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Technological solutions for the efficient protection of workers in the track area

Abstract: Work on and in the vicinity of active railway tracks or other tracks is particularly hazardous work. They involve high risks for workers who may be hit or run over by moving rail vehicles or track machinery. Workers may also be electrocuted by the overhead catenary or overhead electrical network, which for non-traction purposes is supplied with 3000 volts DC. To ensure an adequate level of safety during this type of work, active tracks should be cordoned off and marked in accordance with railway regulations. Guidelines for securing the site of works carried out on closed track during the operation of railway vehicles on live track at a speed of $V \geq 100$ km/h are defined in Railway Instruction Id-18. All types of construction work on live railway lines and overhead contact lines may only be carried out on the basis of the Instruction for Safe Work Performing (IBWR), which is an annex to the Safety and Health Plan (Safety and Health Plan). It is important to remember that the site protection systems used should be certified and approved for use on railway lines. Rail transport is a particularly demanding area in terms of safety. The key to increasing its level is to continue existing and take new measures to promote the idea of safety. Automatic Warning Systems are still an innovative solution in Poland, which has been successfully proven in Europe for several years and is a safer option for the railway signalman. The system is responsible for the safe warning of railway traffic in the area of the repaired and adjacent track. Risks arising due to human fallibility or caused by human error are eliminated to a minimum.

Keywords: Technological solutions; Trackway; Railway line

Introduction

The safety of rail transport is a priority for all entities operating in the rail sector. For many years, the European Union has been making efforts to ensure the interoperability of railways by issuing appropriate legal regulations containing requirements for these entities. They are intended to adapt national regulations so that the level of safety of the European railway system is ensured and maintained at the highest possible level.

The subject of railway safety is extremely extensive and multifaceted. It concerns many business entities, people, and institutions in the rail transport environment. In particular, it is a priority for railway undertakings, infrastructure managers, general contractors carrying out investment and modernization works, as well as other enterprises and persons directly involved in railway traffic. It also includes customers of transport services, central offices, local governments, units, and scientific institutions.

Rail transport is a particularly demanding sector in terms of safety, which is not only a legal requirement but also a key factor in the optimal development of railway specialization. Therefore, each company actively operating in the railway industry should constantly improve the level of safety, which is possible by maintaining the track infrastructure in good working order. Safety management systems will not reach their full potential if they are used on poorly maintained infrastructure. Therefore, it is necessary to use modern control systems for diagnostics, analytics, and periodic assessment of infrastructure and rolling stock, the implementation of which will be a considerable challenge for the Polish railway.

Dynamically changing economic, social, and legal aspects affect the railway sector, which, due to the extensive, difficult to reform structure of organization and resources,

permanent underfunding, as well as historical heritage, does not always keep up with the pace of these changes. In the last decade, the railway market, especially in the legal and organizational environment of the rail transport sector, has undergone major changes. Rail transport is currently the safest branch of land transport. The general picture of safety in rail transport consists of two factors - accidents originating in the railway system and accidents occurring outside this system. The basic factors affecting the safety of railway traffic are:
- technical condition of railway infrastructure and rolling stock,
- employee competencies,
- technical condition of railway traffic control devices,
- operation of rail and road crossings,
- conducting modernization and investment works in compliance with health and safety guidelines,
- society security culture.

Ensuring a further stable increase in the level of safety in rail transport should be based on both technical and organizational safety as well as protection against external factors. The key to a systematic increase in the safety level of the railway sector is the continuation of existing activities and the undertaking of new ones in the field of promoting the principles of safety culture in railway transport. Shaping awareness of the safety culture among managers of railway market entities, their employees and future generations will allow for proper risk management, including the use of knowledge and competence to identify threats and implement adequate risk control measures. Therefore, an important aspect of the implementation of the safety culture is the activity of public institutions, scientific units, industry media, as well as other entities related to the broadly understood railway sector, which, by carrying out their tasks, will support the development of the safety culture. According to applicable national and European legislation, full responsibility for the safe operation of the railway system rests with the entities operating in it. This responsibility applies to infrastructure managers and railway undertakings, as well as their subcontractors and suppliers. It should be emphasized that the work of railways is not based on individual action. The passage of the train and the transport of cargo and passengers are the results of the huge commitment of a team of people working in various, independent entities of the railway sector. Therefore, shaping individual patterns of thinking and behavior is not enough. It is also necessary to properly shape the collective culture - the safety culture of entire organizations.

Security is understood and defined in various ways, but it is one of the most valued and protected values. Activities in the field of occupational health and safety in the company require a systemic approach. The basic principle of this approach is to strive to understand the essence of problems, and to capture the essential issues for the analyzed phenomenon. The accident is the result of human error or system oversight. There is no one right way to achieve safety on a construction site, however, you need to work towards maximizing this level. By correctly assessing t he occupational risk of employees, companies reduce the likelihood of accidents. The risk assessment then plays a preventive role. The frequency of accidents in the construction sector in Poland is still high. The industry leads in the infamous statistics of accidents at work, surpassing even the mining industry in this respect. The increase in the number of events related to the ongoing investment in and modernization of railway lines is noticeable. No compromises or simplifications can be used here. Over the last few years, over 70 events have been recorded resulting from the manner of carrying out works on active railway tracks. Only anticipatory actions of a systemic nature can eliminate the risk of an event and, in the event of its occurrence, contribute to minimizing the effects. Each enterprise is a separate economic entity, therefore high standardization of operational processes is necessary for the field of rail traffic safety.

Works on active railway tracks or other tracks and in their vicinity belong to the group of particularly dangerous works. They involve high risks for workers, who can be hit or run over by moving rail vehicles or track maintenance machines. Employees may also be electrocuted by the catenary or overhead electrical network, which is supplied with 3000 V DC for non-traction purposes. To ensure an appropriate level of safety during this type of work, active tracks should be separated and marked following railway regulations. Regulations in this area include many technical and organizational requirements, primarily instruction Id-1 (D-1), technical conditions for maintaining the surface on railway lines, and guidelines for securing the work site on a closed track when rail vehicles are moving on an active track at a speed of V≥100 km/h, governed by instruction Id-18. Before starting the work, the place of work should be covered in accordance with the "Signaling Instructions" Ie-1. Construction works related to work on active railway lines and live traction networks may be carried out only based on the Instructions for Safe Work Execution (IBWR), which is an appendix to the Safety and Health Protection Plan (BiOZ Plan).

Work security systems

The Contractor has the option of using one of the five systems for securing the work site:

1. Closing the adjacent track - the safest security system that can be used only where it is possible to completely stop the movement of railway vehicles for the duration of the work.
2. Separating the track space with permanent safety barriers, approved for use by the Infrastructure Manager, PKP Polskie Linie Kolejowe S.A.
3. Applications of semi-automatic or automatic (PSO and ASO) warning systems against the approaching train - these are warning systems activated automatically by a rail vehicle approaching the work site on an active track or semi-automatic systems activated manually by the operator (signalman). The signal activating the warning is transmitted by cable or radio. The length of the approach section should guarantee evacuation time from the most distant locations, together with additional safety time. The placement of the transmitters and their locations are specified in the Id-18 instruction according to the algorithm and must be included in the work site security design. The systems found on construction sites, e.g. Zöllner's Autoprow, are distinguished by the highest level of safety thanks to simple operation and mobility.
4. Applications of the warning system on working machines (SOM)
5. Warnings in accordance with the technical conditions specified by the Infrastructure Manager.

Guidelines of PKP Polskie Linie Kolejowe S.A. regarding the protection of the site of works performed on a closed track during the movement of railway vehicles on an active track, provided for in Instruction Id-18, refer to the speed V ≥ 100 km/h, which may be insufficient. The railway undertakings are responsible for the safe operation of the railway system, the supervision of risks related to the involvement of contractors, and the control of suppliers. It is they who are obliged to implement the necessary risk supervision measures as part of the common risk management. However, if the risk supervision measures developed so far do not ensure minimization of its level, they should be revised. The criteria set out in Annex II to Commission Regulation (EU) No 1169/2010, used by national safety authorities when considering applications from infrastructure managers for safety authorizations, should also be taken into account.

Protecting the greatest value, which is human life and safety, as noted by the President of the Railway Transport Office, Dr. Eng. Ignacy Góra, on large-scale contracts, automatic warning systems and railway safety barriers should be used, which meet the construction requirements for railway fencing and are stable during the passage of vehicles at relatively high speeds. However, all of the possible systems and technological solutions have their

advantages and disadvantages. Safety barriers cannot be used on contracts where works are carried out with the use of high-performance machines such as AHM 800R or PUN (track machines used for continuous subgrade replacement without the need to dismantle the railway track), because they enter the track gauge. In addition, assembly and disassembly are time-consuming, and a lot of fencing is needed to secure a longer or several fronts of work, which adds to the costs of storage and relocation at subsequent stages of work and the discomfort of work during the passage of the train. Closing the adjacent track is the safest security system, which, however, can only be used where it is possible to completely stop the movement of railway vehicles for the duration of the work. ASO and PSO systems are also characterized by a high level of security, but they are not always used for economic reasons.

1. Railway safety barriers

In the conventional securing method, it is the railway signaller's responsibility to alert the working groups. Its main task is to give a signal about the approaching train using a flag, trumpet, or radiotelephone. Due to the unreliability of the human factor, most European infrastructure managers have decided to change their internal regulations to increase speed on the adjacent track, while ensuring greater safety for working groups. Conventional security may not be enough. The signaller is exposed to many dangers, often the trains are noticed too late. Limitations in visibility for atmospheric reasons (rain, snow), operating modes (e.g., night), fatigue, or distraction intensify this problem. Other obstacles for the signaller are working on curves or railway stations, which limit visibility and audibility. The Automatic Warning System is a solution that has been used for several years in Europe and is a safer alternative to the traditional solution. ASO Autoprowa® manufactured by the Zöllner Group, having all the necessary approvals of the PKP PLK S.A. infrastructure manager, which are used in Poland by the Torpol Machinery Plant in Kraków, Torpol, Strabag, or FACRAIL, guarantee the highest level of safety. Radio-automatic warning systems (RAWS) are used to warn track workers of an approaching train by means of an acoustic and optical signal. The systems are activated automatically by a railway vehicle approaching the work site on an active track or semi-automatically by the system operator (signalman).

2. ASO operator during work

3. A radio transmitter connected to an inductive wheel detector of a rail vehicle

Another way of securing the work site is by posting a warning on high-performance working machines, aimed at the employees operating the machines, who, due to the high noise level, may not hear the information provided by the signaller. Thanks to the use of industrial magnets, it is possible to equip track machines with Automatic Warning Systems, which, thanks to the Autoprow® effect, automatically adjust to the noise level. The systems ensure the highest safety and comply with the guidelines for securing the site of works performed on a closed track when driving vehicles on an active track at a speed of V>100 km/h, taking into account the noise level at the site of works. Thanks to the use of two-way radio transmission with the highest ranges and broadcasting on three proprietary frequencies, the system devices control each other's correct functioning and radio communication. The key to the development of the Autoprowa® system was its simple operation and quick installation. The sounders are connected using only one cable, and each plug is specially coded. This saves time and eliminates link swapping. ASO Autoprowa® is a flexible modular system that can be used in any situation on small and large construction sites.

4. SOM Warning systems mounted on machinery or other rail vehicles

5. ASO while working with AHM (Zakład Maszyn Torowych Kraków)

6. ASO while working with AHM (Zakład Maszyn Torowych Kraków)

7. ASO while working with AHM (Zakład Maszyn Torowych Kraków)

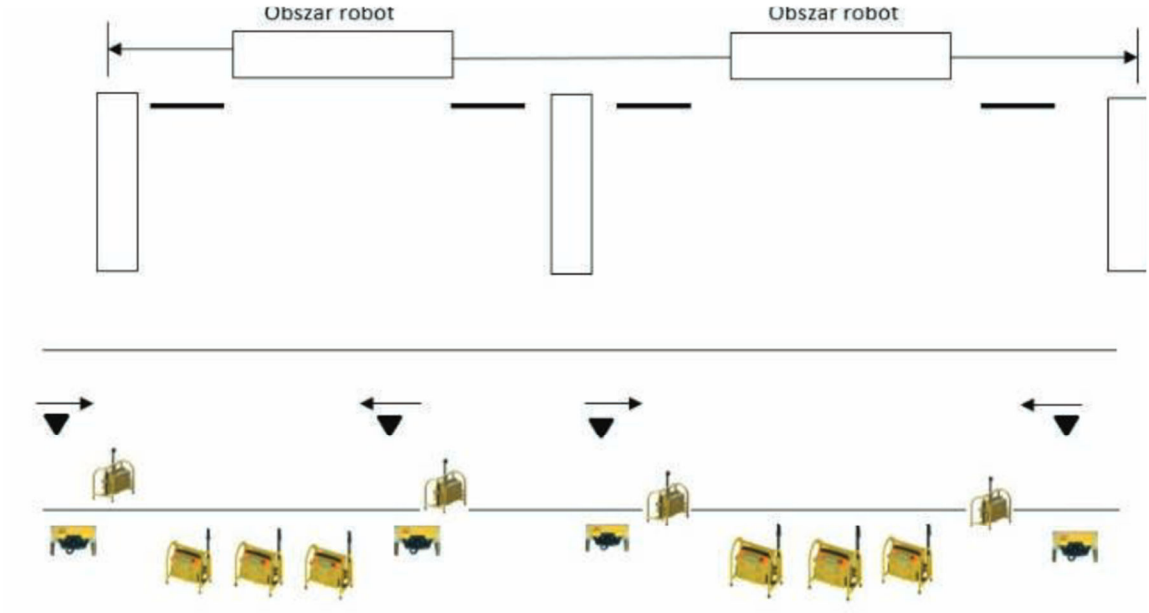
The simple installation of the system begins with measuring and marking the spacing. Next, on- and off-busbar contacts are installed, which are connected to the control panel by cable or wirelessly via radio. At the same time, acoustic signaling devices and warning lamps are placed in predetermined sections. This creates a tight network consisting of optical and acoustic signaling devices. Single components are connected to the control panel. Then the whole system is turned on - the ASO display informs with a clear message about the readiness for operation of the control panel. High system safety has been achieved by the redundant power supply in all sounders, i.e. each sounder of the installation has a built-in battery and forms a closed unit for itself. If the power supply is unexpectedly interrupted, the system will remain active, and a warning signal informs you of its absence. The security idea of the Autoprowa® Automatic Warning System consists of constant monitoring of individual elements by the control panel. A warning tone and an additional clear text message alert you to faults and allow you to quickly identify the cause of the fault. Constant monitoring by the control panel covers both the proper functioning of individual components and individual connections to the control panel. Thus, high safety requirements with regard to the applied system of protection of hazardous places are guaranteed. Autoprowa® means automatic,

proportional warning and automatic adjustment of the warning signal level. If the warning is triggered in places with low noise, the system warns at the minimum level. In the vicinity of loud devices or machines, each siren adjusts the volume of the warning signal. The sounders are always clearly audible. The volume is adjusted individually in each siren, not in the control panel so that on construction sites with different noise levels, the warning signal is always unmistakably audible. Thanks to the modularly assembled system, all elements can be combined, and the configuration of the devices can be adapted to any situation on the construction site. Unity consists of the following areas: train detection, transmission, central, and warning. The train is detected by rail contacts, a remote switch, a hand-held radio transmitter, or a signal box. Transmission to the construction site is via cable, radio, or GSM. The system consists of the following components:

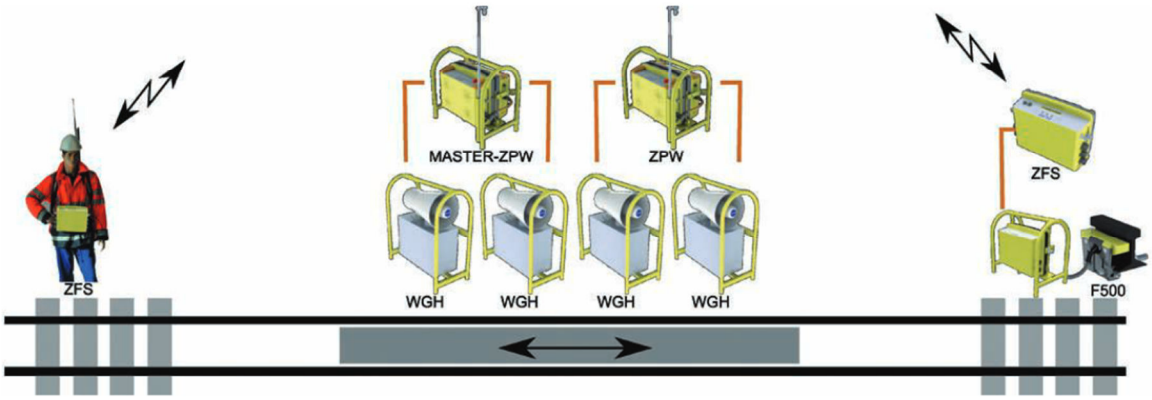
- ZRC (ZÖLLNER Remote Control),
- ZPW (ZÖLLNER Persönliches Warngerät),
- ZFS (ZÖLLNER Funksender),
- F500 (rail detector),
- WGH (Warngeber Horn) warning siren
- ZA24-7W and ZA24-2 batteries.

The ZRC (ZÖLLNER Remote Control) unit connects and controls the radio components of the entire system, thus serving as the control and control unit for the entire system. Mobile use of the ZRC is possible thanks to special carrying straps. The control panel is equipped with functions for canceling and issuing additional warnings. In addition, it has a special impact button to activate the Ro3 distress signal, which orders to leave the tracks immediately by emitting a loud five-time warning signal. The ZPW radio signaling device is a compact warning device, used collectively or individually to inform people in the area of the track. It is equipped with four acoustic signaling devices that give a characteristic warning signal in the event of an approaching train or an error. Additional equipment includes two flashing lamps for optical warning signaling. To guarantee increased vigilance, the battery that is part of the device also has two flashlights. The sound level of the signaling devices can be increased by connecting additional WGH acoustic sirens to the ZPW. The control and control unit of the sirens is then the ZPW. The acoustic signaling of ZPW and WGH is also based on the Autoprow® effect. The ZFS radio transmitter (ZÖLLNER Funksender) has a dual purpose. In the stationary module, it is connected to the train detectors, and in the mobile module, it is operated by an employee. The system is responsible for safe warning against railway traffic in the area of the repaired and adjacent track. The risk arising as a result of human failure or caused by human error is reduced to a minimum. Recognizing the real threat to employees staying in a dangerous environment on the work fronts near the tracks, I would like to point out that the use of ATS should be widespread in Poland, not only at speeds of V > 100 km/h but also much lower, as in other European countries that have confirmed their effectiveness and introduced appropriate regulations. With regard to the "Safety Culture" project, to further raise the level of safety on construction sites, I would like to draw attention to the problem of securing railway works in a way that fully guarantees its proper quality. I would like to emphasize that at present there are no procedures at PKP PLK S.A. or any other institution (including the Office of Rail Transport) regulating the level of performance of such services. Only systemic pre-emptive actions can eliminate the possibility of an event occurring and, in the event of its occurrence, contribute to minimizing the effects. The context of the current situation in the railway sector, the number of contracts and investments underway, which is heading towards the climax, makes this issue even more visible. Only the use of Automatic Safety Systems, with the necessary approvals to guarantee certification, will allow the safety of the works to be maintained, but it will also increase the throughput of the line, improving the smoothness of train traffic. Railway companies implementing

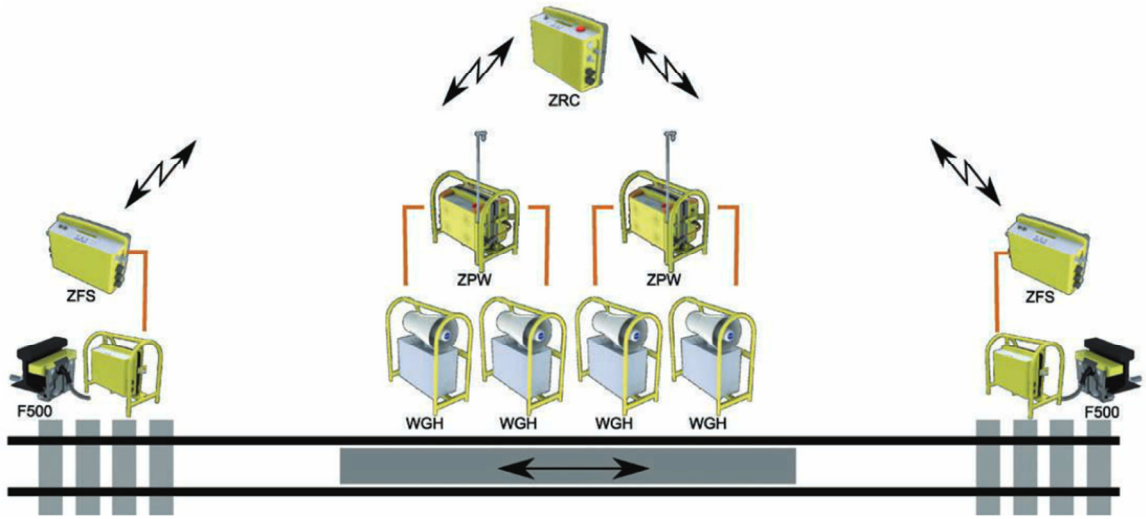
infrastructural contracts recorded a significant improvement in the safety of employees performing investment works with the use of automatic security systems. Technological progress that we observe every day in all spheres of our lives and the availability of new-generation technologies allow us to significantly increase the safety of our employees while optimizing costs. It's high time for a safe railway, a time for safety!
Examples of system configuration at the construction site (fig. **8**-**10**).



8. An example of system configuration



9. An example of system configuration



10. An example of system configuration

Increased traffic of road vehicles causes an increase in the probability of rail incidents at level crossings. This is due to the intersection of rail, road, and pedestrian transport in one place. The specificity of various forms of transport and the imbalance between the scale, weight, and capacity of various types of vehicles are the most common causes of accidents. Breakdowns and misconduct by rail staff compound this problem. An innovative solution for securing a railway crossing, not only during modernization or investment but also in the event of a failure of the existing system or during the temporary shutdown of stationary barriers, is the mobile barrier TH BÜP (Technisches Hilfsmittel Bahnübergangsposten). The use of this solution allows you to secure any railway crossing while maintaining the highest level of safety. The advantage of the system is its versatile use and simple assembly and disassembly, and it is operated by only one operator. TH BÜP is a modular system consisting of traffic lights, crosses, and barriers. A fully automatic barrier allows temporary technical protection of railway crossings, and the LEXOS system supports BÜP in its responsible safety activities and intervenes in the event of human error to avoid accidents. The solution has been tested and is used daily in infrastructure in Germany, France, Austria, Great Britain, Italy, Spain, Switzerland, Belgium, Denmark, Brazil, Australia, etc.

10. Mobile turnpike

12. Mobile turnpike

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