Archives of
Transport System
Telematics

Volume 11

Issue 2

May 2018

# The Strategies of Human Error Mitigation in Railway Traffic Control Systems

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**ABSTRACT**

The search for system solutions for improving the level of safety in rail transport requires focusing on the problem that is weakly exposed but difficult to manage, namely the elimination of human errors in the process of railway traffic and the use of railway traffic control systems. Despite the fact that the existing solutions have a relatively extensive theoretical layer, there is still much to do in terms of practical implications. In particular, the use of human factors, including knowledge and technology, facilitates the achievement of a number of positive effects: reducing the possibility of errors, increasing the margin of safety, reducing expenditures on redesigning solutions, increasing the efficiency and effectiveness of training, reducing the potential of costly staff turnover and increasing the productivity of the entire organization.. This subject has not been solved in a systemic way in Polish conditions. The purpose of the article is to present the holistic and eclectic description of the place and role of the human factor management process in terms of making errors by railway employees, which is designed to eliminate hazards in railway traffic and reduce risk. This has a significant impact on maintaining the expected level of railway traffic safety.

**KEYWORDS: human errors, railway traffic control systems, safety management in rail transport**

## 1. Introduction

Human errors appear very often in safety reports as key causes of railway accidents. Due to the relatively new look at the risk management process related to the occurrence of the human factor, the Polish experience indicates significant needs for the implementation of innovative solutions aimed at eliminating hazards related to the human factor. These occurrences result not only from the failure of technical systems, but also due to the poor psychophysical condition of an engine driver. There are two crucial substantive areas that are important in terms of human errors. The first one is the staff qualification process, which is clearly described in the Act of 28 March 2003 on Rail Transport, as well as in secondary legislation. The training centers of future engine drivers play a key role in this respect. Training programs that result from the law should definitely be extended by training centers with the innovative methods of human factor management already at the stage of engine driver initial training. The second area is the performance of a job of an engine driver, who belongs to a given organization. A fundamental role is played by the awareness of management staff regarding railway occurrences that take into account a human factor, as well as preventive and risk control measures in the form of technical systems and organizational solutions. In order to eliminate human errors, it is important to provide interfaces between technical and organizational solutions in the context of the potential for human error. The smaller the human interference in the system is, the less chance of making a mistake is. It is also important to assess the functionality of railway traffic control systems in terms of human error. Solutions that are possible to be implemented by railway carriers to eliminate human errors are also important in this respect. They may include training aspects and railway traffic management aspects, including methods that increase the concentration of the operator's work and reduce the monotony of work. Railway traffic control systems, especially those whose functionalities largely depend on the operator's work, are an important aspect of the need to implement solutions resulting from the elimination of human errors. This subject should be a priority in the activities of railway traffic safety stakeholders.

## 2. Human error risk management in rail transport

Human error is an inseparable element of human work. It cannot be completely eliminated because its occurrence is a condition of many factors difficult to supervise. However, the risk of its occurrence can be mitigated by using systemic solutions. Table 1 shows selected hazards related to the human factor.

**Table 1. List of selected hazards related to the human factor [own study]**

| No | Hazard |
|---|---|
| 1 | the incorrect assessment of train operation by the engine driver |
| 2 | errors in using a brake - errors in the assessment of the situation |
| 3 | excessive speed due to erroneous speedometer readings |
| 4 | the incorrect use of a coupling/uncoupling button by the engine driver |
| 5 | the incorrect assessment of the situation causing excessive acceleration |
| 6 | the incorrect localization of the semaphore by the driver |
| 7 | the incorrect reading of information on the semaphore |
| 8 | engine driver's disease - failure to report ill health |
| 9 | the incorrect use of the brake due to alcohol/drugs |
| 10 | excessive speed due to alcohol/drugs |
| 11 | the deterioration of the psychophysical condition, a state of intoxication |
| 12 | ignoring instructions by the engine driver |
| 13 | bad information flow between employees |
| 14 | the deterioration of the psychophysical condition due to fatigue |
| 15 | loss of concentration by the engine driver |

The workload of an employee consists of physical, mental and emotional strain, which is caused by work and the environment. It is particularly important in rail transport to maintain proper relationships between the requirements set by the task and the work environment and the operator's abilities. Monotony has a significant influence on the intensity of the psychological strain. Tasks that are devoid of cognitive and emotional factors can increase boredom, i.e. a state of reduced activation of higher nerve centers. Decreased excitement is related to a decline in mental performance and emotional stress is determined by responsibility and hazards.

Most causes of primary rail occurrences result from human error. Based on the data presented by railway commissions on the causes of primary railway occurrences of B04 and C44 categories, the following should be mentioned:

- The incorrect interpretation of signals, indicators, SRJP timetables or commands,
- The insufficient observation of the driving range,
- Incorrect communication regarding maneuvers,
- Too late braking
- No primary cause,
- Starting the vehicle without permission,
- Vehicle failure (e.g. the incorrect operation of the braking system),
- No knowledge of the route,
- The incorrect adjustment of speed to weather conditions,
- The engine driver's collapse,
- An erroneous message given by the train dispatcher,
- An engine driver under the influence of alcohol.

A multidimensional analysis of primary causes indicates that most occurrences result from human errors. Thus, a key question is how to effectively manage rail transport safety by analyzing behavior in the dynamic system of railway system operators, who include engine drivers on the side of the railway carrier and train dispatchers on the side of the infrastructure manager. The complexity of the issue is important as a human factor functions in the context of a dynamic, changing environment. Therefore, the interaction between these components determines railway traffic safety or its lack. In relation to the need to specify diagnostic and maintenance activities outlined above, it is worth referring, for example, to another issue – the verification of the cooperation between rolling stock and traffic control equipment. This is a technical issue that should theoretically be reliably and correctly solved in the rolling stock maintenance system, but it is not.

## 3. B-class traffic control systems and a human factor

Safety in railway traffic depends fundamentally on the properly functioning baseline systems and the appropriate engine drivers' reactions to information received in the railway traffic control process. Safety is also affected by many other factors, such as the technical condition of rolling stock, a railway track, an electric traction, railway traffic control systems used and their functionality. The issue of rail transport safety, risk management and technical development has been broadly discussed in the works [1-5]. In accordance with the provisions of European Union legislation, member states ensure that B-class systems and their interfaces continue to function according to current specifications, unless modifications are necessary to remove deficiencies related to system safety. B-class systems significantly impede the interoperability of railway engines and traction vehicles, but are necessary to ensure safe operation in cases where A-class systems have not been introduced. Therefore, additional obstacles to interoperability should be avoided, for example by modifying B-class systems or introducing new systems. Investments in track-side and on-board systems should be protected by guaranteeing backward compatibility [1] and the stability of the ERTMS specifications [6]. In Poland, rolling (vehicle) devices controlling driver's vigilance are used. These are ATP devices - automatic train protection devices, *dead-man's vigilance devices* and the RADIO STOP system to improve the traffic safety of rail traction

[1] Backward compatibility - a feature of a standard, device or software, thanks to which, despite the change of functionality, a new version enables cooperation with the entire environment of the old version and all its components. It is the extension of functionality.

vehicles. In addition, the Train Braking Control system was developed in the 1980s as track-side devices. The vast majority of railway lines in Poland (about 16 thousand km) are currently equipped with the ATP system, it is also obligatory in traction vehicles. ATP devices aim at improving train traffic safety. They cause automatic braking of trains, for example, if an engine driver falls asleep and the train approaches the semaphore. The essence of the ATP system lies in the fact that along the braking path of the train plus 200 m (usually, but not always), the ATP electromagnet (resonator) is installed, while the locomotive is equipped with a whole set of devices cooperating with this resonator, including a sensor placed on the right side of the locomotive. When the locomotive sensor is over the resonator, an acoustic signal sounds and a control lamp lights up in the locomotive. An engine driver has five seconds to press the standby button. When he presses it, the devices return to the starting condition. However, if an engine driver fails to respond, the train braking device is activated. At this time, it is useless to press the button - the train will start braking anyway. When the train speed drops below 10 km/h, pressing the standby button will unlock the brake and the train may go further (the functionality depends on the type of rolling stock, in some cases the speed must fall to 0 km/h). If the button is not pressed, the train will stop completely. The functionalities of selected rail traffic control systems are presented in Table 2.

**Table 2. Functionalities of control systems [own study]**

| No. | Type of system | Functionalities of the control system |
|---|---|---|
| 1. | Vehicle Braking Control | • informing the traction teams about the readings of trackside signaling devices by transferring the readings to the traction vehicle cabin;<br>• controlling the execution of signaled commands regarding the permissible speed at a given distance and stopping before the „stop" signal;<br>• engine driver's vigilance control 200m before line and entry signaling devices and at the station exit and group signaling devices;<br>• temporary and permanent limitation of train speed on the route;<br>• reaching the full level of technical and mobility safety, as well as the resistance of systems to damage;<br>• the application of the original information transfer technique enabling safe and easy technical implementation of the system in the Polish State Railways, facilitated by the use of other known systems subassemblies manufactured by ZWUS. |
| 2. | ATP - automatic train protection devices | • train automatic braking in the case if, for example, an engine driver falls asleep and the train approaches the semaphore. The ATP system devices have an impact on railway traffic safety by controlling driver's vigilance at critical points (when approaching and leaving the station, most often before the signaling devices that are a warning shield of the next semaphore, among others the semaphores of the automatic block signaling system, distant signals and crossing distant signals, semi-automatic entry and exit semaphores for routes with the automatic block signaling system). |
| 3. | ETCS – level 1 | • the control of the engine driver's work (the supervision of the proper driving of the train) to the extent enabling trains to travel at speeds above 160 km/h;<br>• the boundaries of the permits to drive a train;<br>• controls the driving of the traction unit by the engine driver within the driving limits;<br>• monitors the maximum speed of the train, the direction, and the permanent and temporary speed limits of the train;<br>• adjusts the railway traffic management system to solutions used in European Union countries within the framework of the interoperability of the trans-European railway system. |

The activity of the system operator plays an important role in the railway traffic control systems listed in Table 2. These systems control the driver's vigilance and support or replace the driver in the decision-making process related to receiving information, their processing and proper train driving and braking. Regardless of whether a vehicle management process is manual, power assisted or fully automatic, the system may include additional protection functions in the event of a critical situation. B-class control systems control engine driver's vigilance (understood as consciousness) at specific time intervals. Lack of the required engine driver's response makes the train stop by automatic sudden braking. In this process, there are no control elements, e.g. speed reduction, etc. Although an engine driver used an ATP button, he may not have sufficient psychophysical health to correctly assess the situation on the route, or may not react to signals on the signaling device. In addition, the use of two devices responsive to the reset button in a vehicle may, in certain cases, lead to the incorrect interpretation of the meaning of a light or acoustic signal (similar, or even - identical in some implementations, for both devices).

One of the essential elements of increasing the railway transport capacity and improving train traffic safety is the construction or modernization of current railway traffic control devices. The basic means leading to the implementation of interoperability is the European Rail Traffic Management System (ERTMS), which includes:

1. the European Train Control System ERTMS / ETCS,,
2. The Global System for Mobile Communication-Railways ERTMS / GSM-R.

The implementation of ERTMS in Poland is one of the priority projects of the "Strategy for Responsible Development until 2020 (with a prospect until 2030)", adopted by the resolution of the Council of Ministers. ERTMS is perceived as an element of the implementation of information and telecommunications systems (transport telematics), which should be implemented in all types of transport [7].

Compared to the solutions used so far in Polish rail transport, a key feature is cabin signaling, which allows for visualizing the situation on the railway line on the panel in a railway vehicle, unlike so far only on semaphores along the railway line. This solution allows for the appropriate reaction and adjustment of the ride to the conditions. The implementation of the cabin signaling also eliminates possible human errors resulting, for example, from the lack of visibility of semaphores or from the engine driver's unfamiliarity with the route. If the train is driven contrary to the ETCS command, the system first indicates this incompatibility and starts braking if necessary. According to legal requirements, ETCS is necessary for driving the train at a speed above 160 km/h, or one-person traction service above 130 km/h. GSM-R is a railway variation of GSM digital mobile communication intended for the transmission of data used as a data carrier for ETCS and dispatch systems and for ensuring voice communication with an engine driver. ERTMS implementation is determined by both economic and safety reasons.

## 4. Safety Management Systems in rail transport and a human factor

A modern look at the problems of railways requires a multidimensional approach that takes into account technological as well as organizational and management aspects. Until now, many solutions used in rail transport have not been strongly focused on exposing management issues. Currently, such management methods gain special importance that take into account technological aspects examined in systemic terms. According to Art.3 of Regulation 402/2013:

- risk analysis should be understood as the systematic use of all available information to identify hazards and assess risk,
- safety - no unacceptable risk of damage, Article 3 of Directive 49/2004 and Art. 4 par. 41 of the Act of 28 March 2003 on Rail Transport says about:
- CSM (Common Safety Methods) - methods that should be developed to describe how to assess: the level of safety, compliance with safety requirements, and compliance with other safety requirements.

The intensive and comprehensive development of safety management issues in rail transport in the European Union was initiated by the provisions of Directive 2004/49/EC of the European Parliament and the Council of 29 April 2004 on the safety of the Community railways, which states that to ensure a high level of railway safety and equal, also competition conditions for all railway carriers, all of them should be subject to the same, precisely defined requirements. A safety certificate/safety authorization should be a confirmation that a railway undertaking and an infrastructure manager have approved a safety management system and that they have the ability to meet the requirements of the relevant standards and safety regulations. As regards services in international transport, it should be sufficient to approve a safety management system in one member state so that it is valid throughout the Community. Aspects related to a human factor and the occurrence of human errors are important in safety management systems in rail transport. They should be the subject of internal regulations dedicated to this topic. Based on the author's extensive experience in the field of safety management systems in rail transport, it should be stated that the elimination of human errors at the level of applied system solutions has an initial character and requires extensive analysis as well as practical implementations. These solutions should include the following aspects [8]:

- Training
- Working conditions
- Organizational culture
- Selection of personnel
- Staff efficiency
- Designing technologies and processes.

The human factor is a very important aspect of a safety issue in rail transport, which should now be intensively developed at the level of infrastructure managers, railway carriers, and supported by the National Safety Authority.

## 5. Human errors and their categorization

The effective implementation of SMS procedures depends on the clear mutual understanding of errors and violation and distinguishing one from another. The difference between errors and violation lies in intent. An error is unintentional, while violation is a deliberate act or omission involving the violation of established procedures, protocols, standards or practices. Errors or violation may result in non-compliance with regulations or operational procedures. No solutions other than disciplinary measures taken in response to non-compliance can lead to a decrease in the number of errors reported. Therefore, when determining the appropriate disciplinary measure, it should be considered if non-compliance is the result of violation or unintentional errors, but the usual criterion is whether non-compliance is the result of willful misconduct or gross negligence. As indicated above, an error is defined as "an act or omission of an operational employee, leading to abandoning the intention or expectations of one's own or organization". In the context of the SMS, it is necessary to understand and assume that people will make mistakes regardless of the level of technology used, the level of training and laws, processes and procedures. An important goal is therefore to establish and maintain defensive elements in order to reduce the likelihood of errors and, what is equally important, reduce their consequences when they happen. To effectively implement these assumptions, mistakes must be identified, reported and analyzed so that the right precautionary measures can be taken. Errors can be divided into the following two categories:

1. Slips and failures. These are failures in the implementation of the intended activity. Slips are actions that do not go according to plan, and failures result from a memory defect.
2. Mistakes are defects in the action plan. Even if the implementation of the plan was correct, it would not be possible to achieve the intended result anyway.

To control and eliminate errors, safety strategies must be implemented. Error control strategies strengthen the basic defense elements of the system. They include:

- Reduction strategies, which assume direct intervention to reduce or eliminate factors that contribute to the error. The examples of reduction strategies include the improvement of ergonomic factors and the reduction of environmental disturbances;
- Capturing strategies assume that an error will be made. Their goal is to capture an error before its negative consequences are felt. Capture strategies differ from reduction ones in the fact that they use checklists and other procedural actions rather than eliminate errors directly;

- Tolerance strategies refer to the ability of the system to accept that an error will be made but without serious consequences. The examples of actions that increase the system tolerance for errors include the introduction of redundant systems or multiple-controlled processes.

Because organizational, regulatory, and environmental factors influence staff performance, safety management must include conceptual actions, processes and procedures for communications, staff scheduling, resource allocation, and budget constraints, which can contribute to the occurrence of an error.

# 6. Conclusion

A human factor in railway traffic control systems is crucial. As regards the functionality of the systems in question, the human factor should take into account technical aspects, their relation to the technology of railway traffic management and the aspects of the perception of railway system operators. They should also be included extensively in the procedures and instructions of the railway safety management system. Personal and psychological factors, decision-making processes, team factors, work conditioning factors, environmental aspects, technical configuration and organizational processes, fatigue, workload and others are of key importance. The railway traffic control system will provide the best operational parameters if it is coherently linked to human factor management processes within the framework of the safety management system. As regards the issue of the widespread use of B-class control systems in the Polish conditions, they control the engine driver's vigilance (understood as consciousness) at specific time intervals. Lack of the required engine driver's response makes a train stop by automatic sudden braking. It should be noted that although an engine driver used the ATP reset button, he may not have sufficient psychophysical health to correctly assess the situation on the route, or he may not react to signals on the signaling device. Thus, adverse rail occurrences happen caused by human errors, despite the efficiency of this system. This issue should be the subject of extensive analysis and research aimed at eliminating hazards resulting from human errors.

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