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# Classification and Analysis of Elements of Railway Infrastructure Maintenance in Order to Minimize Costs

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**Summary**

Maintaining the railway infrastructure in a condition ensuring safe railway traffic is the basic responsibility of railway infrastructure managers resulting from the Rail Transport Act. Elements of the railway infrastructure are subject to difficult atmospheric conditions as well as changing dynamic loads resulting from the operation of a given part of the infrastructure. The lack of proper maintenance of tracks adversely affects their operation: lowering the permissible speed, reducing driving calm, decreasing the safety of railway traffic, increasing the degradation of aggregate and railway subgrade, as well as increasing the influence of dynamic impacts on the surrounding buildings. The following article presents an analysis of maintenance tasks performed at 5 different locations. For the purposes of the article, data were collected in 2016–2018 on 100 km of track from daily reports performed by qualified supervisors managing maintenance brigades. The aim of the article is to present the results of the collected data, to analyze the most common maintenance tasks, to determine the root causes that result in the need to perform specific tasks and to propose remedies. The aim of the research was to achieve market competitiveness by minimizing costs because today's performance of duties related to the maintenance of railway infrastructure is characterized by very high costs associated with high workload, repair technology, the need to use specialized equipment, and temporarily exclude a part of the line from traffic.

The research was carried out in a company which is a manager of railway infrastructure.

**Keywords:** conformity proving, railway transport, interoperability, safety

## 1. Description and specification of the research area

An infrastructure manager is an entity responsible for managing the railway infrastructure or, in the case of new infrastructure, an entity that is engaged in its construction as an investor; the tasks of the infrastructure manager can be performed by various entities [16].

Pursuant to art. 5 para 1. of the Rail Transport Act, the infrastructure manager is in charge of the following:

1) managing the railway infrastructure, that is:
   - assigning the rail road the status of a railway line by specifying elements of the railway infrastructure being its parts, its start and end point, railway stations being its part, sections it has been divided into, its number,
   - assigning the rail road the status of a railway siding by specifying its start and end point,
   - withdrawing the status of the railway line and railway siding,
   - specifying the elements of railway infrastructure which serve as private or inactive infrastructure,
   - making rail roads available, rendering related services and collecting fees in this respect,
   - maintaining railway traffic;

2) maintaining the railway infrastructure in the condition ensuring safe railway traffic, including supervision over operation of the following:
   - railway traffic control devices,
   - trackside devices for safe train travel control;
   - managing properties which are part of the railway infrastructure;
   - constructing, developing and modernizing the railway network [16].

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Therefore, maintaining the railway infrastructure in a condition ensuring safe railway traffic is the primary duty of railway infrastructure managers, as arises from the Rail Transport Act [16]. Elements of the railway infrastructure are subject to difficult atmospheric conditions as well as changing dynamic loads resulting from the operation of a given part of the infrastructure. The lack of proper maintenance of the tracks adversely affects their operation:

- lower permissible speed,
- reduced driving calm,
- decreased safety of railway traffic,
- increased degradation of aggregate and railway subgrade,
- as well as increased influence of dynamic impacts on the surrounding buildings.

Maintaining the railway infrastructure can be divided into two elements:

1) scheduled repairs arising from the period of operation of the specific element (these include the scheduled replacement of sleepers, track renovation),
2) running repairs (defects found during walk-around inspections and technical inspections, such as a broken rail joint bar or rail, lack of bolts or track fixing elements, and the need to replace a single sleeper).

The performance of duties arising from the maintenance of the railway infrastructure entails a very high cost resulting from the considerable workload, repair technology and need to use specialist equipment, as well as temporary exclusion of part of the line from traffic. The need to hire well-qualified employees holding relevant licenses for periodic walk-around inspections and supervision over all works on the railway is another factor which generates substantial maintenance costs [13]. Another important aspect is the constantly rising average age of employees in the railway industry, increasing salaries and the lack of competent young workers.

A decrease in the number of well-qualified employees who deal with maintaining railway surfaces is also the result of a reduction in the number of railway-related vocational and technical schools. According to the data presented by the Office of Rail Transport, there are now 37 railway technical schools in Poland (Fig. 1).

Out of the 37 schools shown in Figure 1, only 7 deal with rail infrastructure. These data clearly illustrate the root cause of staff shortages in the railway industry. In the last couple of years, the situation has gradually improved as most schools have been assigned a patron and cooperate closely with the largest infrastructure manager in Poland – PKP Polskie Linie Kolejowe S.A. (Fig. 2). Potential candidates are educated in accordance with the requirements and needs of the manager, and their knowledge and skills are acquired through repairs, constructions and any engagement into infrastructure-related investments on the Polish railway network [17].

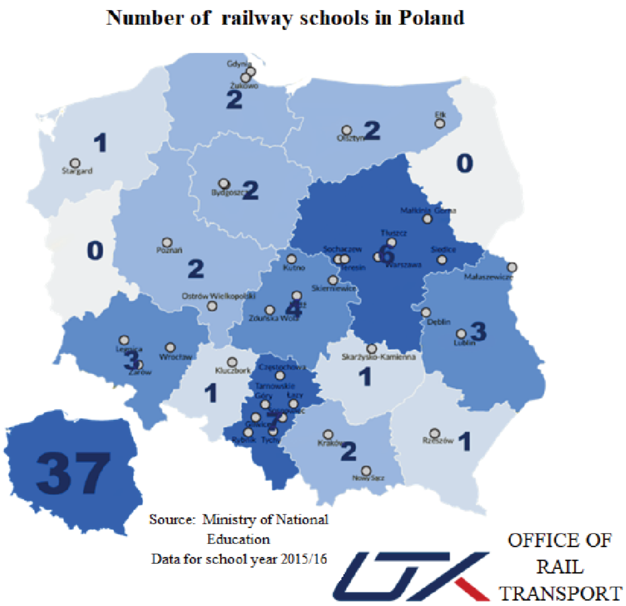


Fig. 1. Distribution of technical schools specializing in rail transport [17]

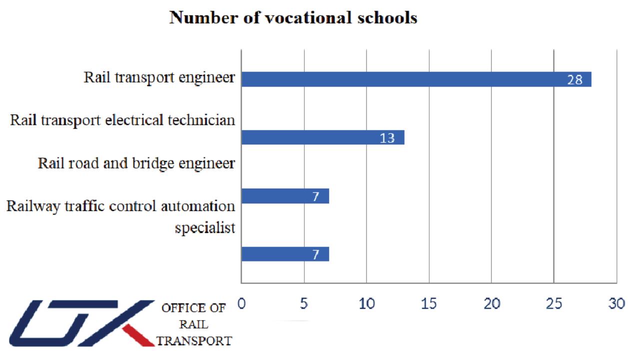


Fig. 2. List of railway schools divided into particular specializations [17]

Due to the fast development of technology, there are more and more novel solutions, thanks to which it is possible to minimize costs, raise quality and limit the human impact on particular tasks, which seems to be a promising solution for the railway industry.

In the analysis, 100 km of track were investigated, and the total number of work hours a year in facilities checked was 59,171.

## 2. Methods of studying

As of 31 December 2017 [15], PKP Polskie Linie Kolejowe S.A., as an infrastructure manager, uses the following in its daily operation:

- 18,513 km of railway lines covering 35,967 km of tracks (27,120 km of plain lines and mainline tracks at stations and 8,847 km of station tracks),
- 39,482 turnouts (17,950 turnouts on plain lines and mainline tracks and 21,532 turnouts on station tracks),
- 14,442 level crossings, 12,354 of which are on operated lines (incl. 2,392 railway and road crossings category A, 1,192 category B, 1,386 category C, 6,343 category D, 562 category F, 479 pedestrian crossings category E.),
- 25,324 engineering facilities (including 6,375 bridges and overpasses),
- 5,823 buildings,
- 14,108 structures.

Additionally, there are 9 small managers who share their infrastructures and 3 private infrastructure managers [18].

**Other widely available infrastructure managers:**

1. CARGOTOR Spółka z o.o. – 170 km of tracks;
2. EUROTERMINAL SŁAWKÓW Spółka z o.o. – 24.256 km of track with regular gauge and 17.521 km of track with broad gauge;
3. Infra SILESIA S.A. – 162.5 km of track;
4. Jastrzębska Spółka Kolejowa Spółka z o.o. – 149 km of track;
5. PMT Linie Kolejowe Spółka z o.o. – 2.299 km of track;
6. PKP Szybka Kolej Miejska w Trójmieście Spółka z o. o. – 32.4 km of track;
7. Pomorska Kolej Metropolitalna S.A. – 19 km of tracks;
8. Warszawska Kolej Dojazdowa Spółka z o.o. – 38.921 km of track;
9. Dolnośląskie Province, Dolnośląska Służba Dróg i Kolei we Wrocławiu – 38.555 km of track.

**Private infrastructure managers:**

1. CEMET S.A.;
2. PGE Górnictwo i Energetyka Konwencjonalna S.A. – Elektrownia Opole Branch;
3. Polska Grupa Górnicza S.A. – KWK Mysłowice Branch – Wesoła.

## 3. Analysis of research results

The studies were conducted in the years 2016–2018 and were based on daily railway reports drawn up by qualified track supervisors performing their duties at railway stations. For the studies, 1 railway station and 4 railway sidings in the Śląskie Province with a total track length of 100 km were qualified. The facilities listed in the article are small and of medium size. They are intended for the loading of coal and excavated material on wagons. The stations are on lines of local importance, and permissible speed does not exceed 40 km/h. The reports include daily activities with the number of work hours taken by the track supervisor and group of workers.

A total number of 260 reports a year were collected from each location, which gave a sample of about 4,000 daily reports in total. Based on the aforesaid reports, the annual list of tasks was drawn up. It was supplemented with the number of hours which employees spend on specific types of duties. Next, following the Pareto rule, according to which 20% of tasks generate 80% of costs, relevant tables, diagrams and analyses were prepared. Relying on the data received, potential reductions in the costs of railway infrastructure maintenance were specified.

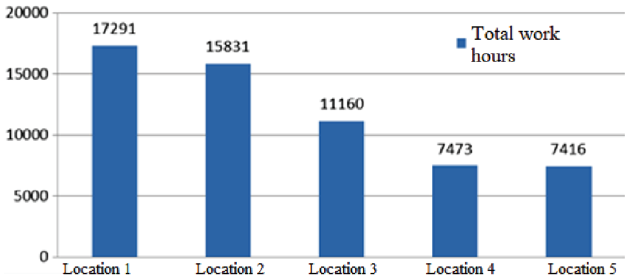


Fig. 3. Diagram showing work hours on maintaining the infrastructure at particular locations [own elaboration]

The number of work hours is strictly related to the number of tracks and turnouts located at the specific railway station, as well as activities which were performed at a specific time. For example, a major renovation related to a worn-out track section at a smaller station may require considerably more hours than running maintenance at a larger facility. For this reason, the current data analysis excluded such activities as modernization, which enables the reliable comparison of data related solely to maintenance tasks (Fig. 3 and 4).

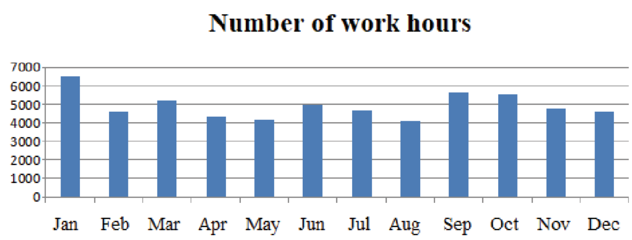


Fig. 4. Diagram presenting the number of hours a year at all facilities divided into particular months [own elaboration]

In view of the climatic zone applicable to the facilities in question, maintenance of the railway infrastructure is strictly related to weather conditions. In winter, when the temperature drops below 0°C, it is important that the track and turnouts are properly secured against snow and frost. In other seasons, all repair and renovation works can be performed.

## 4. Analysis of the most frequent maintenance tasks

Maintaining railway infrastructure requires repeatable activities arising from the use of the infrastructure. For the purposes of research, a decision was taken to group particular activities with a view to classifying them. Thanks to the classification of particular tasks, it is possible to specify time consumption and financial outlays which the company should dedicate within the year. The studies allowed the identification of the 20 most frequent tasks (Table 1).

Taking into consideration the activities presented in Table 1, it seems that 20% of the tasks took up 49,454 work hours, which translates into 85% of all the work hours dedicated to maintaining the infrastructure a year. Pareto analysis is most popular with regard to quality management, where the Pareto-Lorenz diagram is considered one of the most popular traditional instruments used to raise the quality of products and improve processes [10].

Pareto analysis influences the quality of products mainly through the analysis of frequency and significance of non-conformity, elimination of quality-related issues in the enterprise and elimination of quality-related issues generating the highest costs.

The use of Pareto analysis allows corrective and preventive actions to be taken for a narrow group of identified causes, which translates into the elimination of mistakes and an improvement in quality.

Table 1

**List of 20% of maintenance tasks generating 85% of work costs**

| | Task name | Total wh/year | Percent share [%] | Total value [%] |
|---|---|---|---|---|
| **1** | Walk-around inspection | 6396 | 11 | 11 |
| **2** | Winter challenge | 5043 | 9 | 20 |
| **3** | Tightening up/replacing bolts/screws | 4774 | 8 | 28 |
| **4** | Replacing sleepers | 3981 | 7 | 35 |
| **5** | Cleaning | 3980 | 7 | 41 |
| **6** | Other | 3265 | 6 | 47 |
| **7** | Transporting | 2678 | 5 | 52 |
| **8** | Selecting ballast | 2656 | 5 | 56 |
| **9** | Construction/cleaning works | 2578 | 4 | 61 |
| **10** | Adjusting clearance | 2399 | 4 | 65 |
| **11** | Renovating track | 2217 | 4 | 68 |
| **12** | Replacing rail joint bars | 1373 | 2 | 71 |
| **13** | Supervision | 1285 | 2 | 73 |
| **14** | Measurement/technical inspection of turnouts | 1187 | 2 | 75 |
| **15** | Eliminating defects | 1143 | 2 | 77 |
| **16** | Cutting/mowing | 999 | 2 | 79 |
| **17** | Tamping | 919 | 2 | 80 |
| **18** | Sprinkling the breakstone | 883 | 2 | 82 |
| **19** | Replacing switch sleepers | 877 | 2 | 83 |
| **20** | Adjusting facing point locks | 825 | 1 | 85 |

[Own elaboration].

This means that the analysis indicates directions for actions (on a minor scale and without additional major costs), which influences the most significant issues and therefore contributes to maximum effects (through impact on the most frequent problems or problems generating the highest costs) [9].

In the group of 20 separate tasks, an expert team distinguished 3 tasks for further analysis. The tasks in question are the following: the need to tighten up bolts and rings, the replacement of rail joint bars, walk-around inspections and measurements. In total, the specific elements of the railway infrastructure maintenance represent 23% of the time dedicated to yearly infrastructure maintenance. The studies for specific tasks were carried out in order to find root causes which require these tasks (5 Whys, Ishikawa diagram) or modern technologies were suggested with a view to optimizing the processes.

### 4.1. Need to tighten up bolts, rings

The need to tighten up/replace bolts, screws and spring rings is one of the basic activities which belong to the maintenance groups in the specific field.

Its time consumption is related to the large number of track attachments, to periodical inspections whether fixings and connections are proper, as well as to the transportation of special equipment to the work site (e.g. bolting machine). The analysis demonstrates that this task requires 4,774 work hours a year per 100 km of track. The costs of tightening up and replacing track fixing elements at specific locations per year has been estimated to be about 300,000 PLN, including the costs of labor, materials, equipment and means of transport [12]. In picture 5 a graph depicting application of the method 5 was presented why, next on picture 6 diagram of Ishikawa depicting source causes.

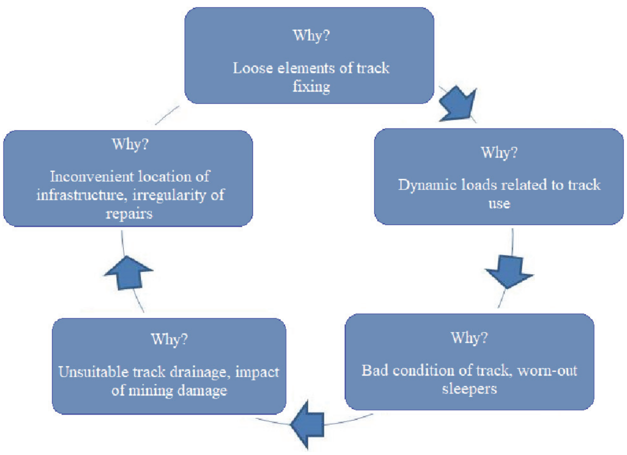


Fig. 5. Graph showing the use of the 5 whys method in relation to the issue of tightening/replacing bolts, screws and spring rings [own elaboration]

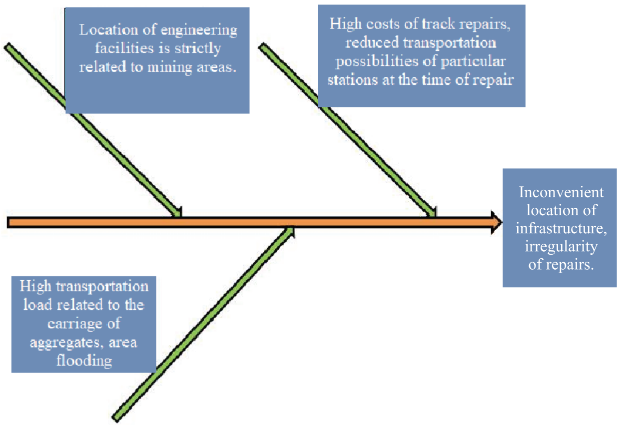


Fig. 6. Ishikawa diagram showing root causes of the need to tighten up/replace bolts, screws and spring rings [own elaboration]

### 4.2. Replacement of rail joint bars

A broken rail joint bar is one of the most frequent railway track defects, and systematic replacement of these bars is one of the most significant tasks of the maintenance group because they have a direct impact on safety in railway traffic. Rail joint bars are elements of classic rail joints. The bars are selected for a suitable kind of rail and type of joint. The work load dedicated to their replacement at the specific locations was 1,373 work hours. The costs related to this activity are estimated to be about 100,000 PLN (Fig. 7, 8).

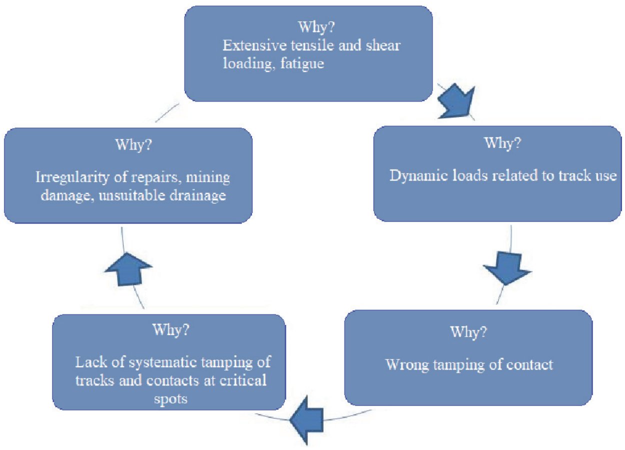


Fig. 7. Graph showing the use of the 5 whys method in relation to the issue of replacing breaking rail joint bars [own elaboration]

### 4.3. Walk-around inspections and measurements

Another important aspect of maintenance tasks is walk-around inspections and measurements. Measurements made with a track gauge are very time-consuming because they are required every several

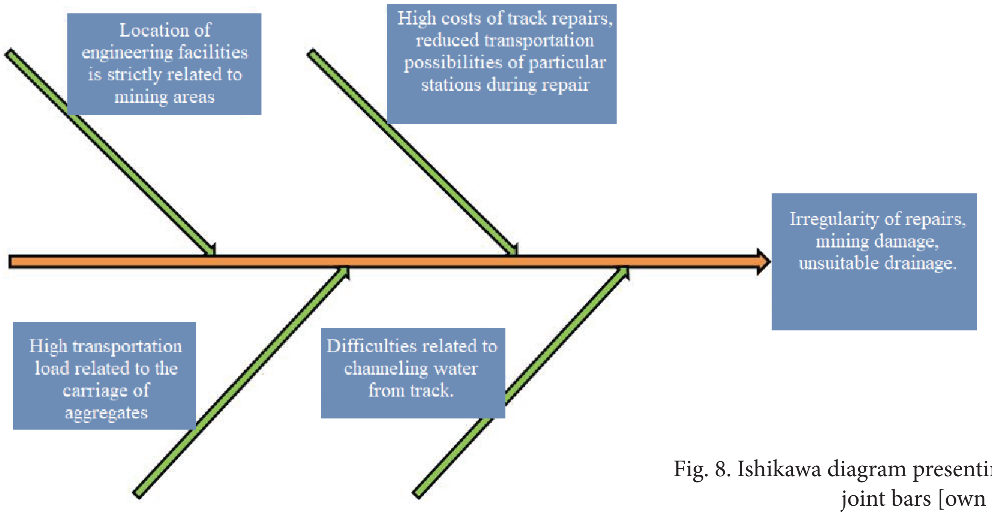


Fig. 8. Ishikawa diagram presenting root causes of breaking rail joint bars [own elaboration]

meters, and in the case of tracks on curves – every meter. Measuring turnouts in any position requires close cooperation with the train dispatcher, which takes extra time. Walk-around inspections and measurements of tracks are substantially hindered by the need to perform them irrespective of current weather conditions. Additionally, pursuant to the Id-7 instructions (D10), the person who carries out an inspection should be properly qualified to do so. According to the regulations, the person who inspects should be a track supervisor, yet he/she may appoint an authorized lineman [8]. The time devoted to both activities was 7,583 work hours a year on the 100 km of track in question. The total time at railway stations in question where employees carried out walk-around inspections and made measurements generated costs of 400,000 PLN [3].

Currently, thanks to the following modern devices, it is feasible to considerably simplify the activities:

- **self-registering track gauge** – this device is intended to measure track geometry and register the results of track visual inspection. Thanks to the adoption of the gauge, it is possible to record the following parameters: track width, superelevation, horizontal and vertical irregularities, road and GPS position, which are saved in real time in the device memory. Additionally, the self-registering track gauge provides a number of useful advantages: precision, speed, reliability and low weight [22].
- **Unmanned aircraft (Drone)** – current technology allows the functions of drones to be expanded to include autonomic railway infrastructure inspections. Depending on the camera, altitude and other parameters, it is possible to specify the selected technical parameters of the railway track [19, 21].
- **Rail-Pod** – this has self-registering track gauge functions, yet its operation is more independent [20].
- **Diagnostic handcar** – this is a traction vehicle which measures the following parameters: track and rail geometry, video-inspections, infrastructure scanning, measurement of contact system parameters, acceleration on journal box (dynamic influence) measurements, and measurement of train impact devices (SHP electromagnet measurement). All systems are automatically synchronized with the location system, the vehicle reaches the speed of 120 km/h with its own drive with measurement functions for this speed [23].

## 5. Conclusions

The results of the studies demonstrate the scale of railway infrastructure maintenance costs for an infrastructure manager. For the 100 km of track studied, the average annual railway infrastructure maintenance costs range from 3.5 to 3.7 million PLN. The average yearly number of work hours dedicated to tasks related to infrastructure maintenance per 100 km of track was 59,171. Pareto-Lorenz analysis shows that 20% of the tasks performed by maintenance teams generates 49,454 work hours a year, which accounts for 85% of the total number of work hours a year.

The studies conducted allowed data to be collected which were then used to analyze and distinguish the 20 most frequent maintenance tasks. The group of experts chose 3 tasks which were subject to further analysis. Thanks to the use of the 5 whys method and Ishikawa Diagram, the railway infrastructure manager raised the awareness of root causes applicable to the need to perform the aforesaid tasks. Another step is to find remedial measures for each root cause, which was not a subject of this article.

Additionally, modern technologies which may improve both track inspection and railway infrastructure measurements were proposed. There is no doubt that the above-stated measuring devices will gradually displace traditional measuring methods. Currently, the cost of such devices is exorbitant, but with further growth of technology and popularity, their price will gradually drop. Another important aspect is the adaptation of regulations for independent use and supervision of specific elements of infrastructure. Taking into account the real scale of use, we can assume that their use will considerably lower railway infrastructure maintenance costs.

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