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ANALYSIS OF THE RUNNING OF LONG-DISTANCE TRAINS ON NON-ELECTRIFIED LINES IN POLAND

Summary. In recent years, the number of long-distance trains running on non-electrified lines has been increasing in Poland. Unfortunately, trains running on non-electrified lines, unlike those running on the hook of electric locomotives, are very often canceled, especially in the winter. In this research, the analysis of which lines had the most frequent cancellations of trains in 2021 and the reasons for these cancellations were analyzed. The results show that the most common cause of train cancellations was the lack of an efficient locomotive at the starting station. Most often, accessibility problems concern Czech series 754 diesel locomotives. The numbers of canceled trains in February 2021 and 2022 were also compared. The comparison showed that although the situation is far from ideal, it has improved significantly.

1. INTRODUCTION

In Poland, after years of limiting the transport offered and closing railway lines, the process of increasing the number of connections has begun. From the beginning of the 21st century until 2020, passenger traffic was introduced in 63 previously suspended sections. The total length of these sections is 1,992 km. On some routes, the reactivation of connections was not successful, and the train traffic was suspended again, but most of them are still active [1]. In addition to regional traffic, the network of long-distance connections has been expanding for several years. As a result, an increasing number of large and medium-sized cities are gaining access to direct connections in different parts of the country.

In order to increase the share of rail transport in the total number of trips made, similar to public transport, it is necessary to improve the accessibility of stations [2]. Another important factor is increasing the number of direct connections. The increase in the number of trains and routes on which they are run is related to the constant failure to meet transport needs. The possibility of direct movement between large cities and between spas is limited. Access by train is possible to less than half of spa towns. Even fewer spas have direct connections with voivodeship capital cities [3].

Most long-distance trains run on electrified lines. The same is true in other countries where most of the main lines are electrified. A large number of long-distance trains run in such countries. Actions are also taken to save energy [4]. In Poland, electrified lines for servicing long-distance trains, apart from traditional trainsets pulled by an electric locomotive, also use electric multiple units. These are the ED160 (Flirt 3) vehicles by Stadler, ED161 (Dart), ED74 (Bydgostia) by Pesa, and ED250 (Pendolino) by Alstom [5]. However, the number of trains that run on non-electrified lines in Poland, for which diesel locomotives are used, is also increasing. Some electrified lines are overloaded, which makes it difficult to improve the offer and increases the carrier's costs [6]. Running long-distance trains on alternative, non-electrified lines relieve the main line. In addition, it allows direct access to the destination for towns along the route. Rail transport, even with the use of diesel locomotives, is more environmentally friendly than individual car transport. Various studies of exhaust gas emissions from diesel engines installed in locomotives have been carried out [7].

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The offer of long-distance connections is not stable. Currently, many trains run regularly in a similar or identical relationship in subsequent timetables. However, this is not necessarily the case, and many changes are happening. Especially at the turn of the 20th and 21st centuries, the offer of long-distance connections was subject to many modifications [8]. Long-distance trains are launched by the state-owned carrier PKP Intercity. It runs national trains in the categories of Express InterCity Premium, Express InterCity, InterCity (IC), as well as Your Railway Lines (in Polish, TLK). Only the last two categories of trains (not counting the seasonal trains to Hel) run on non-electrified lines. IC trains consist of new or modernized carriages, while TLK trains are made of cars of a slightly lower standard. Long-distance passenger trains in Poland, like regional trains, are unprofitable, as in all countries of the European Union and most countries in the world. They are organized as part of the public service and subsidized by the state treasury [9]. Long-distance trains of higher categories are excluded from the subsidy. IC and TLK trains (i.e., trains that also run on non-electrified lines) are financed [10]. Sometimes, due to technical problems, long-distance PKP Intercity trains are canceled. In such cases, an alternative bus service is launched, or passengers are allowed to travel on regional trains. Traffic problems occur on both electrified and non-electrified lines. However, problems with running long-distance trains on non-electrified lines appear more often and, therefore, are felt more by passengers.

Long-distance rail transport is an element of international transport corridors and enables the transport of goods and passengers over long distances [11]. So far, many analyses related to trains running across national borders have been carried out. The procedures for operating in the event of disruptions to rail traffic also differ from country to country [12]. The railway connection with Lithuania, which is a non-electrified railway line from Suwałki to Mockava via Trakiszki, was analyzed. Several years ago, this line was used by the fast train Hańcza, a route that has since been shortened to Suwałki and has ceased to be an international train [13]. Railway connections with Belarus were also analyzed, where the problem is a different track gauge [14]. Due to the different track gauges used in passenger transport, it is necessary to replace or change train bogies, which creates a bottleneck for the entire transport corridor [15]. On the other hand, in the Polish-German borderland, the problem is a different type of traction network power supply, which means that, even on electrified lines, diesel locomotives have been used for many years [16]. When planning rail transport, including long-distance transport, it is important to define the development mode and the expected characteristics of intercity rail transit [17].

The aims of this research are to determine the number of canceled long-distance trains on non-electrified lines, to identify the reasons for the cancellation of trains, and to check how this situation has changed over time. The biggest problem with the running of trains occurs in the winter. This is due to difficult weather conditions, as well as the need to drive trains by locomotives with an installation that enables the heating of wagons to be supplied with 3kV electricity. Therefore, the period from 13 December 2020 to 13 March 2021 is analyzed. This period begins with the introduction of the 2020/2021 timetable and ends with the March correction of the timetable. Then, from the analyzed period, the month in which the most trains were canceled is selected. Data for this month is compared with the same period in 2022. This enabled the determination of whether the number of problems in the movement of long-distance trains on non-electrified lines is decreasing or increasing.

2. NON-ELECTRIFIED LINES WITH LONG-DISTANCE TRAIN TRAFFIC IN POLAND

The movement of long-distance trains on non-electrified lines is conducted in several different regions of Poland. Because replacing an electric locomotive with a diesel one is time-consuming (a minimum stop of 15 minutes is necessary), diesel locomotives also run long-distance trains on some electrified lines. This shortens the travel time, thus making rail transport more attractive to passengers. However, such an operation requires the use of additional diesel locomotives.

2.1. Train traffic in 2021

Railway lines with long-distance train traffic in the 2020/2021 timetable are shown in Fig. 1. The red color shows non-electrified railway lines with at least one long-distance train running along it. The green color represents non-electrified railway lines with long-distance train traffic in the summer season. Orange represents electrified railway lines on which at least some of the long-distance trains are run by diesel locomotives.

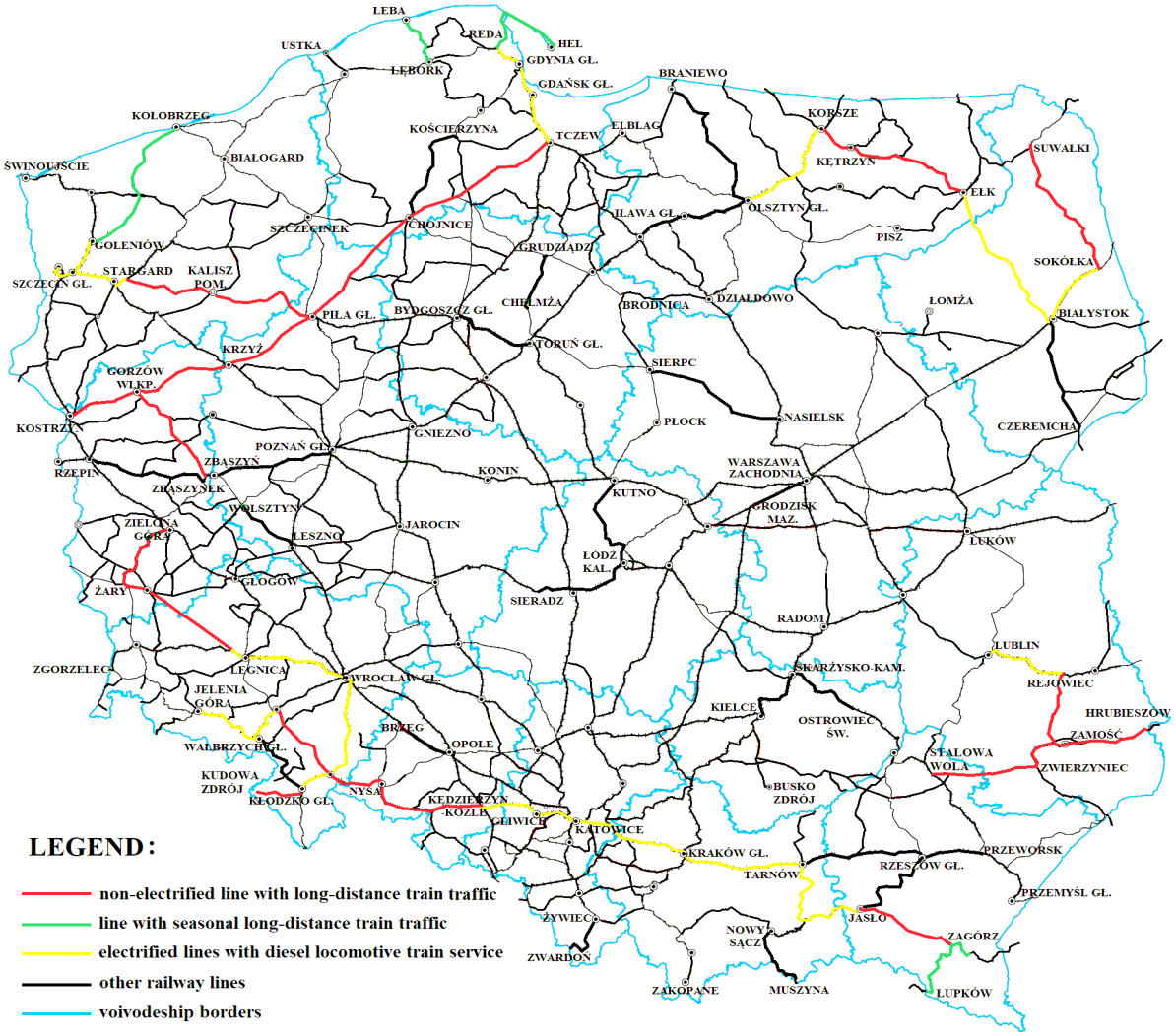

Fig. 1. Railway lines on which long-distance trains were run by diesel locomotives in 2021 [18]

Because no seasonal holiday trains ran in the analyzed period from 13 December 2020 to 13 March 2021, the sections on which these trains run were omitted. Non-electrified railway lines on which long-distance trains appear in the summer season are located mainly by the sea along a section from Reda through Władysławowo to Hel, from Lębork to Łeba, and from Goleniów to Kołobrzeg. Moreover, during the holiday season, long-distance trains cover the mountain route from Zagórz to Łupków. Table 1 shows the number of trains running on the analyzed sections, their distance, and the type of diesel locomotive that serves long-distance trains on this section.

From the introduction of the 2020/2021 timetable to the March correction, there were 19 long-distance trains in total run by a diesel locomotive for at least part of the route. This was because the trains crossed onto non-electrified railway lines. Long-distance trains ran on 1366 km of non-electrified railway lines. In addition, diesel locomotives ran trains on 934 km of electrified lines, which was associated with the elimination of the time-consuming process of changing locomotives. In total, diesel locomotives ran trains along 2300 km of the line. Every day, diesel locomotives traveling with long-

distance trains covered a total distance of 4236 train-kilometers on non-electrified lines. Moreover, these locomotives covered 3362 train-kilometers on electrified lines daily, meaning the total daily mileage of all diesel locomotives amounted to 7598 train-kilometers.

Table 1

Sections served by diesel locomotives for long-distance traffic in 2021

Section	Electrification	Number of trains	Locomotive type	Distance [km]
Suwałki – Sokółka	no	2	SU160/754	99
Białystok – Sokółka	yes	2	SU160/754	41
Białystok – Ełk	yes	3	SU160	103
Ełk – Korsze	no	3	SU160	99
Korsze – Olsztyn Główny	yes	3	SU160	67
Hrubieszów M. – Zawada	no	2	SU160	61
Zawada – Rejowiec	no	1	SU160	54
Lublin Główny – Rejowiec	yes	1	SU160	54
Zawada – Stalowa Wola Rozw.	no	1	SU160	96
Zagórz – Jasło	no	2	SN84	69
Jasło – Kraków Główny	yes	2	SN84	178
Kraków G. – Katowice	yes	1	754	77
Katowice – Kędzierzyn-Koźle	yes	2	754/SU4210	64
Kędzierzyn-K. – Kamieniec Z.	no	2	754/SU4210	113
Kamieniec Z. – Jaworzyna Śl.	no	1	754	60
Jaworzyna Śl. – Jelenia Góra	yes	1	754	78
Wrocław Gł. – Kamieniec Z.	yes	2	SU4210	72
Kamieniec Z. – Kłodzko Nowe	yes	3	SU4210	26
Kłodzko N. – Polanica Zdrój	no	3	SU4210	10
Polanica Zdrój – Kudowa Zdrój	no	1	SU4210	30
Wrocław Gł. – Miłkowice	yes	1	SU4210	74
Miłkowice – Zielona Góra	no	1	SU4210	131
Zbąszynek – Gorzów Wlkp.	no	2	SU4210	74
Kostrzyn – Gorzów Wlkp.	no	1	SU4210	43
Gorzów Wlkp. – Piła Główna	no	2	SU4210	118
Piła Główna – Tczew	no	1	SU4210	180
Tczew – Gdynia Główna	yes	1	SU4210	52
Piła Główna – Ulikowo	no	1	SU4210	129
Szczecin Główny – Ulikowo	yes	1	SU4210	48

2.2. Train traffic in 2022

Trains running from the introduction of the 2021/2022 timetable on 12 December 2021 until the March timetable correction, which took place on 12 March 2022, were also analyzed. This was done in order to identify changes in the running of long-distance trains on non-electrified lines in Poland. Railway lines with long-distance train traffic in this period are shown in Fig. 2.

Compared to the corresponding period of the previous year, the number of long-distance trains running on non-electrified lines increased. The trains began to run from Białystok through Bielsk Podlaski, Hajnówka and Czeremcha to Siedlce. This is related to the extension of the TLK Biebrza train to Warsaw, which previously ended its run from Gdynia Główna in Białystok. Moreover, an additional TLK Żubr train was launched on this section. After the renovation works were completed and the line was restored, two pairs of long-distance trains returned to the line from Lublin to Łuków. These trains are led to Warszawa Wschodnia by a diesel locomotive in order to eliminate the need to change the locomotive. The long-distance train also covers the non-electrified section from Opole to Nysa, as well

as the electrified section from Gliwice Łabęd to Opole. This is due to the extension of the TLK Wetlina train from Zagórze to Kłodzko Miasto, which previously ended in Kraków. A new train (TLK Flisak) from Gdynia to Katowice was also launched. This train is operated by a diesel locomotive on the electrified section from Gdynia to Laskowice Pomorskie and then non-electrified from Laskowice Pomorskie via Grudziądz, Brodnica, and Sierpc to Płock. Table 2 shows all the sections along which long-distance trains were run by diesel locomotives in the analyzed period.

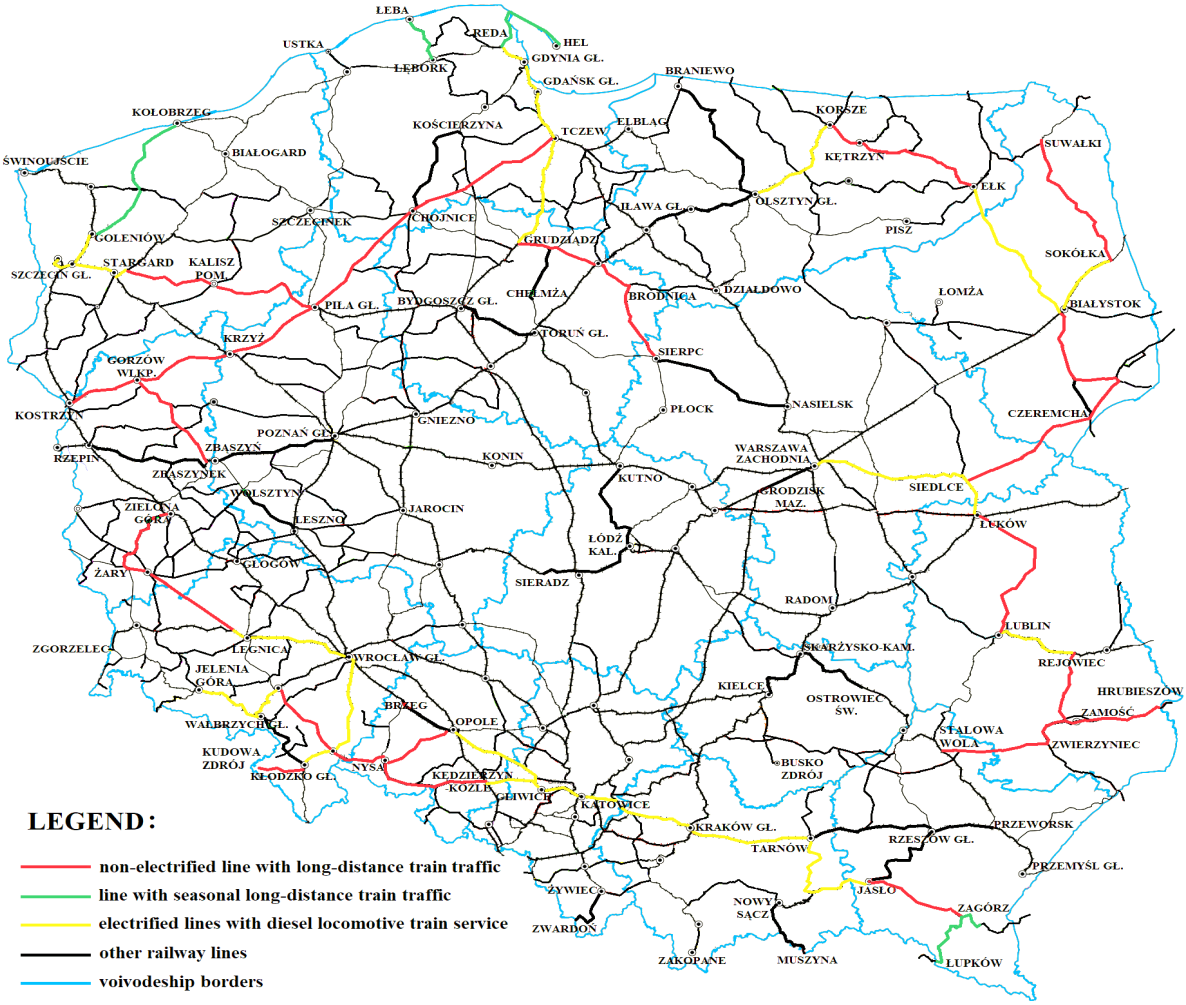

Fig. 2. Railway lines on which long-distance trains were run by diesel locomotives in 2022 [18]

From the introduction of the 2021/2022 timetable until the March correction, a total of 23 long-distance trains were operated by a diesel locomotive for at least part of the route. Compared to the previous year, this number increased by four trains. Long-distance trains ran on 1888 km of non-electrified railway lines. Moreover, diesel locomotives traveled along 1191 km of electrified lines. In total, diesel locomotives ran along 3079 km of the line, which is over 700 km more than in the previous year. Every day, diesel locomotives traveling with long-distance trains covered a total of 5970 train-kilometers on non-electrified lines. Moreover, these locomotives covered 4278 train-kilometers on electrified lines every day, which yields a total daily mileage of all diesel locomotives of 10,248 train-kilometers (almost 3000 train-kilometers more than in the previous year). By comparing the data contained in Tables 1 and 2, it can also be noticed that there have been changes in the type of vehicles serving individual sections. The section from Suwałki to Sokółka was no longer served by locomotives of the 754 series; only SU160 locomotives remained on it. Similarly, the TLK Sudety train ceased to be driven by a series 754 locomotive and was replaced by a diesel multiple unit series SN84. This resulted in a change in the rolling stock serving trains between Krakow and Jelenia Góra. In turn, the series 754

locomotives appeared in the service of trains on the section Gorzów Wielkopolski – Zbąszynek, Kostrzyn – Gdynia Główna, and Piła – Szczecin.

Table 2

Sections served by diesel locomotives in long-distance traffic in 2022

Section	Electrification	Number of trains	Locomotive type	Distance [km]
Suwałki – Sokółka	no	2	SU160	99
Białystok – Sokółka	yes	2	SU160	41
Białystok – Ełk	yes	2	SU160	103
Ełk – Korsze	no	3	SU160	99
Korsze – Olsztyn Główny	yes	3	SU160	67
Białystok – Siedlce	no	2	SU160	196
Lublin Główny – Łuków	no	2	SU160	111
Łuków – Warszawa Wsch.	yes	2	SU160	116
Hrubieszów M. – Zawada	no	2	SU160	61
Zawada – Rejowiec	no	1	SU160	54
Lublin Główny – Rejowiec	yes	1	SU160	54
Zawada – Stalowa Wola Rozw.	no	1	SU160	96
Zagórz – Jasło	no	2	SN84	69
Jasło – Kraków Główny	yes	2	SN84	178
Kraków G. – Katowice	yes	2	SN84	77
Katowice – Gliwice Łabędy	yes	3	SN84/SU4210	33
Gliwice Ł. – Kędzierzyn-Koźle	yes	2	SN84/SU4210	31
Gliwice Ł. – Opole Główne	yes	1	SN84	65
Opole Główne – Nysa	no	1	SN84	50
Kędzierzyn-K. – Nysa	no	2	SN84/SU4210	75
Nysa – Kamieniec Z	no	3	SN84/SU4210	38
Kamieniec Z. – Jaworzyna Śl.	no	1	SN84	60
Jaworzyna Śl. – Jelenia Góra	yes	1	SN84	78
Wrocław Gł. – Kamieniec Z.	yes	2	SU4210	72
Kamieniec Z. – Kłodzko M.	yes	4	SN84/SU4210	26
Kłodzko M. – Polanica Zdrój	nie	3	SU4210	10
Polanica Zdrój – Kudowa Z.	no	1	SU4210	30
Wrocław Gł. – Miłkowice	yes	1	SU4210/SU42	74
Miłkowice – Zielona Góra	no	1	SU4210/SU42	131
Zbąszynek – Gorzów Wlkp.	no	2	754/SU4210	74
Kostrzyn – Gorzów Wlkp.	no	1	754	43
Gorzów Wlkp. – Piła Główna	no	2	754/SU4210	118
Piła Główna – Tczew	no	1	754	180
Tczew – Gdynia Główna	yes	2	754	52
Piła Główna – Ulikowo	no	1	754/SU4210	129
Szczecin Główny – Ulikowo	yes	1	754/SU4210	48
Tczew – Laskowice Pom.	yes	1	754	76
Laskowice Pom. – Płock	no	1	754	165

3. CANCELED TRAINS IN THE FIRST QUARTER OF 2021

In the period from 13 December 2020 until 13 March 2021, a total of 163 diesel locomotive long-distance trains were canceled, at least for part of the route. Twenty-three of these trains were canceled

or did not reach the destination station due to a breakdown of the locomotive. As many as 118 trains were canceled due to the lack of an available diesel locomotive at the starting station. Most of the problems with running the trains were related to the diesel locomotive. Furthermore, 20 trains were canceled due to an impassable railway line, and two trains were involved in incidents that prevented access to the destination station. A total of 163 trains were canceled during the analyzed 90 days. On average, 1.81 trains were canceled per day. The reasons for the train cancellations are presented as percentages in Fig. 3.

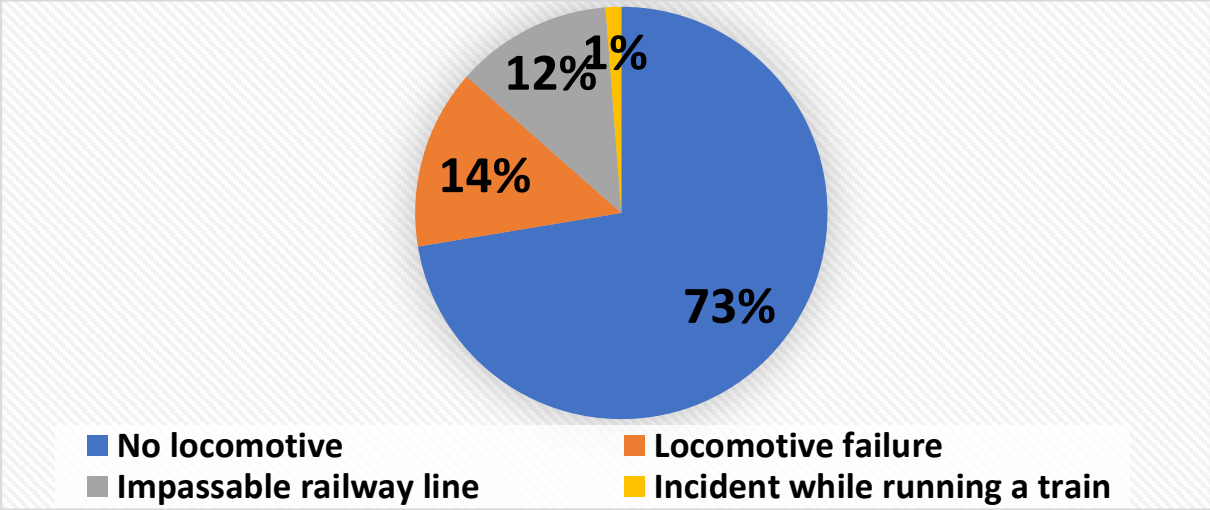

Fig. 3. Reasons for canceling long-distance trains on non-electrified lines

3.1. Locomotive failures

In the analyzed period, diesel locomotives of various series suffered failures. Table 3 shows the number of failures of diesel locomotives in each series, as well as the percentage values in relation to all failures.

Table 3

Failures of various series of diesel locomotives

Series of locomotives	Number of failures	Failures as a percentage
SU4210	13	57%
SU160	9	39%
SN84	1	4%
Sum:	23	100%

Over 50% of breakdowns of diesel locomotives resulting in the cancellation of a train on all or part of the route concerned locomotives of the SU4210 series. The SU160 series of locomotives had slightly fewer failures. Meanwhile, only one SN84 diesel multiple unit failed in the analyzed period. This failure took place at the station in Zarszyn while traveling as a TLK Bieszczady train to Zagórz. There were no cases of breakdowns of the series 754 locomotives that led to the cancellation of a train.

3.2. Lack of a locomotive

The most common reason for canceling a train was the lack of an available diesel locomotive. This was the reason for as much as 73% of all canceled trains. The shortcomings of various series of locomotives are presented in Table 4. When a given train was driven by different types of locomotives, the type of locomotive was taken into account, which was provided for in the ordered timetable for a given day on which the train did not run.

Table 4

Lack of locomotives of different series

Series of locomotives	Number of shortages	Shortages as a percentage
754	58	49%
SU4210	32	27%
SU160	28	24%
Sum:	118	100%

While the series 754 locomotives did not experience any breakdowns that resulted in train cancellations in the analyzed period, almost half of all trains that did not run due to the lack of a locomotive concerned locomotives of this series. Thus, already at the starting station, there were no operational series 754 locomotives, which were planned to lead the train. Slightly smaller but still noticeable shortcomings concern the SU4210 and SU160 series locomotives. In the analyzed period, there was no case of a lack of an available SN84 series diesel unit intended for servicing a long-distance train. The lack of locomotives at the starting station needed to run the train was due to insufficient rolling stock. In the event of a breakdown of a locomotive or the need to perform a scheduled technical inspection, it is necessary to move the train onto another vehicle. If the rolling stock reserve is insufficient, the temporary shutdown of even one in-use diesel locomotive results in the lack of a vehicle needed to drive the train and, thus, a cancellation. In the case of series 754 locomotives, the situation is additionally complicated by the fact that on site at the Polish locomotive shed, it is possible only to perform control inspections and make minor repairs. All repairs of a larger scope are carried out in the Czech Republic. Due to the considerable distance that needs to be covered, for example, from the depot in Białystok or Gdynia, this situation significantly extends the locomotive's unavailability. In the case of SN84 series diesel multiple units rented from SKPL Cargo, four vehicles were available in the analyzed period. Thus, the timetable provided the daily use of two vehicles. Therefore, the rolling stock reserve was sufficient, and, in turn, there was no shortage of SN84 series vehicles at the starting station needed to service the train. In the case of diesel locomotives of the remaining series, the rolling stock reserve was too small and did not allow for the trouble-free operation of trains.

The diesel locomotives that experienced shortages were also analyzed. Diesel locomotives for long-distance trains are stationed in five different depots. Table 5 shows the number of missing locomotives from each locomotive shed that resulted in the cancellation of a train.

More than half of the shortages of diesel locomotives occurred at the Białystok depot. In the analyzed period, vehicles from this depot served trains on the Białystok – Olsztyn and Białystok – Suwałki sections. There were also significant shortages of locomotives in Gdynia. However, this depot serves trains over a very large area, running to Zbąszynek, Kostrzyn, and Szczecin. The locomotive can reach Gdynia only with the TLK Bory Tucholskie train, so the possibility of a quick repair or sending a replacement locomotive to the area served by the locomotive depot in Gdynia is limited. The locomotives are outside the locomotive shed for a long time and are refueled in other areas (e.g., Szczecin).

Table 5

Lack of different series of locomotives in different depots

Location:	Number of shortages:	Shortages as a percentage:
Białystok	60	51%
Gdynia	20	17%
Kraków	16	14%
Wrocław	12	10%
Lublin	10	8%
Sum:	118	100%

Fig. 4 shows the routes on which trains were canceled due to the lack of an available diesel locomotive as percentages. Almost half of the trains that were canceled due to the lack of an available locomotive ran on the Sokółka – Suwałki section. The TLK Hańcza train running on this section was canceled the most times; the TLK Podlasiak train running this route was also often canceled, as was the TLK Sudety train running between Kraków and Jelenia Góra, which was operated by a series 754 locomotive. In the remaining sections, the trains were canceled less frequently due to the lack of a locomotive.

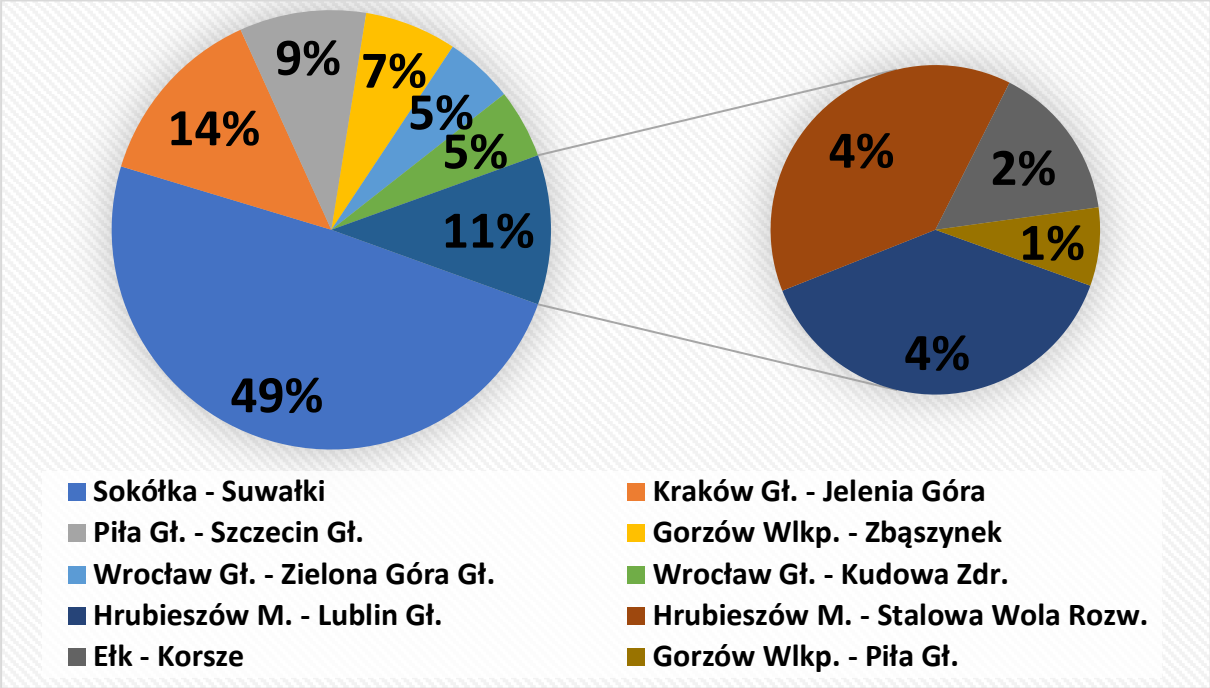

Fig. 4. Sections on which trains were canceled due to a lack of a diesel locomotive

3.3. Other reasons for train cancellations

In the analyzed period, two events prevented trains from reaching their destination stations. On January 12, 2021, the TLK Bory Tucholskie train collided with a road vehicle on the Starogard Gdański – Tczew route. On February 3, 2021, the TLK Biebrza train driven by the SU160-009 locomotive collided with a tanker truck transporting milk at the crossing near Grajewo. This event caused the SU160-009 locomotive to be permanently decommissioned. A fragment of the track and the traction network was also damaged, which made the Ełk – Mońki route impassable for two days. In addition, the running of long-distance trains driven by diesel locomotives disrupted the blockage of the route due to an accident or failure of a passenger train, as well as due to difficult weather conditions (heavy snowfall or strong winds).

4. COMPARISON OF THE NUMBERS OF CANCELED TRAINS IN FEBRUARY 2021 AND 2022

In the period from 13 December 2020 until 13 March 2021, the most canceled long-distance trains operated by diesel locomotives occurred in February. A comparison was made of the number of cancellations of individual trains in February 2021 and 2022 in order to check how this situation changed during the year. These data are presented in Table 6.

In February 2021, the most frequently canceled long-distance train was TLK Hańcza on the Sokółka – Suwałki section. The train was driven as planned by a series 754 locomotive and was canceled as many as 20 times. In the same period of 2022, the train was canceled only twice. The leading locomotive

was changed to the SU160 series. Another frequently canceled train was TLK Staszic, which failed to travel from Piła to Szczecin 13 times in 2021.

Table 6

Comparison of canceled trains in February 2021 and February 2022

Train	Canceled trains in February 2021	Canceled trains in February 2022	Difference
TLK Hańcza	20	2	-18
TLK Staszic	13	5	-8
IC Podlasiak	12	0	-12
TLK Sudety	10	2	-8
IC Hetman	6	0	-6
IC Mamry	5	0	-5
TLK Zamoyski	4	2	-2
TLK Biebrza	4	1	-3
IC Rybak	3	0	-3
IC Lubuszanin	3	8	+5
IC Gałczyński/Dionizos	3	11	+8
TLK Śnieżka	2	4	+2
TLK Rozewie	2	1	-1
TLK Kociewie	2	0	-2
IC Konopnicka/Hetman	0	13	+13
TLK Bory Tucholskie	0	3	+3
TLK Kormoran	0	1	+1
TLK Flisak	No train	1	+1
Sum:	89	54	-35

The train was operated by a SU4210 locomotive. In the following year, the train was canceled only five times. In February 2021, the TLK Podlasiak train was also frequently canceled, which failed to run 12 times on the Sokółka – Suwałki section. In 2022, the train was not canceled. The driving vehicles of this train remained the SU160 series locomotives. Problems with frequent cancellations also concerned the TLK Sudety train from Kraków to Jelenia Góra. In 2021, it was routed along the entire route by a series 754 locomotive. In the absence of an available diesel locomotive, it was led by an electric locomotive to Kędzierzyn-Koźle, and a replacement bus service was introduced further along. In February 2021, 10 trains on this route were canceled. In February 2022, the train was operated by a diesel multiple unit of the SN84 series. Only one pair of trains on the section from Kędzierzyn-Koźle to Jelenia Góra was canceled when one of the vehicle's engines failed. Compared to February 2021, in 2022, the number of long-distance trains canceled in the Gorzów Wielkopolski – Zbąszynek section increased. The IC Lubuszanin train was canceled five additional times, while the IC Dionizos train (which replaced the IC Gałczyński train) was canceled an additional eight times. In 2021, trains on this section were driven by locomotives of the SU4210 series. In 2022, however, locomotives of this series appeared only sporadically, and they were replaced by the 754 series vehicles. In February 2021, on the section from Zielona Góra through Żary and Miłkowice to Wrocław, a TLK Konopnicka train ran and was not canceled even once. In 2022, the train on this route was replaced by IC Hetman, and in Wrocław, direct carriages from Zielona Góra were attached to the train going to Hrubieszów. In February 2022, the train was canceled 13 times on the section from Zielona Góra to Wrocław. The TLK Konopnicka train was operated by the SU4210 series vehicles. The IC Hetman train to Zielona Góra was also driven by locomotives of this series, supported by the SU42-536 locomotive.

In February 2021, a smaller number of trains were launched than in February 202, and this difference should be taken into account for a full comparison of canceled trains. A comparison of the number of scheduled and actually started trains is shown in Table 7.

Table 7

Comparison of canceled trains with those that have been launched

Factor:	In February 2021:	In February 2022:
Number of running trains	532	644
Number of canceled trains	89	54
Percentage of canceled trains	16.73%	8.39%
Mileage of diesel locomotives to be performed	222,824 train-km	286,944 train-km
Actual performed mileage of diesel locomotives	207,417 train-km	277,910 train-km
Percentage of not performed mileage	6.91%	3.15%

In February 2021, almost 17% of the long-distance trains scheduled in the timetable traveling on non-electrified railway lines were canceled, at least along part of the route. In the corresponding period in 2022, only slightly more than 8% of trains were canceled. Despite the increase in the number of trains driven by diesel locomotives, significantly fewer trains were canceled. The number of train-kilometers traveled by diesel locomotives was also compared to the number of train-kilometers provided for in the timetable. Like the number of trains, the number of train-kilometers to be traveled by diesel locomotives in the timetable increased. In February 2021, diesel locomotives failed to perform almost 7% of the planned train-kilometers while operating long-distance trains. In the same period in 2022, slightly more than 3% of the planned train-kilometers were not performed. It should be noted that both in February 2021 and 2022, not many more trains were canceled along at least part of the route in comparison to the number of planned train-kilometers that were not completed. A significant number of canceled trains covered only a part of their route led by a diesel locomotive. The remaining trains driven by a diesel locomotive along a longer distance were not canceled as often. Moreover, the number of missed train-kilometers by long-distance trains is even smaller when compared to diesel locomotives. This outcome is related to the replacement of diesel locomotives by electric locomotives on electrified sections (e.g., on the Kraków – Kędzierzyn-Koźle or Białystok – Sokółka section).

5. COMPARISON OF THE RUNNING OF LOCOMOTIVES SERIES 754

Most types of diesel locomotives used to drive long-distance trains on non-electrified lines are used only in Poland. However, series 754 locomotives are mainly used in the Czech Republic. Since 2014, the Czech Republic has rented five vehicles of this series to Poland. Due to large problems with the availability of these vehicles in Poland, it was checked how these vehicles travel in the Czech Republic. The comparison was made for February 2021, which is the month in which the most trains were canceled in the analyzed period. This comparison is shown in Table 8. During this period, in Poland, three pairs of long-distance trains were served daily by locomotives of the 754 series. In the Czech Republic, these locomotives ran 49 pairs of fast and accelerated trains every day (the comparison did not include regional trains due to their different specificity). The daily mileage of locomotives in the Czech Republic was much higher than in Poland. The average distance of one train driven by a 754 series locomotive in Poland was 224 km, and in the Czech Republic, this distance was only 78 km. Thus, the daily mileage of one vehicle in Poland in the analyzed period was much higher than in the Czech Republic, which may contribute to the higher failure rate of locomotives. In Poland, as many as 41 trains were canceled in February 2021 due to the lack of an available locomotive at the starting station. In the Czech Republic, this situation occurred only once. However, there were a total of 10 locomotive failures while driving with a train in the Czech Republic; in Poland, no failures of the series 754 locomotives occurred while driving. The main reason for the frequent lack of available locomotives at departure stations in Poland is the need for locomotives to travel to the Czech Republic for major repairs. In the Czech Republic, all repairs are carried out on site, which means that an inoperative vehicle can return to traffic faster.

Table 8

Comparison of the running of the series 754 locomotives in Poland and the Czech Republic

Factor	Poland	Czech Republic
Number of pairs of trains per day	3	49
Number of trains per month	168	2744
Number of trains canceled due to a lack of a locomotive	41	1
Number of locomotive failures	0	10
Total daily mileage of locomotives	1344 km	7602 km
Average mileage of one train	224 km	78 km

6. DIESEL LOCOMOTIVES

The diesel locomotives used to drive long-distance trains on lines not electrified by PKP Intercity are listed in Table 9. The number of operational locomotives changes over time due to breakdowns, scheduled repairs, and railway incidents. The table shows the status of locomotives on 12 March 2022. The PKP Intercity company owns 10 diesel locomotives of the SU160 series. Due to the exclusion of some vehicles for driving long-distance trains, the prototype locomotive 111Db-001, owned by the manufacturer PESA Bydgoszcz, is also used. The SU160-009 locomotive was out of service after an accident with the tanker near Grajewo on 3 February 2021. In turn, the SU160-004 locomotive collided with a semi-trailer near the Niemojki station on 19 January 2022 and has been waiting for necessary repairs since then. PKP Intercity also owns 10 SU4210 series locomotives. These are the SM42 series vehicles modernized by Newag. The SU4210-009 and 010 locomotives were undergoing repairs of the P4 at Newag. Moreover, PKP Intercity placed an order with FPS – H. Cegielski for the modernization of 13 SM42 series vehicles. After modernization, they receive the designation of SU4220. In March 2022, three vehicles from this order were available.

The PKP Intercity company also uses rented vehicles. It rents five series 754 locomotives from České dràhy (Czech Railways). A total of seven vehicles of this series are approved for traffic in Poland, five of which should be regularly available. The SU42-536 locomotive owned by Morvi is also rented. Moreover, the SKPL Cargo company rents four diesel multiple units of the SN84 series, which service long-distance trains on non-electrified lines in the vicinity of Krakow. The most significant problem is the availability of diesel locomotives equipped with 3kV electricity, which is necessary for heating and air-conditioning system operation. During the holiday season, long-distance trains consisting of non-modernized carriages can be run by diesel locomotives without such an installation, the availability of which is greater. The maximum permissible speed on non-electrified lines in Poland is 120 km/h. The problem with maintaining the scheduled travel time occurs mainly in the case of SM42 series locomotives and their modernization. These vehicles can travel at a maximum speed of 90 km/h.

Table 9

Efficient diesel locomotives of the PKP Intercity company

Series	Numbers	Maximum speed	Diesel engine power
SU160	111Db-001, 001, 002, 003, 005, 006, 007, 008, 010	140/160 km/h	2400 kW
SU4210	001, 002, 003, 004, 005, 006, 007, 008	90 km/h	563 kW
SU4220	001, 002, 003	90 km/h	?
754	015, 025, 026, 028, 037, 041, 046	100 km/h	1460 kW
SU42	536	90 km/h	588 kW
SN84	001, 002, 003, 004	140 km/h	754 kW

7. CONCLUSIONS

In the period from 13 December 2020 until 13 March 2021, 163 long-distance trains on non-electrified lines were canceled in Poland. The main reason for canceling trains was the lack of an available diesel locomotive at the departure station. As many as 73% of canceled trains were canceled for this reason. Most often, the lack of a locomotive occurred for trains intended to be driven by Czech 754 series vehicles (49% of cases). The locomotive shortages also concerned other vehicles operated by PKP Intercity (i.e., the SU4210 and SU160 series locomotives). The greatest shortages of locomotives in the analyzed period occurred in Białystok (51% of all trains were canceled for this reason). This problem mainly concerned trains running on the non-electrified section from Sokółka to Suwałki (as many as 49% of all canceled trains were scheduled to run on this section).

Problems with running long-distance trains on non-electrified lines in the analyzed period occurred most often in February. A comparison shows that in February 2021, as many as 89 trains were canceled on at least part of the route; in February 2022, 54 trains were canceled. A significant improvement in the regularity of trains was recorded on the section from Sokółka to Suwałki. On this section, the 754 series locomotives serving the TLK Hańcza train were replaced by SU160 series vehicles. Another significant decrease in the number of canceled trips concerns the TLK Sudety train from Kraków to Jelenia Góra. On this section, the previously operating locomotives of the 754 series were replaced by diesel multiple units of the SN84 series. A significant increase in the number of canceled trains was found regarding the IC Hetman train on the Zielona Góra – Wrocław section (which replaced the TLK Konopnicka train). This is due to the lack of the SU4210 series locomotives in Wrocław, delays in the deliveries of the modernized SU4220 locomotives and failures of the rented SU42-536 locomotives. The number of canceled trains also increased on the section from Gorzów Wielkopolski to Zbąszynek due to the replacement of SU4210 locomotives by 754 series vehicles. Between February 2021 and February 2022, there was an increase in the number of long-distance trains launched on non-electrified lines in Poland. Despite this increase, 8.39% of scheduled trains were canceled in February 2022 (in the same period of the previous year, this percentage was 16.73%). In February 2022, more of the planned mileage of diesel locomotives was also completed. It can be noticed that the percentage of canceled trains is much higher than the percentage of unrealized operational work by diesel locomotives. This is because mainly short-distance trains were canceled.

Currently, the PKP Intercity company has 10 diesel locomotives of the SU160 series, as well as 10 vehicles of the SU4210 series. The modernization of 13 SM42 series locomotives is also being carried out; they will be equipped with devices that will supply them with electricity and will be marked SU4220. After all the ordered SU4220 series locomotives have been received, the rolling stock problems will decrease. Five series 754 locomotives, one SU42-536 locomotive, and four diesel multiple units must be rented to implement the planned connections. There are no plans to purchase new diesel locomotives to drive long-distance trains. In the future, hybrid diesel-electric locomotives are to be purchased. This will eliminate the time-consuming process of changing the locomotive from electric to diesel when the train enters a non-electrified section. In addition, the need to use an internal combustion engine while driving on electrified lines will be eliminated. An additional factor that will reduce the demand for diesel locomotives in the coming years is the electrification of some railway lines. Currently, activities related to the modernization and electrification of the line on the Ełk – Korsze section are underway. The electrification of this communication route will allow the use of one to two diesel locomotives on other routes.

References

1. Smolarski, M. Reaktywacje pasażerskich linii kolejowych w Polsce w latach 2000-2020. *Studia Regionalne i Lokalne.* 2021. Vol. 85. No. 3. P. 68-83. [In Polish: Reactivations of passenger railways in Poland in the years 2000-2020. *Regional and Local Studies*].

2. Soczówka, P. & Kłos, M.J. & Żochowska, R. & Sobota, A. An analysis of the influence of travel time on access time in public transport. *Scientific Journal of Silesian University of Technology. Series Transport*. 2021. Vol. 111. P. 137-149.
3. Płachta, O. Analiza sieci połączeń kolejowych między miastami wojewódzkimi a miejscowościami uzdrowiskowymi na obszarze Polski. *Rozwój Regionalny i Polityka Regionalna*. 2018. No. 20. P. 37-52. [In Polish: Analysis of the network of railway connections between voivodeship capitals and health resorts in Poland. *Regional Development and Regional Policy*].
4. Ghaviha, N. & Campillo, J. & Bohlin, M. & Dahlquist, E. Reviev of Application of Energy Storage Devices in Railway Transportation. *Energy Procedia*. 2017. Vol. 105. P. 4561-4568.
5. Graff, M. Nowe elektryczne zespoły trakcyjne w obsłudze ruchu regionalnego i dalekobieżnego w Polsce w 2015 r. *TTS Technika Transportu Szynowego*. 2016. Nos. 1-2. P. 22-33. [In Polish: New electric multiple units in servicing regional and long-distance traffic in Poland in 2015. *TTS Rail Transport Technique*].
6. Dolinayova, A. & Zitricky, V. & Cerna, L. Decision-making process in the case of insufficient rail capacity. *Sustainability.* 2020. Vol. 12. No. 5023.
7. Abramesko, V. & Tartakovsky, L. Ultrafine particle air pollution inside diesel-propelled passenger trains. *Environmental Pollution.* 2017. Vol. 226. P. 288-296.
8. Soczówka, A. Kolejowe połączenia dalekobieżne wybrzeża w latach 1987-2006. In: Machowski, R. & Ruman, M. *Z badan nad wpływem antropopresji na środowisko*. Vol. 7. Sosnowiec: Wydział Nauk o Ziemi UŚ. 2006. P. 86-97. [In Polish: Long-distance coastal connections in 1987-2006. In: *From research on the influence of anthropopressure on the environment.* Faculty of Earth Sciences University of Silesia in Sosnowiec].
9. Przybysz, B. Modele organizacji przewozów kolejowych w służbie publicznej. In: *III Krakowska Ogólnopolska Konferencja Naukowa Transportu "KOKONAT".* Kraków. 2016. [In Polish: Models of the organization of rail transport in the public service. In: *3rd Krakow National Scientific Conference of Transport "KOKONAT"*].
10. Engelhardt, J. Zarządzanie publicznym transportem kolejowym w Polsce w latach 1990-2018. *Transport Miejski i Regionalny*. 2018. No. 11. P. 17-23. [In Polish: Management of public rail transport in Poland in 1990-2018. *City and Regional Transport*].
11. Wiegmans, B. & Janic, M. Analysis, modelling, and assessing performances pf supply chains served by long-distance freight transport corridors. *International Journal od Sustainable Transportation*. 2019. Vol. 13. No. 4. P. 278-293.
12. Schipper, D. & Gerrits, L. Differences and similarities in European railway disruption management practices. *Journal of rail transport planning & management*. 2018. Vol. 8. No. 1. P. 42-55.
13. Graff, M. Komunikacja kolejowa pomiędzy Polską i Litwą. *TTS Technika Transportu Szynowego*. 2017. No. 7. P. 45-52. [In Polish: Railway communication between Poland and Lithuania. *TTS Rail Transport Technique*].
14. Maciążek, F. Komunikacja kolejowa między Polską a Białorusią. *TTS Technika Transportu Szynowego*. 2017. No. 10. P. 22-40. [In Polish: Railway communication between Poland and Belarus. *TTS Rail Transport Technique*].
15. Gniedziejko, J. Can the Polish-Belarusian border become the railway gate of the Belt and Road Initiative? *Advances in Natural and Applied Sciences*. 2020. Vol. 14. No. 3. P. 61-68.
16. Graff, M. Komunikacja kolejowa na polsko-niemieckim pograniczu. *TTS Technika Transportu Szynowego*. 2017. No. 3. P. 22-33. [In Polish: Railway communication on the Polish-German border. *TTS Rail Transport Technique*].
17. Gong, M. System and prospects of China's intercity rail transit technology. *Frontiers of Mechanical Engineering*. 2018. Vol. 13. P. 323-328.
18. *Ogólnopolska Baza Kolejowa*. Available at: https://www.bazakolejowa.pl. [In Polish: *Nationwide Railway Base*].

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