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The effect of breaks on a railway line capacity

Wpływ przerw na przepustowość linii kolejowej

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Abstract

Using the example of one section of a railway line, the effect of various factors on breaks in train service has been analysed. The types, number and duration of breakdowns, as well as their influence on both passenger and goods trains service have been specified. The traffic capacity of a railway line is related to the possibility of meeting the timetable, which is therefore affected by all breaks. It is very important to know the type of breakdowns, their number and influence on a railway line capacity as well as their causes.

Słowa kluczowe: przerwa niezaplanowana, linia kolejowa, przepustowość

Abstrakt

Na przykładzie jednego odcinka linii kolejowej przeanalizowano wpływ różnych czynników na przerwy w ruchu pociągów. Wyszczególniono rodzaje awarii, liczbę oraz czas ich trwania, a także ich wpływ na kursowanie pociągów osobowych i towarowych. Przepustowość linii kolejowej dotyczy możliwości zrealizowania rozkładu jazdy i dlatego wszystkie przerwy mają wpływ na jego planowość. Bardzo istotna jest również wiedza nie tylko o rodzaju, liczbie awarii i ich wpływie na przepustowość linii kolejowej, ale również przyczyny ich powstawania.

Introduction

A break in work is a planned or unplanned stoppage of the process of work during a working day.

Breaks in work fall into the following categories:

- arbitrary breaks – initiated by an employee on his/her own,
- organised breaks – prearranged by the company,
- unplanned breaks – result from unpredictable events e.g.: a machine breakdown, the lack of raw materials etc.

A breakdown is an object's failure, which prevents it from functioning or causes its immobility. Such an occurrence is usually unpredictable and does not require the use of specialist research equipment. Also its range is impossible to foresee. Sometimes, however, a "possibility of a breakdown occurrence" can be anticipated. There are certain symptoms (signals), which finally result in a breakdown.

The most frequent causes of breakdowns include:

- a designer's error,
- a production defect (workmanship, assembly),
- a material defect,
- improper use (not compliant with the conditions specified by the producer),
- physical wear,
- unfavourable (specific) environmental conditions.

The possibility of a breakdown is most frequently defined in the scale of a year as a probability of its occurrence, referred to the number of events or the duration of the object's immobility.

Practice proves, that absolute technical perfection is unattainable – therefore an admissible degree of imperfection is defined. The effects of breakdowns resulting from imperfection are reduced by using adequate protection.

Railway lines

The task of railway transportation is to provide mass carriage in both freight and passenger traffic. It plays a special role in the transport of people, as well as goods between big agglomerations.

PKP PLK SA is the biggest administrator of the railway infrastructure in Poland. Its main task is to maintain the network of railway tracks in a condition, which enables making the routes available to railway carriers and providing other services on their behalf – this is the basic product of the enterprise. The railway network is made available on the basis of a timetable, which is established according to a customer's order and sold in a form of a fixed route.

A railway network is a system of interconnected railway lines functioning on the territory of the whole country [1, 2], which are owned or administered by the infrastructure administrator [3].

A railway line is an element of a railway network, consisting of one, two or more tracks between the starting and terminal point, which has its own chainage, number and name (granted by PLK SA Managing Board.) The line also comprises the ground on which the tracks are laid and the area adjacent to the track together with the buildings and structures for train traffic management and operational works.

A railway line should fulfil the operational parameters necessary to render the transport of people or goods possible. The route of a railway line, the constructional standards of a rail track, as well as traffic control and communication equipment should correspond to the category of railway lines, the operational parameters of which are defined by the Order of MTiGM (Ministry of Transport and Maritime Economy) on the technical requirements and location of railway structures as of 10th April 1998 [4].

The basic source of information and detailed data on particular railway lines in Poland is: The list of lines – Infrastructure Id-22 (D-29), which specifies the nomenclature and numbering principles and contains characteristics of all railway lines.

Unfortunately, the condition of the railway lines has been steadily deteriorating. More and more restrictions are being introduced, which results in the prolonged duration of journeys; more and more sections are being closed. This is chiefly due to the worsening technical condition of the track structure and the lack of resources for modernization or new investments. Tracks, turnouts and railway traffic control equipment built at the beginning of the previous century have been undergoing only current repairs. This contributes to frequent incidents of this equipment malfunctioning, which has a significant impact on the railway traffic. Transportation possibilities are therefore limited.

The capacity of a railway line is connected with the possibility of meeting the timetable, which is therefore affected by all breaks. The installed equipment is supposed to help control the traffic, improve the railway line capacity as well as ensure safety and reduce the effect of a human factor in this process. A break in the equipment work is likely to result in delays. Information on the type and number of breakdowns as well as their influence on the railway line capacity is important, but so are the causes of breakdowns.

Short characteristics of PKP PLK SA

PKP PLK SA is a part of PKP group, which was established in 2001 as a result of restructuring of the state enterprise Polish State Railways (Polskie Koleje Państwowe).

PKP PLK SA is the administrator of the railway lines network on the territory of Poland. The basic tasks of the company include [5]:

- making the railway lines available to carriers, while observing the principle of equal treatment;
- modernization of railway lines so as to adjust them to European Union standards;
- preparation of railway timetables;
- the management of railway traffic on railway lines;
- maintaining the railway infrastructure in a condition that ensures safe railway traffic;
- cooperation with neighbouring administrators of the railway infrastructure.

The strategy of the company activity is based on strategic governmental documents, EU transport policy, Polish and EU regulations, while taking into consideration its needs resulting from current activity, commercial conditions and the situation on the market [5].

The railway network administered by PKP PLK SA is divided between Railway Lines Plants (Zakłady Linii Kolejowych). The task of these Plants is to maintain and operate the railway infrastructure in a way guaranteeing its technical and operational efficiency and projected reliability.

Moreover, the tasks performed by particular Plants include:

– management of railway traffic, while ensuring its regularity, punctuality and safety;
– removing the effects of accidents and incidents on railway lines;
– administration and operation of the railway infrastructure in order to make it available to railway carriers.

The condition of the track structure is constantly deteriorating due to insufficient financial resources. The general evaluation of the tracks technical condition has been presented in figure 1. The following criteria were adopted to assess the technical condition of the tracks [5]:

- good – the lines are used according to preset operational parameters;
- satisfactory – the lines are used according to reduced operational parameters;
- unsatisfactory – the lines are used according to considerably reduced operational parameters.

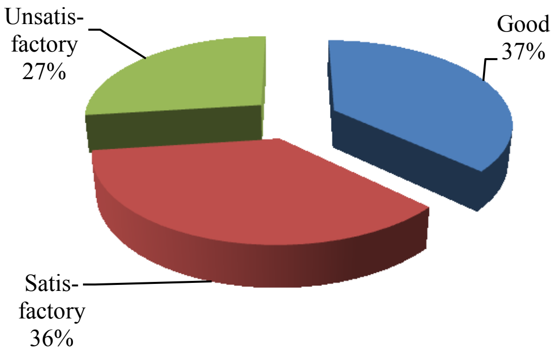

Fig. 1. Technical condition of railway tracks in Poland
Rys. 1. Stan techniczny torów linii kolejowych w Polsce

Apart from railway tracks, PKP PLK SA is also the owner of all equipment used for railway traffic protection. The group of rail traffic control equipment (RTC) consists chiefly of relay and mechanical devices. The latest generation of RTC includes computer systems, which are more reliable and ensure a high level of traffic safety.

Short characteristics of the investigated area

The railway infrastructure area subjected to analysis is one of Railway Lines Plants belonging to PKP PLK SA, which operates on the territory of Silesia. It is line 135, providing a route between the stations Gliwice Łabędy–Pyskowice and a section of line 132 between Pyskowice and Toszek (Fig. 2).

The analysed area is covered by an AGTC agreement – a European agreement regarding the most important routes of combined international transportation and off-site facilities, drawn up in Geneva on 1st February, 2001. The line in question belongs to the international line C-E30.

The first part of the examined area is line 135 connecting the stations of Gliwice Łabędy (GŁ) and Pyskowice (PKA). Below have been outlined the general characteristics of the line, based on the instruction Id-13 PKP PLK SA:

- line length – 6,097 km;
  - ∗ the beginning of line at: – 0,408 km,
  - ∗ starting point: Gliwice Łabędy – turnout No. 29,
  - ∗ end of line at: – 5,689 km,
  - ∗ terminal point: Pyskowice – turnout No. 161,
  - ∗ splits off line: 137 – at 32,577km,
  - ∗ reaches line: 132 – at 40,488km,
- line category – main line,
- number of tracks – two,
- electrification – yes, over the whole length,
- track width – standard,
- line significance – state line,
- track class – track No. 1 and 2 – class 2,
- covered by agreement – AGTC over the whole length,
- construction speed – for track No. 1 and 2 – 100 km/h.

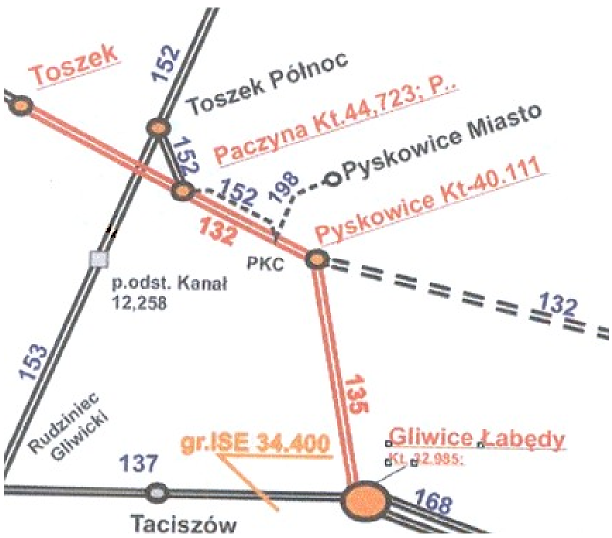

Fig. 2. Diagram of analysed lines
Rys. 2. Schemat badanych linii

Apart from the starting and terminal station, the analysed line includes a station in Gliwice Kuźnica, which is permanently open for passenger traffic. Since the traffic on this line is influenced by breakdowns at the station of Gliwice Łabędy and Pyskowice, the analysed area has been extended with some parts of the infrastructure and equipment participating in the process of train acceptance and dispatch on this trail.

A part of line 132 (Bytom–Wrocław Gł.) covers a section between Pyskowice–Toszek stations. This part of line consists of two trails: Pyskowice-Paczyna and Paczyna–Toszek (Fig. 2).

Below have been given the main parameters of this section:

- line length – 10,180 km,
  - ∗ the beginning of line at – 39,640km,
  - ∗ the end of line at – 49,800km,
  - ∗ the terminal point – railway sign W4 by the axis of Toszek station,
- line category – main line,
- number of tracks – two,
- electrification – yes, over the whole length,
- track width – standard width,
- line significance – state line,
- track class – track No. 1 and 2 – class 2,
- construction speed – for track No. 1 and 2 – 100 km/h.

Breaks in traffic on the selected railway line

The breakdowns which occurred on the analysed railway line have been given in table 1 [2]. The list of breakdowns has been based on the following documents:

- the book of events for lines 132 and 135 – in an electronic form, in which all additional "minutes" of a train passage in relation to the timetable are recorded with the specification of their causes;
- the book of events and incidents;
- the book of defects and closures;
- technical documentation kept at signal boxes;
- telephone logs.

Due to the high number of breakdowns and many causes of their occurrence, they have been grouped into the following categories:

- failures related to RTC (Rail Traffic Control) functioning,
- failures related to the functioning of trains,
- defects in track structure,
- damage and breaks in the contact line supply,
- defects and breaks in the functioning of communication equipment,
- damaged power unit (damage which has resulted in trail blockage),
- other.

Table 1 presents the types of breakdowns, data on the quantity and time, the number of delayed trains and the effect of breakdowns on the duration of train delays.

As can be concluded from the data contained in table 1, the number of breakdowns does not directly translate into their duration and effects of breaks.

Table 1. Failures at investigated area
Tabela 1. Awarie na badanym obszarze

No.	Types of breakdowns, failures, and other events	Quantity	Duration [mns]	Number of delayed trains	Total duration of train delays [mns]
1	Breakdowns related to RTC (Rail Traffic Control) functioning	140	75,019	6	34
2	Breakdowns related to the functioning of trains	36	4,665	40	4,334
3	Defects in track structure	31	106,054	18	399
4	Damage and breaks in the contact line supply	30	5,536	1	5
5	Damaged power unit (damage which has resulted in trail blockage)	8	1,770	19	1,283
6	Defects and breaks in the functioning of communication equipment	3	14,795	0	0
7	Other	7	660	8	354
Total:		255	208,499	92	6,409

Table 2. Percentage distribution of the number of breakdowns
Tabela 2. Procentowy rozdział liczby awarii

No.	Types of breakdowns, failures, and other events	Quantity	Share [%]
1	Breakdowns related to RTC (Rail Traffic Control) functioning	140	56
2	Breakdowns related to the functioning of trains	36	14
3	Defects in track structure	31	12
4	Damage and breaks in the contact line supply	30	11
5	Damaged power unit (damage which has resulted in trail blockage)	8	3
6	Defects and breaks in the functioning of communication equipment	3	1
7	Other	7	3
Total:		255	100

The percentage distribution of the number of breakdowns has been presented in table 2 and in the graph (Fig. 3).

Information on the number of particular types of breakdowns points to the necessity of repairs and changes in the manner of traffic management. Equally important is the duration of breakdowns.

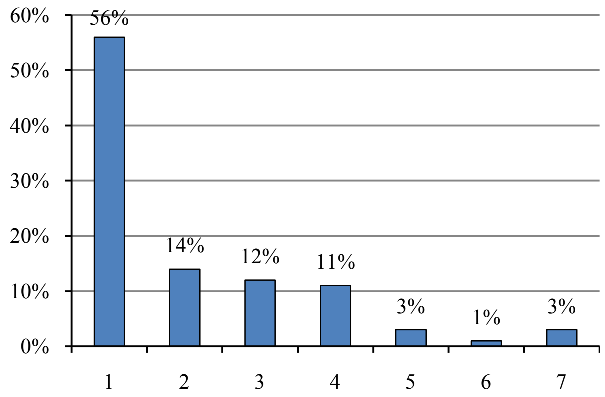

Fig. 3. Percentage distribution of the number of breakdowns
Rys. 3. Rozkład liczby awarii

Table 3 presents the percentage share of the duration of particular types of breakdowns and their average duration. Graphically this dependence has been shown in figure 4.

Table 4 shows the total time of all train delays according to the cause of a breakdown. This dependence has also been presented in a graphic form (Fig. 5).

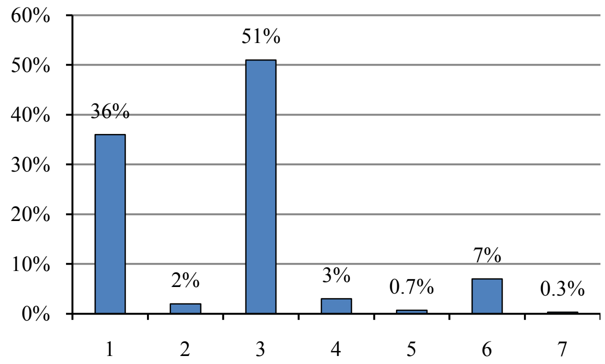

Fig. 4. Percentage share of the duration of particular types of breakdowns
Rys. 4. Procentowy rozkład czasów trwania poszczególnych rodzajów awarii

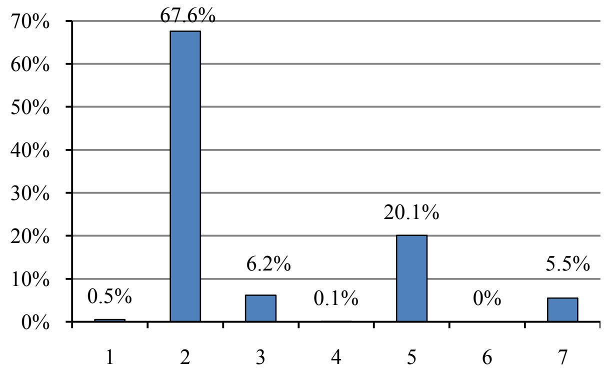

Fig. 5. Total time of train delays according to the cause of a breakdown
Rys. 5. Łączny czas opóźnień pociągów w zależności od rodzaju awarii

Table 3. Percentage share of the duration of breakdowns
Tabela 3. Procentowy rozdział czasów trwania awarii

No.	Types of breakdowns, failures, and other events	Duration [mns]	Average duration [mns]	Share [%]
1	Breakdowns related to RTC (Rail Traffic Control) functioning	75,019	535.9	36
2	Breakdowns related to the functioning of trains	4,665	129.6	2
3	Defects in track structure	106,054	3,421.1	51
4	Damage and breaks in the contact line supply	5,536	184.5	3
5	Damaged power unit (damage which has resulted in trail blockage)	1,770	221.3	0.7
6	Defects and breaks in the functioning of communication equipment	14,795	4,931.7	7
7	Other	660	94.3	0.3
Total:		208,499	9,518.4	100

Table 4. Total time of all train delays according to the cause of a breakdown
Tabela 4. Procentowy rozkład łącznego czasu opóźnień pociągów w poszczególnych rodzajach awarii

No.	Types of breakdowns, failures, and other events	Total time of train delays [mns]	Share [%]
1	Breakdowns related to RTC (Rail Traffic Control) functioning	34	0.5
2	Breakdowns related to the functioning of trains	4,334	67.6
3	Defects in track structure	399	6.2
4	Damage and breaks in the contact line supply	5	0.1
5	Damaged power unit (damage which has resulted in trail blockage)	1,283	20.1
6	Defects and breaks in the functioning of communication equipment	0	0
7	Other	354	5.5
Total:		6,409	100

Table 5. Breakdowns share in train delays
Tabela 5. Udział rodzajów awarii w opóźnieniach pociągów

No.	Types of breakdowns, failures, and other events	Train delays			
		Passenger		Freight	
		Quantity [pcs]	Duration [mns]	Quantity [pcs]	Duration [mns]
1	Breakdowns related to RTC (Rail Traffic Control) functioning	6	34	0	0
2	Breakdowns related to the functioning of trains	19	332	21	4002
3	Defects in track structure	16	139	2	260
4	Damage and breaks in the contact line supply	1	5	0	0
5	Damaged power unit (damage which has resulted in trail blockage)	13	329	6	954
6	Defects and breaks in the functioning of communication equipment	0	0	0	0
7	Other	5	80	3	274
Total:		60	919	32	5490

The analysis of tables (1, 2, 3 and 4) reveals, that the number of breakdowns in not tantamount to the duration of breaks or train delay times – in terms of both the number of trains and the duration of delays.

Train delays are an important element showing the effect of breakdowns on a railway line capacity. The analysis has been conducted separately for passenger and freight trains. Table 5 presents the number of particular types of breakdowns and the total time of delays caused by these breakdowns, with a division into passenger and freight trains.

The chart in figure 6 presents the influence of the number of breakdowns on the number of delayed trains, whereas the chart in figure 7 shows the impact of breakdowns on the total time of train delays.

The presented charts indicate that the number of breakdowns is not in direct proportion to the time of train delays.

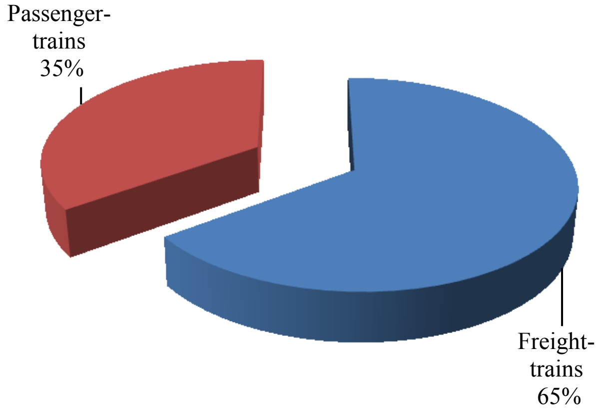

Fig. 6. Influence of the number of breakdowns on the number of delayed trains
Rys. 6. Wpływ liczby awarii na opóźnienia pociągów

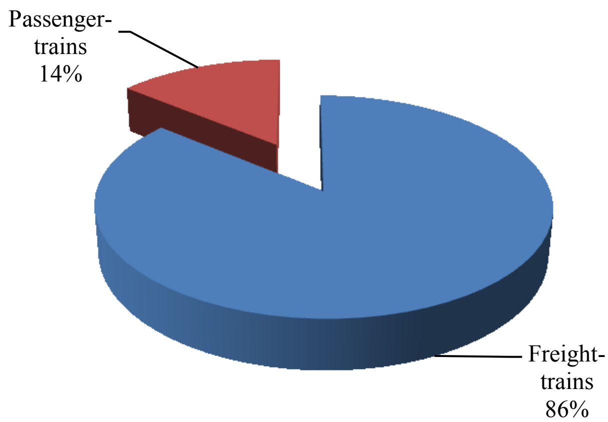

Fig. 7. Impact of breakdowns on the total time of train delays
Rys. 7. Wpływ awarii na czas opóźnień pociągów

The data contained in table 5 provided a basis for the charts presenting the delays of passenger trains from the point of view of:

– the quantity of breakdowns (Fig. 8),
– time (Fig. 9).

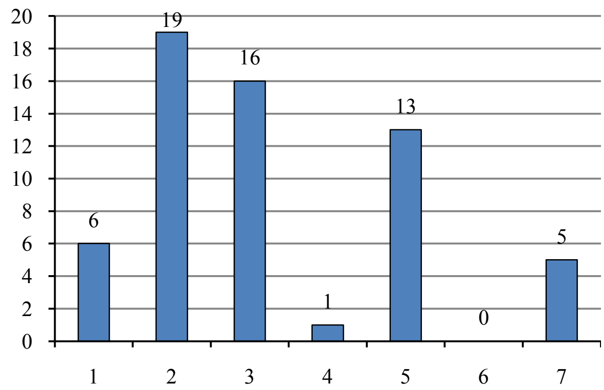

Fig. 8. Quantity share of breakdowns in passenger trains delays
Rys. 8. Udział ilościowy poszczególnych rodzajów awarii w opóźnieniach pociągów osobowych

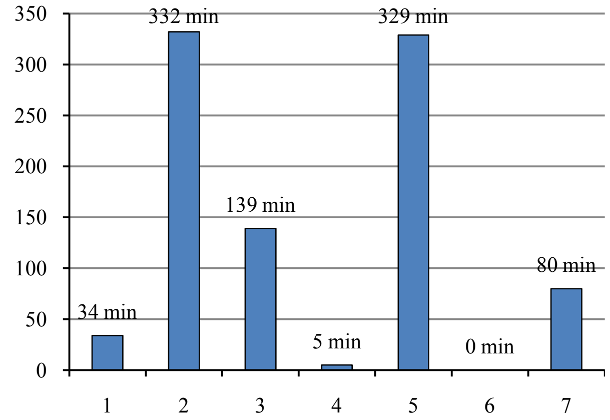

Fig. 9. Breakdowns share in the time of passenger trains delays
Rys. 9. Udział poszczególnych rodzajów awarii w czasie opóźnień pociągów osobowych

The data in table 5 has also been used to prepare charts presenting the delays of freight trains, taking into consideration:

– the number of breakdowns (Fig. 10),
– the duration of breakdowns (Fig. 11).

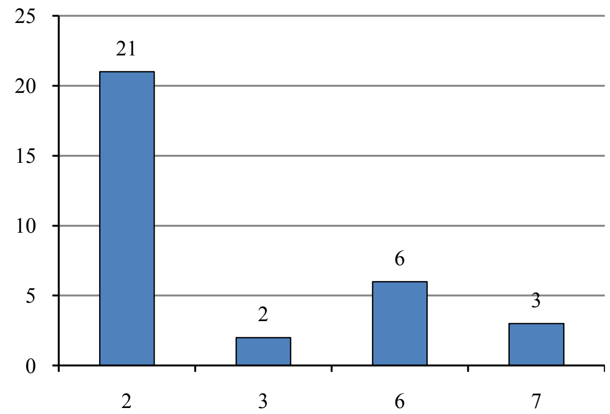

Fig. 10. Quantity share of breakdowns in freight trains delays
Rys. 10. Udział ilościowy poszczególnych rodzajów awarii w opóźnieniach pociągów towarowych

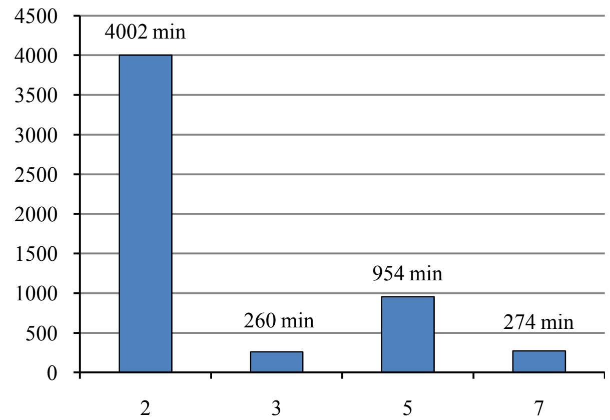

Fig. 11. Breakdowns share in the time of freight trains delays
Rys. 11. Udział poszczególnych rodzajów awarii w czasie opóźnień pociągów towarowych

Conclusions

The conducted analysis of faults and breakdowns on the sections of lines 132 and 135 indicates that the total time of breaks reached 144 days, 18 hours and 48 minutes, which is an alarming amount. The biggest share in the time of breaks belonged to failures related to the railway infrastructure, namely defects in track structure. The total time of these breakdowns reached 106054 min. This is due to the disastrous condition of the tracks, resulting from long-lasting use and the lack of investments – the tracks on these sections are 30–40 years old or more. That is why the track number 1 in Toszek was closed for a period longer than 3 months. It should also be emphasized, that for the same reason numerous speed limits have been introduced, e.g. at the station Gliwice Łabędy the admissible speed is 40km/h.

The majority of all the breakdowns (255), which occurred on the analysed section of the railway line, were directly related to the Railway Traffic Control Equipment (140 – 56%). Despite such a high number of RTC failures, the time of breaks caused by this equipment accounted for 36% of the total time of breaks.

The number of failures, irrespective of their causes and subjects contributing to their occurrence, reached as much as 83%. The remaining breaks resulted from traction equipment malfunction and other events. Other events included: the incidents of theft, devastation, accidents.

The effect of particular types of breakdowns on the number and duration of train delays depended on the type of breakdown. The highest share in the time of delay of both passenger and freight trains belonged to a damaged rail traction unit. Passenger train delays prevailed (60 out of 92), with an average delay of 15 min. Surprisingly, despite the low number of freight train delays (32 out of 92), their average time reached 177 min/train.

The relatively slight delays of passenger trains were influenced by the fact that the analysed section of the railway line (135) is covered by an AGTC agreement. In this case, each failure to meet the timetable term results in contractual penalties to be paid by the administrator, i.e. PKP PLK SA.

It is worth emphasising, that communication equipment failures did not have any adverse influence on the railway traffic. This results from the fact that every signal box is equipped with several units of both wired and wireless (radio) communication. In the event of a failure in one of these units, there is a possibility to change the manner of traffic management.

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