early January 2022 via the Internet using a survey form. Due to the prevailing COVID-19 pandemic, the online survey was conducted via. A request was sent on social networks such as Facebook, in private messages, through Outlook mail at the company where the respondent did their professional work, by email to the Pila Municipality Office, Wielkopolska Railways and family members, among others, to complete the survey reliably. In calculating the selection of the research sample, a minimum of 384 respondents was calculated. It was calculated based on the following parameters: the population size in the country or region, the size of the fraction and the maximum error (NETSTEL Software Marcin Matusiak, 2021). The total number of questionnaires was 398.

6.1 Research sample

A total of 398 people took part in the study of the impact of the modernisation of rail route No. 354 on the section Piła – Poznań on the quality of travel. Women comprised the majority of respondents, i.e. 221 people (56%), while among men, 177 people (44%) took part in the survey. Respondents were divided into five age groups. The number of those who participated in the survey under 18 was 16 (4%); respondents between 18 and 24 were as many as 181 (45%), which was the vast majority. This is because it was possible to target the closest acquaintances in this age bracket. In the age bracket from 25 to 40, 130 people (33%) participated in the survey. The large size of this age group is due to the completed questionnaires of people who worked in the same company where one of the authors undertook his professional work. In the age group from 41 to 65, 65 people (16%) participated in the survey. This may also be because the questionnaire was filled out by family members who did professional work at the company where one of the authors worked, people from the City of Pila and Wielkopolska Railways. The age group with the least number of people addressed in the survey was people over 65. It consisted of 6 people (2%).

Respondents were divided into groups based on their place of residence four main groups: those living in the countryside were 75 (19%); those living in cities up to

50,000 residents were 99 (25%); the largest number of respondents came from a city of 50,000 to 100,000 residents, the number was 165 (41%). This may be because the authors' place of residence and that of their friends who filled out the survey fell within this range. Respondents living in cities with over 100,000 residents were 59 (15%).

A detailed analysis was conducted; 46 (59%) women and 32 (41%) men from cities with a population of 50,000 to 100,000 were most likely to choose the carrier PKP Intercity. This choice can be justified by access to long-distance trains that travel throughout the country.

Among women from cities with a population of up to 50,000, 22 (25%) respondents chose Wielkopolska Railways. Across the railway, most cities fall into this range. Such cities are, Chodzież, Budzyn, Rogożno Wielkopolskie. The offer of Regional Railways among men was chosen by as many as 15 (17%) people. Like Wielkopolska Railways, this company also services smaller towns (Table 9):

The survey was divided according to the status in the labour market. This study area was divided into seven groups. The group of students is understood to be people at any stage of education below higher education, such as technical, high, and elementary. 20 (5%) students filled out the survey; one of the largest professional groups we have been able to reach is students. This area is where it is easiest to reach to conduct the survey. The number of students was 147 people (37%). The largest professional group filling out the survey was comprised of working people. This is because the survey was filled out by people from the company where one of the authors did his professional job. Railway employees and family, the number of respondents was 189 (47%); the number of self-employed respondents was 22 (6%); only five people (1%) who were unemployed participated in the survey. A group of respondents, 11 (3%) people, were pensioners; in the survey, we allowed entering an optional proposal of status in the market, and the respondent of 4 people (1%) answered as a working student (Fig. 1).

Respondents were asked about their level of education. They were divided into six levels of education. The respondents who declared they had no education were two people (1%). With primary education, 15 people (4%) participated in the survey. The number of respondents with basic vocational education was 24 (6%). 86 (22%) of the respondents were people with secondary technical education; 92 respondents with secondary education other than technical education participated in the survey (23%). The largest group of respondents were people with higher education. Their number was 179 (45%) (Fig. 2).

One of the most pertinent questions in the entire survey was "How often do you travel by rail transportation on the railway line 354 Piła – Poznań?" which allowed

Table 9 Carrier selection by size of respondents' cities of residence

	A city with a population of 50,000 to 100,000 inhabitants	A city of more than 100,000 inhabitants	A city of more than 100,000 inhabitants	Village	Sum
Woman					
Wielkopolska Railway	13%	8%	25%	20%	17%
PKP Intercity	28%	25%	16%	25%	26%
Regional Transport	11%	12%	15%	14%	13%
Male					
Greater Poland Railways	8%	14%	11%	20%	13%
PKP Intercity	19%	15%	16%	4%	17%
Regional Transports	11%	8%	17%	18%	14%
Total	165	59	88	56	342

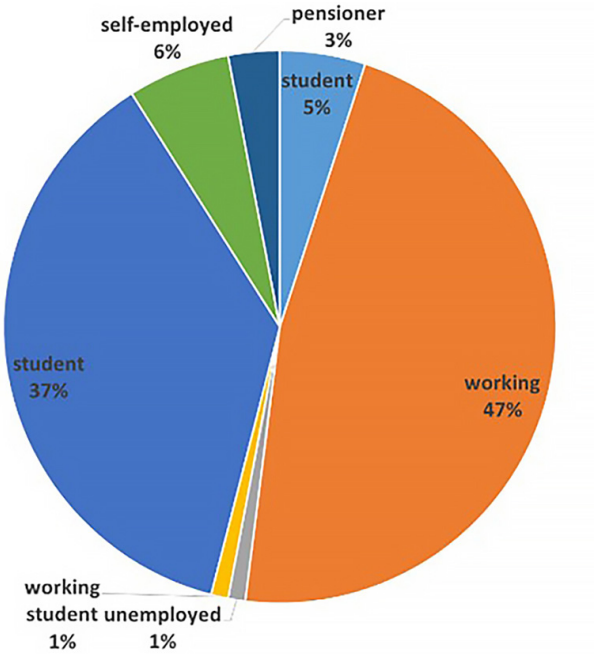

Fig. 1 Labour market status of respondents

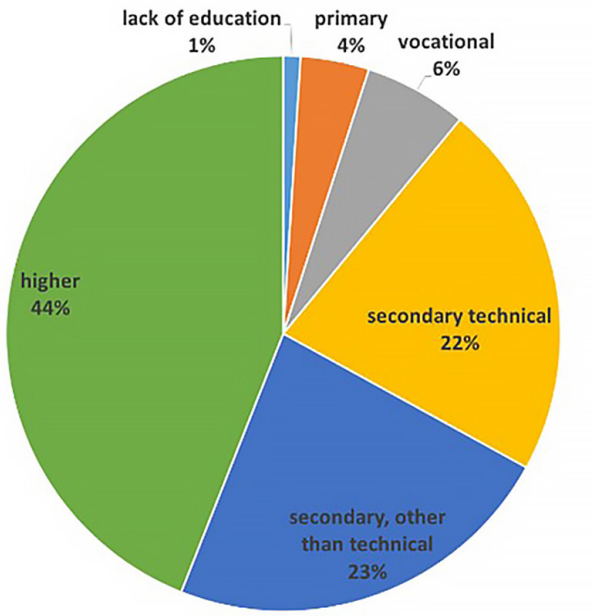

Fig. 2 Breakdown by level of education

us to determine how often respondents chose this mode of transportation and the reasons why they did not use rail transportation.

In response to the above-mentioned question, 342 out of 398 respondents used the train on railway line No. 354 Piła – Poznań. 19 people (4%) used it daily and once a week. 47 people (12%) used rail transportation several times a week, i.e. from 3 to 6 days in a weekly interval. The number of respondents using the train between 1 and 2 times a month was 51 (13%). This mode of transportation was used by 29 people (7%) several times a month, i.e. more than two times a month. 177 people of the respondents (44%) answered several times during the calendar year (Fig. 3).

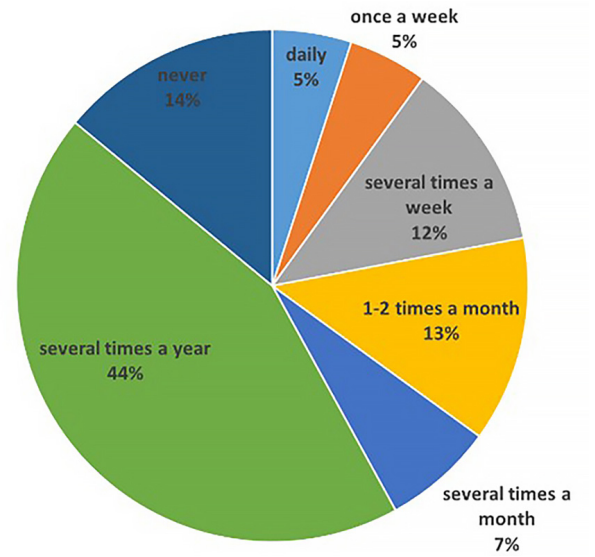

Fig. 3 How often do you travel by rail on the 354 Piła - Poznań railway line?

The answer "never" was given by as many as 36 respondents. After answering "never," respondents were asked why they do not use this mode of transportation. The reasons why respondents did not use railway line No. 354 Piła – Poznań were: they move by car, they did not need to use this railway line, travelling by car is faster than travelling by train on this line anyway, considering further shuffling, e.g., around Poznań, there is no need to use rail transportation, other travel routes, car transportation is most often chosen, travelling by car is more convenient.

The vast majority of those who gave the above answer gave one argument: to move by car. They claimed it is more convenient and comfortable for them, especially when they continue their journey to further destinations.

Every trip made by respondents has a purpose. To the question "What is your main reason for travelling on the railway line No. 354 Piła – Poznań?" 6 answers were offered, as well as the opportunity to suggest the purpose of travel (Fig. 4). 29 people (7.3%) of respondents travelled for business purposes, 38 (9.5%) respondents answered for commuting to work, 48 people (12.1%) used rail transportation to go to college. The largest number of responses were for private travel, 214 (55,5%); the answer that the purpose of their trip is school transportation was declared by six people (1.5%). In the answer "other", respondents declared such reasons as:

- recreational or for shopping purposes – 1 person (0.5%)
- in order to visit friends – 1 person (0.3%)
- due to relocation – 1 person (0.3%)

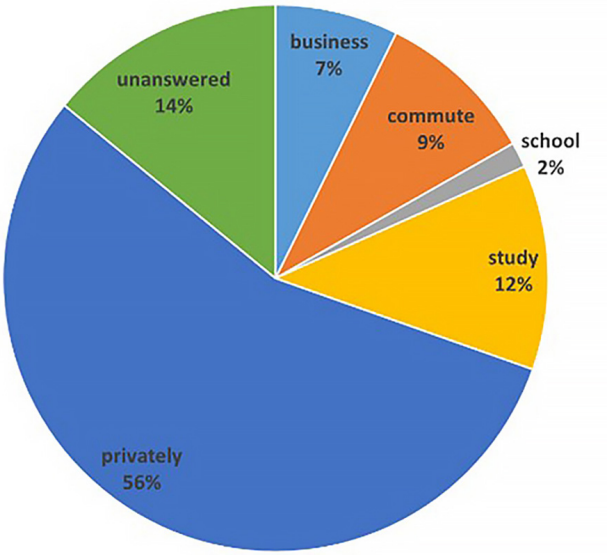

Fig. 4 What is your main reason for travelling on railway line No. 354 Piła – Poznań

- in order to visit family – 2 persons (0.6%)
- vacation – 1 person (0.3%)
- medical visit – 1 person (0.3%).

Most working people, 103 respondents, use railway line No. 354 on Pila – Poznań for private trips. 34 respondents who travelled to work indicated the second most frequent reason. Only one person moved along the said route for recreation or shopping. The reason may be the easier access to travel by private cars. The most common reasons for travel on this railway line No. 354 Piła – Poznań were for private purposes for 75 people and 42 respondents for the study (Table 10).

According to working people, the main argument for travelling by rail was the accessibility to stops, whether on long-distance or shorter routes, as reported by 81 respondents. A very important argument for this occupational group, i.e. working people, was travel time between sections. Travel time by rail between the stations of Pila – Poznań is 1 hour and 7 minutes, while the average travel time on this route is 1 hour and 50 minutes by car.

In the next stage of the survey, we asked respondents about improving travel comfort in connection with the modernisation of the railway line. By the statement of travel comfort, we meant adapting the rolling stock to the travelling public, such as air conditioning on the train, the availability of seats, the ability to travel with their pets, and the carriage of bicycles. To the question "In your opinion, has the modernisation of railway line No. 354 Piła – Poznań affected the comfort of travel?" on a scale from 1, i.e., no comfort, to 5, very good, full travel comfort, only seven people (2%) were not fully satisfied with travel comfort. 11 (3.2%) respondents declared insufficient improvement in travel comfort on this railway line, while sufficient improvement was noted by 57 people (16.7%). The largest number of people, 155 (45.4%), noted a significant improvement in travel comfort due to the modernisation of the railway line. 112 people (32.7%) declared that modernisation greatly affected travel comfort (Fig. 5):

Analysing evaluations of the impact of the modernisation of railway line No. 354 on the route Pila – Poznań, 44 people in the age range of 25 to 40 years assessed that the modernisation work had had a very good impact on the comfort of travel. Those between the ages of 18 and 24, in the number of 84 respondents, noted a significant improvement in travel comfort (Table 11).

The next question in the survey was, "In your opinion, has the modernisation of railway line No. 354 Pila – Poznań affected the punctuality of trains? (1- trains are not punctual / worse than before modernisation; 5- trains are punctual)". By punctuality of trains, we meant the arrival of trainsets at the destination station according to the timetables provided by the carrier. The answer to the question could be expressed on a scale from 1, meaning trains are not punctual, worse than before modernisation, to 5, meaning trains have improved their punctuality, arriving on time (Fig. 6)

According to 16 people (4.7%), the punctuality of trains has not changed at all, and trains are still delayed.

Table 10 Reasons for travel on railway line no. 354 Piła – Poznań by working people and students

working	What is your main reason for travelling on railway line 354 Piła – Poznań?
For work	26.03%
To study	1.46%
Private	30.12%
Recreation, shopping	0.29%
Business	4.39%
Student	
For work	0.88%
To study	12.28%
Private	21.93%
Transfer	0.29%
Business	1.75%
On a visit to the family	0.29%
Going on vacation	0.29%

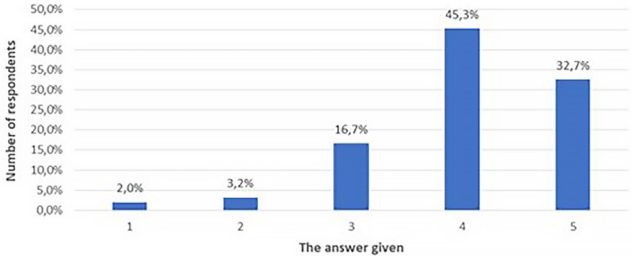

Fig. 5 In your opinion, has the modernisation of railway line No. 354 Pila – Poznań affected the comfort of travel?

Table 11 Evaluation of the impact of modernisation on travel comfort by age of respondents

Age	1	2	3	4	5	Final total
18–24 years old	0%	36%	42%	54%	38%	39%
25–40 years old	57%	27%	33%	29%	39%	29%
41–65 years	29%	27%	19%	11%	20%	14%
Under 18 years	14%	9%	4%	4%	3%	3%
Over 65 years	0%	0%	2%	2%	1%	1%
Final total	7	11	57	155	112	398

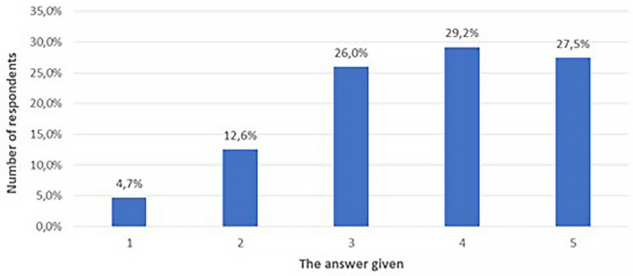

Fig. 6 In your opinion, has the modernisation of railway line No. 354 Piła – Poznań affected the punctuality of trains? (1- trains are not punctual; 5- trains are punctual)?

43 respondents (12.6%) noticed a minimal, slight improvement in the punctuality of trains at railway stations, while an improvement in punctuality was noticed by 89 people (26%). A significant improvement in punctuality was declared by 100 people (29.2%). According to 94 people (27.5%) of the total respondents, trainsets were punctual, and they saw a big improvement in this sector. Regarding rail modernisation, it is important to consider the quality of the means of transportation, such as train sets.

The next question in the survey was, "In your opinion, how has the modernisation of railway line No. 354 Piła – Poznań affected the quality of the means of transport that travel along this railway route?" The answer could be expressed on a scale from 1, i.e. bad quality of means of transportation, no improvement, to 5, i.e. very good quality of means of transportation, significant improvement (Fig. 7).

According to the respondents, only 3 (0.9%) people described the quality of the means of transportation as bad, with no improvement. 16 (4.7%) respondents noted a minimal improvement in the quality of the means of transportation. 61 (17.8%) travellers noted a sufficient improvement in the aspect of the means of transportation. Good quality of the means of transportation was described by 135 people (39.5%), while very good quality and great improvement were also declared by 127 people (37.1%).

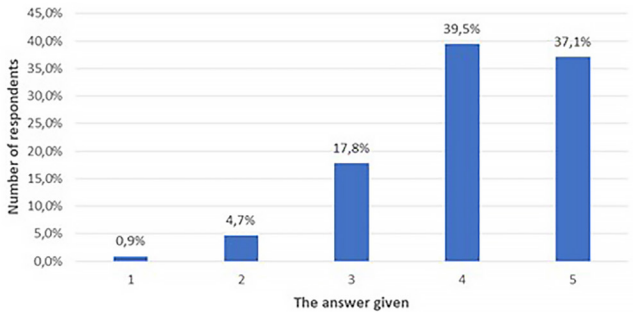

Fig. 7 In your opinion, how has the modernisation of railway line No. 354 Piła – Poznań affected the quality of the means of transportation that travel along the railway line?

Three carriers operate trains on the railway line No. 354 Piła – Poznań. In the survey, we included the question, "Which carrier do you choose most often when travelling on railway line No. 354 Pila Main – Poznan Main?" The most frequently chosen carrier among respondents was PKP InterCity; this choice was declared by 146 people (43%). The second chosen carrier was Przewozy Regionalne; this choice was declared by 94 people (27%); the third carrier was Koleje Wielkopolskie; this choice was declared by 102 people (30%) (Fig. 8).

Reasons for choosing a particular carrier:

- PKP InterCity,
- travel time,
- travel outside the province/long-distance train route,
- favourable number of stops,
- most suitable travel time,
- timetables,
- starting station,
- convenience and comfort,
- Przewozy Regionalne,
- ticket price,
- travel time,
- number of stops,
- timetables,
- purchase of tickets through apps,
- most adjusted time,
- Wielkopolska Railway,
- no seat reservations are required,
- travel time,
- travel time, the comfort of a mode of transport,
- frequency of service.

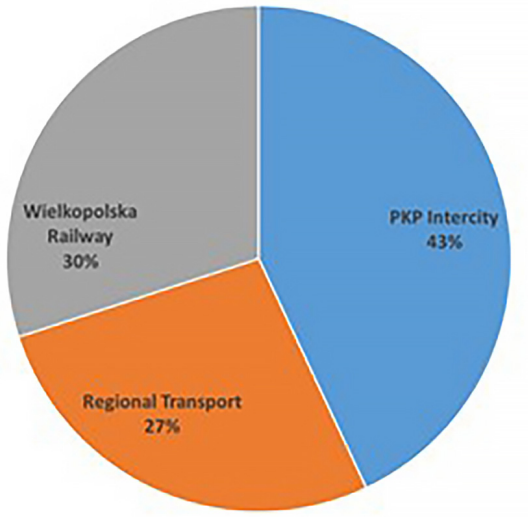

Fig. 8 Which carrier do you choose most often when travelling on railway line No. 354 Piła Poznań?

Wielkopolska Railway usually runs only from Piła to Poznań or from Poznań to Piła (not like Regio, which usually goes to Kołobrzeg), so there is less crowding than on other trains with longer routes,

- the cost of the trip,
- number of stops,
- most adjusted time,
- timetables,
- courtesy of service.

With the modernisation of railway line No. 354 Piła – Poznań, a new carrier – Wielkopolska Railways – has entered the tracks. This entails an increased number of trains running. The survey asked, "Thanks to the modernisation of railway line No. 354, the number of running trains has increased. Have you noticed this change?" (Fig. 9).

A very important aspect when travelling by this means of transportation is the adaptation of infrastructure for people with disabilities. So we asked, "In your opinion, was the infrastructure on platforms during the modernisation of railway line No. 354 Piła – Poznań adapted to travel for people with disabilities?"

234 respondents (68.4%) said that the infrastructure is adapted for people with limited independence, but 96 people (28.1%) did not notice any improvement due to the modernisation. Twelve people (3.5%) of the respondents said that the infrastructure is not adapted for people with disabilities. Reasons they believe this include:

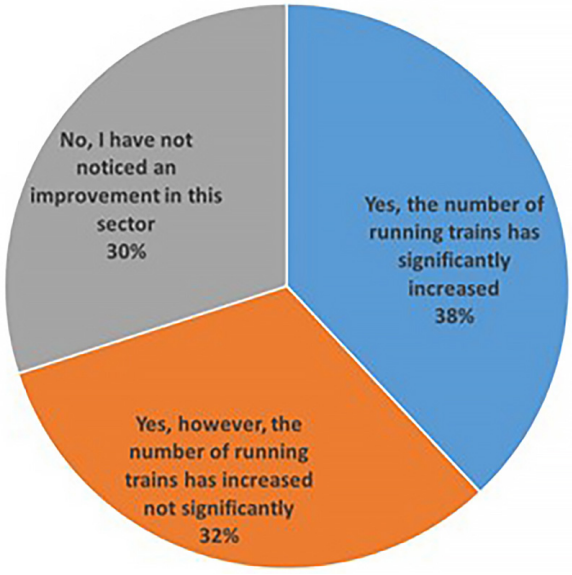

Fig. 9 The number of trains running has increased thanks to the modernisation of railway No. 354. Have you noticed this change?

- Platforms at Pila station need to have their pavement replaced.
- Many stations along the route have not been adapted.
- Problems were getting on and off, and platforms were too high.
- Still no elevators or ramps on platforms.
- A large number of stairs.
- At the end of the questionnaire, there was an opportunity to express opinions and comments on the modernisation of railway line No. 354 Piła – Poznań. Below are some of them:
- Wargowo station is located far from the buildings.
- Modernisation took longer than expected, and replacement buses did not always provide a comfortable ride for all travellers (no free seats).
- Carriages with 8-seat compartments should have already been phased out without travel comfort.
- Significant improvement in travel time.
- Lack of ticket offices at all stations.

There is still no second track on the section Dziembówko – Oborniki Wielkopolskie (beyond Warta River in the direction of Poznań). When one train is late, there is an accumulation of delays for other trains or further delays due to passing. Scheduled stops also increase travel time (differences for trains of the same class are up to 25 minutes). None of the previously decommissioned stations (e.g., Parkowo) has been restored, nor has a new station been built (new stops as a plus, of course). The traffic control system often has failures (especially the turnouts at Dziembówek and Poznań PoD). On the Poznań PoD subgrade, there are delays for trains going to Szczecin (branch line). The use of the LCS and the lack of staffing at the signalling posts on the route make it impossible to rectify faults quickly. Speed restrictions are becoming more frequent (slips on the tracks, unravelling and other causes).

The next step was to correlate the answers given by the respondents according to their gender. Based on the survey, it can be concluded that the respondents' gender depended on their labour market status and reasons for travelling by rail transport (Table 12).

where:

- df – the degrees of freedom,
- α – the significance level,
- χ^2 – the Chi-square statistic,
- χ^2_d – the critical Chi-square value.

Table 12 Correlation of answers given by gender

Criterion	*df*	α	χ^2	χ^2_d	Conclusion
Age	4	0.05	9.44	9.49	no correlation
Place of residence	3	0.05	1.98	7.82	no correlation
Status in the labour market	5	0.05	21.35	11.07	is correlation
Educational level	5	0.05	10.81	11.07	no correlation
Travel by rail	6	0.05	9.40	12.59	no correlation
Reason for travelling by rail	5	0.05	30.26	11.07	is correlation

7 Conclusions

A total of 398 respondents took part in the survey. Of this number, 342 people travelled on this rail line. The data shows that respondents' main reasons for travelling by rail are shorter travel time, cheap ticket prices and accessibility to train stops. On the other hand, 44% of respondents most often travel several times a year, 53.8% travel for private purposes, and 12.1% travel by rail transport to study. When asked about the change in the area of travel comfort on railway No. 354, 45.3% of respondents rated a significant change in the above-mentioned area. Travel comfort includes the quality of the mode of transportation, with 45.3% of respondents rating a significant improvement in train sets. This is influenced by newly upgraded train cars, electric trainsets and access to bar cars. According to 29.4% of respondents, the punctuality of trains has significantly increased compared to the punctuality before the modernisation. In turn, 27.5% of respondents noted a big improvement in the above aspect. This also affects the comfort of travel. Another aspect is the variation in the availability of rail carriers. The PKP Intercity company is the first choice of as many as 43% of respondents.

The services of the company Przewozy Regionalne are used by as much as 27%, and the company Koleje Wielkopolskie is chosen by 30%. According to the respondents, the biggest problem on railway line No. 354 Piła Poznań is the lack of a second track on the Dziembówko section to Oborniki Wielkopolskie station. This significantly limits the capacity of trains on this line, as they have to wait to pass at stations such as Chodzież, Rogoźno Wielkopolskie, and Parkowo station. Funding for extending this section of the rail route could be obtained from the European Fund from the Connecting Europe Facility or the government's National Railway Program, among others. The extension of the second track between Dziembówko and Oborniki Wielkopolskie stations could be part of the investment in the development of rail infrastructure based on the construction of the Central Transport Port. Line No. 354 is the main rail route from the central part of Wielkopolska province toward the Baltic Sea. The second track will increase the possibility of passenger and freight transportation to seaports in cities with access to the sea.

Based on the survey, it can be concluded that the respondents' gender depended on their labour market status and reasons for travelling by rail transport.

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