Article citation info:
Surma S, Łukasik J, Konieczny J, Labisz K, Atapek ŞH. Defects of railway traffic control devices on a selected railway route. Diagnostyka. 2025;26(4):2025406. https://doi.org/10.29354/diag/211215.

DIAGNOSTYKA, 2025, Vol. 26, No. 4

e-ISSN 2449-5220
DOI: 10.29354/diag/211215

DEFECTS OF RAILWAY TRAFFIC CONTROL DEVICES ON A SELECTED RAILWAY ROUTE

Szymon SURMA [1], Jerzy ŁUKASIK [1], Jarosław KONIECZNY [1], Krzysztof LABISZ [1,*], Şaban Hakan ATAPEK [2]

[1] Department of Railway Transport, Faculty of Transport and Aviation Engineering, Silesian University of Technology, Katowice 40-019, Krasińskiego 8 Street, Poland
[2] Kocaeli University, Faculty of Engineering, Department of Metallurgical and Materials Engineering, Laboratory of High Temperature Materials, Turkey
[*] Corresponding author, e-mail: krzysztof.labisz@polsl.pl

Abstract

The article discusses the problem of the safety of rail Traffic Control Devices (TCD) in the process of exploitation. Particularly the article presents an analysis of failures of components of railway traffic control devices (TCD) during 12 months throughout Poland and an assessment of the impact of external factors. This article creates the basis of knowledge for modeling the system of station setting devices. the specific results include, among others, an analysis by season and time of occurrence, as well as by meteorological phenomena. The analysis used, among others, such parameters as devastation and theft as well as strictly operational factors. The existence of a relationship between the above factors and the time period of their occurrence was confirmed.

Keywords: safety, railway traffic control, efficiency of railway traffic

List of Symbols/Acronyms

FFT – Fast Fourier Transform;
l – distance [mm];
Δ – measurement tolerance [mm].

1. INTRODUCTION

In railway traffic control systems, one can distinguish many technical objects that fulfill their functions divided into certain subsystems, for which operational and reliability processes can be considered separately.

The main purpose of the TCD devices is to ensure the safety and efficiency of railway traffic [7]. Thanks to their efficient operation, they facilitated the performance of setting operations of devices at railway stations and their time was shortened. Today, as a result of the implementation of modern design and electronic solutions, hybrid and computer devices are commonly used in addition to mechanical, electromechanical and relay devices [6]. In addition, sound metaphors have also been developed as tools to support rail traffic management, supporting/supplementing line occupancy control [12] and controlling the occupancy of railway lines is the main issue related to the smoothness of rail traffic [12].

The optimization of the railway traffic control system is also constantly being carried out in order to avoid congestion in railway traffic and to ensure timely passage of passengers and delivery of goods on time [14]. The use of high-quality microprocessors in railway traffic control devices has made them even more reliable and ensures safety, e.g. at railway crossings. An example of such modern solutions are automatic crossing signaling systems made in computer technology, which use structural redundancy, programmable logic controllers and have extensive self-diagnostics and technical diagnostics mechanisms [15]. Along with the development of microelectronics, the rapid development of computer science and their applications resulted in the emergence of a new generation of electronic safe signaling devices [16].

The condition for safe and smooth running of train traffic is the availability of railway traffic control devices without restrictions. Maintenance activities, such as repair of damaged Control Command and Signalling devices, maintenance or diagnostics, are associated with carrying out verification tests [13].

Many types of motion control systems are available today. Centralized Traffic Control (CTC) and Total Traffic Control System (TTC, PTC, PRC, ARC) are currently the most commonly used techniques [14].

Received 2025-02-10; Accepted 2025-09-23; Available online 2025-09-25.

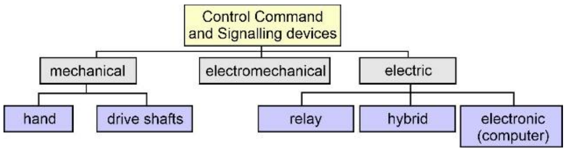

Fig. 1. Division of railway traffic control devices according to the implementation criterion dependencies [22]

Exploitation theory deals with synthesis, analysis and research exploitation systems in which certain processes take place. According to [24], a process is a phenomenon whose description has the form relationships between system states in time and execution. Moreover also diverse types of material plays an important role in the maintenance and life time of the applied system, which necesarrys are made from materials [28, 29]. The process is called the course of these changes in a specific interval time. From the definition of exploitation, the range of expected and marital skills, which include:

- operation management, including control of operation processes, instruction and training of employees,
- formulating project tasks,
- identification of emergency states of exploitation systems,
- identification of the characteristics of the exploitation system,
- determination of system efficiency,
- determination and assessment of risk system,
- development and modernization planning,
- selection of exploitation technologies and organization of maintenance services.

The above assumptions of systems exploitation lead to defining the tasks of exploitation theory, which are:

- designing and organizing systems,
- risk and opportunity analysis,
- strategic planning of exploitation,
- operation management and process control,
- economic analysis,
- operational tests,
- instructing users.

Rail traffic control devices can be classified taking into account various division criteria. However, one of the most important of them is the way of setting external devices and implementing dependencies. For this reason, station railway traffic control devices were divided as shown in Figure 1 [22, 23].

2. INVESTIGATION METHODOLOGY

The basic task of operating railway traffic control systems is safe and efficient movement of people and loads along the railway network. In this system, transport streams will constitute a supersystem (environment) in relation to the tested object, which interact with each other through its entrances and exits.

In order to carry out a systemic analysis of the safety of station traffic control systems, it is first necessary to isolate this one system from the environment in which it works and determine the relationship between ruling them. In this system, such a system is called a supersystem with respect to the object under study.

The data was collected throughout the calendar year 2016 based on monitoring of the entire territory of Poland, owned by PKP Polskie Linie Kolejowe (Polish State Railways).

The nature of the damage and repairs concerned:

- sensors at crossings,
- cables,
- isolated kn circuits,
- occupancy control,
- point drives,
- crossing components,
- station subassemblies,
- signaling devices,
- faults of the computer controlling the railway traffic control devices.

Damage was caused by factors resulting from operation, investment activities, changing weather conditions - storms, salinity of crossings as well as devastation and theft.

$$a^2 + b^2 = c^2 \quad (1)$$

3. INVESTIGATION RESULTS

Among the listed TCD components, the most frequent failures were the crossing components and the occupancy control (Fig. 1), while the sensors at the crossings and the track-vehicle communicating systems rarely failed. These are particularly important devices for the safe operation of railway traffic, and track vacancy control (track circuits or axle counters with sensors) also allows for the automation of railway traffic control processes [8]. The number of failures of occupancy control devices has been increasing month by month since March to reach the highest number in July (926 failures) and then decrease month by month to reach the lowest value in December (490 failures).

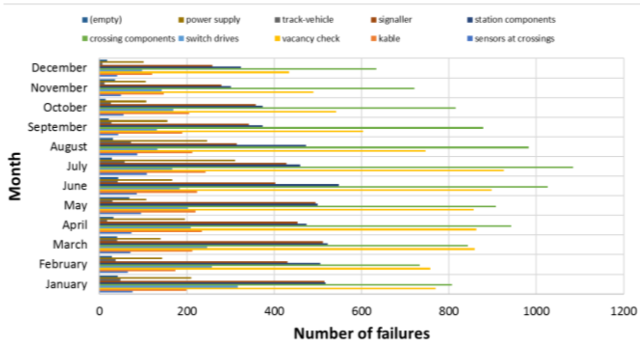

Fig. 2. Damage to the TCD subassembly

As shown in Fig. 2, among the damages to the railway traffic control devices, the most common failures are the crossing subassemblies. The smallest number of them occurs in the winter months of December-February, which is related to pre-emptive maintenance this equipment and the emergence of defects during deteriorating weather conditions in the period September-October On the other hand, the highest number of failures of crossing components was recorded in the summer months of June-August, which can be linked to the holiday period of the operating staff. It should be mentioned that during the whole year there were two failures caused by the lack of control on the repeater (ASP SPA4, V20km/h) in July, one failure of the computer controlling the railway traffic control devices (January) and one failure of kn isolated circuits also in July.

Based on the obtained results, it can be concluded that point drives were characterized by a very small number of failures in the period under study (Fig. 3). Although they are electrically controlled devices, they are used for automatic shifting of the switchpoint, they consist of several subassemblies, including an electric motor and transmission [9] as well as a hydraulic system and a piston pump [10]. However, their low number of failures compared to crossing components is caused by short between maintenance period (2 weeks). Point drives are repairable technical devices [11], in which, during a long period of use, there are random periods between successive failures. However, the repair is not complicated because the manufacturers of point drives have largely unified their technical solutions while maintaining different performance [17].

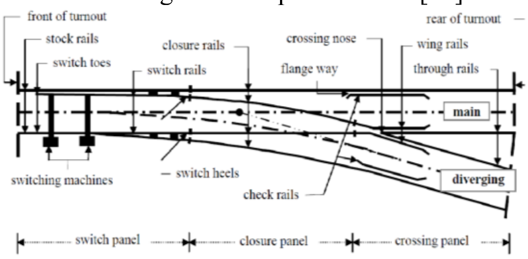

Fig. 3. Standard right-hand turnout [18]

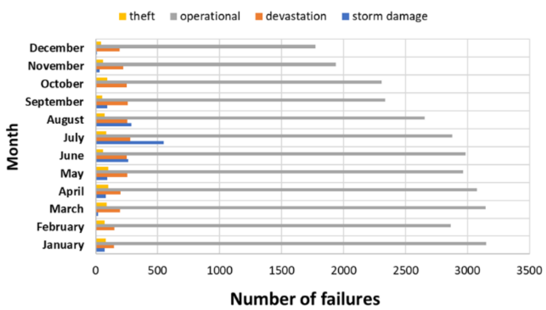

Fig. 5. The nature of damage to TCD

As shown in Fig. 4. The number of points drive failures reached its maximum in January (317) and decreased over the next month to reach a minimum in December (98). The increase in the number of faults in October should be correlated with the autumn-winter solstice, when the impact of the decrease in ambient temperature may cause a decrease in the value of the setting force. A sudden decrease in the ambient temperature in January has a direct impact on the coupling parameters [19]. The average temperature in Poland in 2016 in the coldest months, i.e. in January, ranged between -9 and 0°C, while in December between -5 and + 4°C. Even in February, temperatures ranged from -2 to +5°C [20].

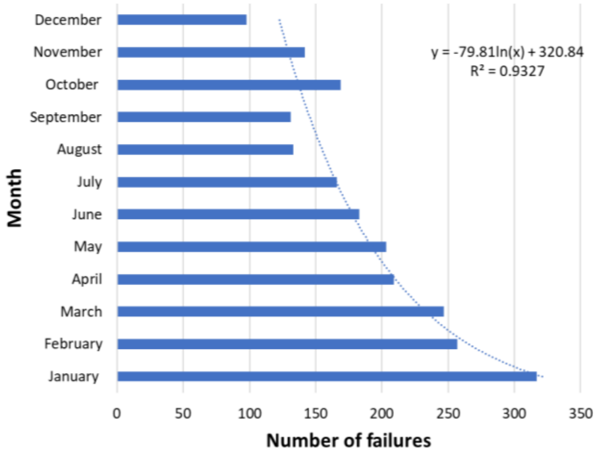

Fig. 4. Number of point drive failures during the calendar year 2016

The logarithmic approximation of the number of points drive failures in 2016 is highly consistent with the data R2=0.93. Therefore, this relationship can be described by equation (1):

$$y = -78,81\ln(x) + 320 \quad (1)$$

where: x is the value between 1 and 2 (1=January, 2=February…..12=December)

The influence of weather conditions and the season of the year on the failures of points drives was confirmed in [21]. It was observed that most faults occurred in winter and spring.

Describing the nature of the damage, it should be stated that the damage resulting from the operation of the TCD was dominant (Fig. 5). The largest number of operational failures was recorded in January - July, with the largest number of failures recorded in January - 3150. The polynomial approximation of the number of operational failures of TCD in 2016 is highly consistent with the data R2=0.9595 and this relationship is described by equation (2) :

$$y = -15,953x2 + 88,138x + 2963,8 \quad (2)$$

Damage caused by storms occurred in the months of April - September, with their culmination in July - 546.

So while a massive storm can cause catastrophic derailments, daily weather can also have a major impact on your bottom line. In fact, weather-driven delays alone cost rail companies today at least $10 million per year [27]. The average cost of a single delayed train is $45,000. Of those delays, 18% are directly caused by weather conditions.

Train delays, which resulted from the failure of the TCD, amounted to over 20 hours a month (November), while they reached the maximum in

July (Fig. 6), when the total time of train delays due to the failure of the TCD was 1896 minutes (31.6 h).

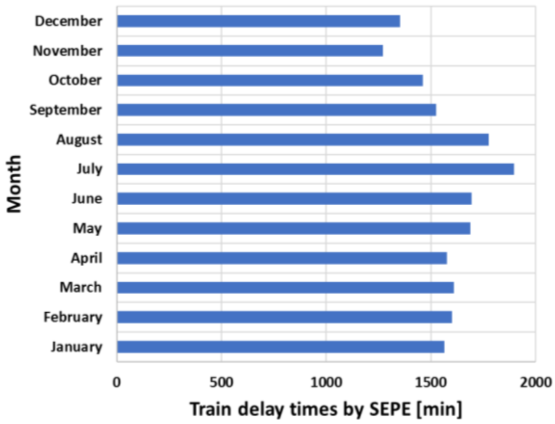

Fig. 6. Time of train delays according to SEPE [min]

Substitute signals, which are used to issue permission to drive, when it is not possible to give a normal permission signal, e.g. due to a failure of the TCD [1] in the examined period, were used most often due to operational damage (13614 times in total), and definitely less often due to damage caused by storms (619 times), due to devastation of equipment (1072 times) and theft (463 times) (Fig. 7).

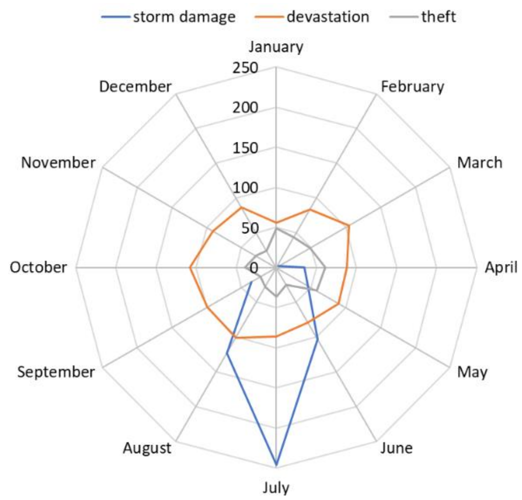

Fig. 7. Number of substitute signals used

Examples of damage symptoms according to the copy in E-1758:

- failure of the computer controlling the TCD. After restarting the computer, it works fine;
- semaphore 128 expired with reference no. S2 to S;
- failure of the SSP (signalling device);
- failure of the SBL devices. No possibility to switch the direction of the lock (split);
- broken tollgates at the "B" category crossing by unknown perpetrators (devastation);
- no possibility to close and open the drive (transition subassemblies);
- turnout no. 5 cannot be moved to the minus position from the panel (point drives);

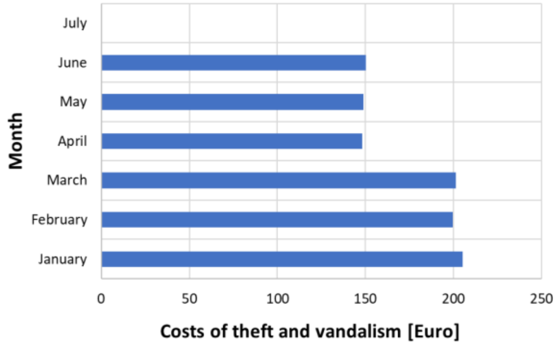

Fig. 8. Repair costs resulting from theft and devastation

On nearly 20,000 km of railway lines and in over 6,000 passenger, fast and freight trains, there are numerous thefts and disturbances of public order every day. The scale of theft of the traction network and goods transported by rail freight trains, as well as robbing passengers, still requires the activity of Police officers, the Railway Protection Guard, other protective formations, and above all, the integration of physical protection and technical security installed by administrators in areas and facilities most at risk of crime and offenses. The railway area is a specific, difficult and extensive area, which is why the requirements for officers and technical support systems for protective measures are high.

Thefts and devastations of equipment and elements of railway lines - account for 32.26% of all events. The largest part of this category is made up of events related to theft of railway traffic control devices (TCD), as they account for 23.99% of events. Compared to the period of 8 months of 2012, however, the number of these events decreased by 129 cases (from 2302 to 2173 in the period of 8 months of 2013), which means a decrease of 5.60% [25]. The theft of RTC devices poses a very high risk and exposes travelers and railway employees to loss of health or life, there are also numerous train delays, communication disruptions (the so-called substitute communication is launched), serious material losses for the manager of a given area due to the reconstruction of infrastructure, and sometimes it leads to the death or disability of the perpetrator, e.g. as a result of electric shock.

Direct costs resulting from the theft and devastation of TCD in the period under review were valued at PLN 4,477. It is worth noting that they were recorded in the first half of the year: January - July (Fig. 8), mainly in the southern woiwodshafts as well as in the Mazovia region. For comparison, in 2012 PKP Polskie Linie Kolejowe S.A. had to spend PLN 22 million on removing the effects of theft and devastation of the railway infrastructure [3].

In turn, in 2017, 2121 cases of theft and devastation of infrastructure were recorded. However, compared to 2016, the number of thefts decreased by 14.7%. A significant part (68%) concerned railway traffic control devices.

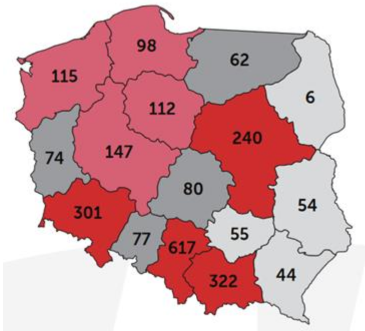

Fig. 9. The number of incidents of theft and damage to infrastructure in the railway industry in 2016 in individual provinces [4]

4. CONCLUSIONS

Based on the investigation results the relative share of damage types could be determined, so the most frequently damages concerns the crossing components followed by the the vacancy checks.

The most common reason for the theft of devices and elements of railway infrastructure is the possibility of easy sale of goods, the availability and extent of the railway area, as well as the difficult socio-economic situation of a given region. Based on results presents in fig. 7, there is a need for mounting of anti-theft and anti-devastation systems, which – placed accurately – could help to avoid damages in few tenth millions PLN.

The highest amount of damages occurs in the holiday season - June July – reaching even up to 1000 issues per month, where the strongest group of the damages is related to occupancy control as well as crossing subassemblies; this phenomenon could be related to higher temperatures as well as the growing passenger density during holiday time, which makes the devices have to work more intensively.

An important issue directly convertible in economic values is the delay time of the trains resulting due to the described factors. The total time of train delays due to the failure of the SRK devices was 1896 minutes (31.6 h). Some results indicated that the annual cost caused by main-line delay was substantial compared with the annual cost of track and equipment damages from main-line derailments caused by mechanical causes [26].

Source of funding: *This research received no external funding.*

Author contributions: *research concept and design, S.S.; Collection and/or assembly of data, J.L.; Data analysis and interpretation, J.K., K.L.; Writing the article, S.S., J.L., J.K., K.L., Ş.H.A.; Critical revision of the article, HA.; Final approval of the article, S.S., J.L., J.K., K.L., Ş.H.A.*

Declaration of competing interest: *The author declares no conflict of interest.*

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Szymon SURMA, M.Sc. in Traffic Engineering, Silesian University of Technology in 2005, PhD in Railway Traffic Control, University of Technology and Humanities in Radom (UTH) in 2013. Current work: research on railway traffic safety, road–rail interfaces (e.g., level crossings), and the use of renewable energy sources to power non-traction railway systems
e-mail: szymon.surma@polsl.pl

Jerzy ŁUKASIK MSc Assistant at the Department of Railway Transport at the Faculty of Transport and Aviation Engineering of the Silesian University of Technology. The research area is railway automation, systems and devices of railway traffic control. Currently I am dealing with the problems of rail-road crossings
e-mail: jerzy.lukasik@polsl.pl .

D.Sc. Eng., **Krzysztof LABISZ,** assistant professor, was the chief or main staff member of 8 scientific grants as well as head coordinator of education projects for students scholarship; author of 68 papers on Web of Science. He cooperates with Kocaeli University Turkey, University of Sophia Rumania, Kaunas Technical University Vilnius, VŠB-Technical University of Ostrava Czech Republic, University of Zagreb Croatia, University of Trnava Slovakia. His research and teaching areas: Light alloys, Laser surface treatment, Production Engineering, Metallurgy of ferrous and non-ferrous alloys, Transmission electron microscopy investigations, Copper alloys, Electron diffraction. Is also the board member of the Czech Kovarenstvi Journal Editorial BoardD.Sc. Eng.
e-mail: krzysztof.labisz@polsl.pl

Jaroslaw KONIECZNY, associate professor, was the manager of 3 scientific grants, reviewer of 2 research grants, main expert in a development project financed from European Union funds: TEMPUS-PHARE FSB-32/RMT1/2009, author of 41 SCI/SCI-Exp articles and over 50 oral presentations at national, international and foreign conferences, including 8 conference lectures at the invitation of the organizers, cooperates with Kocaeli University (Izmit, Turkey), Polytechnic University of Bucharest (Romania), University of Zagreb (Croatia), Vilnius Gediminas Technical University (Lithuania). His research interests include plastic processing and anodizing of aluminum alloys, studies of amorphous and nanocrystalline cobalt-based alloys obtained in the process of high-energy milling, studies of metal and ceramic materials from archaeological excavations, composite materials based on polymers reinforced with glass fiber, graphite fiber, natural fibers (WPC composites - Wood Plastic Composites), as well as polyamides reinforced with copper powders, graphite or molybdenum sulphide, connections of dissimilar alloys: D04 steel and aluminium alloy 6063 by means of laser welding. Recently, his interest has been focused on studies of precipitation and recrystallization mechanisms in alloyed copper alloyed CuTi4 and CuNi2Si. mechanisms of destruction of rail traction guides(Cu-ETP).

e-mail: jaroslaw.konieczny@polsl.pl

Prof. Dr. **Şaban Hakan ATAPEK** is the coordinator of High Temperature Materials Lab. and Thermal Analysis Lab. at Kocaeli University. He has been the leader of 30 projects supported by Scientific Research Projects Coordination Unit of Kocaeli University. He has been the advisor of a project TUBITAK 2211-C National PhD Scholarship Program in the Priority Fields in Science and Technology, the author of more than 70 SCI/SCI-Exp articles and more than 230 oral presentations at international conferences, collaborates with Karlsruhe Institute of Technology, Brandenburg University of Technology Cottbus-Senftenberg, University of Pittsburgh, National Technical University of Athens, Patras University, Thessaly University, Ss. Cyril and Methodius University, Lodz University of Technology, Medical University of Varna, Sfax University, Amirkabir University of Technology, Silesian University of Technology, University of West Attica, Osaka University. His research interests are physical metallurgy of metallic materials, casting, crystallization, heat and surface treatments, characterization of microstructure and failure analysis. He has supervised 3 PhD student and 15 MSc students.

e-mail: hatapek@kocaeli.edu.tr