INNOVATIVE MECHANICAL ENGINEERING **ISSN 2812-9229 (Online)**
University of Niš, Faculty of Mechanical Engineering
VOL. 1, NO 3, 2022, PP. 87 - 92

Original scientific paper *

DEFINING OPERATIONAL REQUIREMENTS FOR AN OBSTACLE DETECTION SYSTEM USING A RISK-BASED APPROACH

Slobodan Rosić[1], Dušan Stamenković[2], Miloš Simonović[2]

[1]Railway Infrastructure of Serbia, Nemanjina 6, Belgrade, Serbia

[2]University of Niš, Faculty of Mechanical Engineering in Niš, Serbia

Abstract. *Railway traffic automation has recently become a generally accepted trend and represents one of the main conditions for further development of this type of transport. Automatic control of trains/traction units implies the introduction of an obstacle detection system. The usual approach to defining operational requirements for the development of new technical systems on railways is the so-called project approach. Operational requirements for a new system are defined in advance, according to valid standards, defined goals and available technology. However, the development of an obstacle detection systems has its own specificities, where this approach does not necessarily give satisfactory results. Successful functioning of this system in terms of railway traffic safety, i.e., successful detection of obstacles, is not a goal in itself, the goal is to avoid an obstacle or minimize its negative impact as much as possible. In order to achieve this, in addition to successfully detecting an obstacle, it is necessary to react adequately to it. Therefore, to define operational requirements for such a system, it is necessary to start from the analysis of the requirements in terms of adequate response and not from the requirements in terms of obstacle detection. This implies the application of a risk-based approach.*

Key words: *Railway traffic, Automatization, Obstacle detection, Operational requirements, Risk*

1. INTRODUCTION

The automation of the railway system is necessary for its successful development in relation to other modes of transport, considering the increasingly demanding conditions on the transport market. This process is ongoing in all segments of the railway system, especially for traffic management, transport maintenance and infrastructure capacities.

*Received: December 14, 2022 / Accepted January 10, 2023.**
Corresponding author: Slobodan Rosić
Railway Infrastructure of Serbia, Nemanjina 6, Belgrade, Serbia
E-mail: srosic1964@gmail.com

Table 1 Main characteristics of the five Grades of Automation (GoA)

GoA levels	Door Closure	Setting train in motion	Stopping train	Operation in case of disruption
GoA0	Driver	Driver	Driver	Driver
GoA1	Driver/Automatic	Driver	Driver	Driver
GoA2	Driver	Automatic	Automatic	Driver
GoA3	Attendant	Automatic	Automatic	Attendant
GoA4	Automatic	Automatic	Automatic	Automatic

Automation, after electrification and the introduction of high-speed trains, represents the third revolution in the railway transport development. In the field of railway traffic, there are four levels of automation (Table 1) [1]. In the case when remote control and management of the vehicle from the command/dispatch center is possible, the level of automation is additionally marked with a + sign.

Full automation implies GoA level 4, in which case the traction unit is controlled without the presence of a person in the cabin. For complete automation of the railway traffic, a system for detecting obstacles on the driving path is one of the most important requirements. Regardless of the fact that the train path is controlled and that as a rule there should not be any obstacles on it, the effectiveness of that control is not such to provide real absence of all risks associated with obstacles on the train path. So far, GoA 4 level of automation has been implemented in several metro and light rail systems. The only application in classic railway systems is on the Rio Tinto mining tracks in Western Australia, where fully autonomous operation for its entire rail system has been in use since 2019. This Rio Tinto rail network is recognized as the world's first fully autonomous rail network [2].

All systems in which GoA 4 level of automation has been implemented so far are significantly different from most public railway systems in terms of the type and magnitude of risks associated with obstacles. They are either closed systems such as subways, mining lines in desert areas without major environmental hazards, or light rail systems with low speeds and short stopping distances. Experiences from these systems are only applicable to a limited extent for classic public railways.

The introduction of GoA 4 level of automation in public railway traffic is planned worldwide. The EU countries and Russia have gone the furthest in this process, where test drives and tests of obstacle detection devices are carried out. In the US and China, the introduction of this level of automation is still in the planning phase [2-4].

The development and implementation of any new railway system requires defining functional and operational requirements. The usual approach to defining operational requirements for the development of new technical systems on railways is the so-called project approach, where operational requirements for a new system are defined in advance, according to valid standards, defined goals and available technology. However, the development of obstacle detection systems has its own specificities, where this approach does not necessarily give satisfactory results. In order to achieve this, besides successfully detecting an obstacle, it is necessary to react adequately to it (warning, reducing speed, braking). Therefore, in terms of defining operational requirements for such a system, it is necessary to start from the analysis of the requirements in terms of adequate response and not from the requirements in terms of obstacle detection. This implies the application of a risk-based approach, which is considered in this paper.

2. Defining the Operational Requirements for the Obstacle Detection System

The traditional approach to defining operational requirements for a new technical railway system is to define them in advance based on the project goals. For the obstacle detection system, they mainly refer to the definition of object/obstacle categories that the system should detect and the maximum distance of their detection.

2.1 Project base defined operational requirements for the obstacle detection system

Table 2 Objects that represent an obstacle to the safe movement of the train

Objects within the railway system	**Obstacle detection distance**
signals prohibiting further driving	braking distance
broken signals	braking distance
position of the switch blades	not precisely defined - only when the train stops or starts
other railway vehicles on the path	not precisely defined - only on shunting
Other objects	**Obstacle detection distance**
objects in the free (Bern) profile	≈ 2000 m
people in the free (Bern) profile	≈ 2000 m
animals in free (Bern) profile	≈ 2000 m
road vehicles in free (Bern)profile	≈ 2000 m

The disadvantage of the operational requirements for such a defined obstacle detection system is that it does not take into account the magnitude of the risk associated with different categories of obstacles; how the control system reacts depends on the risk size.

Operational requirements defined in this way can function satisfactorily in conditions where for each obstacle category there is one usual way of reacting: quick braking with possible warning signs, as is for trams. However, this is not the case in railway traffic.

Fast braking, i.e. emergency braking, also represents a risk to traffic safety, sometimes greater than the risk represented by the obstacle itself, and should not be applied by default. Also, the risk carried by a certain category of obstacles depends on other factors: position, dimensions, speed and direction of movement, etc., and their identification is also required for the correct selection of regaging.

Operational requirements defined in such a manner increase the occurrence of false positives (where ODS detects obstacles that do not present a real collision risk). This can be a problem for the application of GoA level 4 in tram LRT systems [5], and in the railway system it would certainly have very large negative consequences on the regularity of traffic and the system economy.

Last but not least, the operational conditions defined this way for the obstacle detection system usually take into account only obstacles in the free profile (the so-called Bern profile). However, considering the braking distance length in railway traffic, it is necessary to observe a wider strip next to the tracks where there may be objects that could endanger traffic safety. Reactions to such objects (warning, reduction of speed, etc.) must take place (existing railway regulations also require it) before they enter the free profile.

Bearing in mind the definitions of risk on the railway (risk is the occurrence of a dangerous event probability multiplied by the magnitude of possible consequences) and the frequency of certain dangerous events. It can be concluded that the most important task of the obstacle detection system is to recognize these types of dangers and issue a warning about them.

Although warning drivers, pedestrians and animals with sound and light signals is not in the foreground when thinking about obstacle detection, it is very important. Research conducted in the late 1980s in the USA by the FRA (USA Railway Safety Authority) on the ban on giving audible (whistle) signals at level crossings in urban areas, which the state of Florida tried to introduce, showed that the omission of warnings with audible signals increased the number of fatalities at level crossings by about 38% [6].

Bearing in mind that accidents with collisions with vehicles and people are by far the most numerous dangerous events on European railways (10 times more frequent than significant accidents resulting from train collisions with obstacles) and that for every collision of a train with road vehicles or people there are minimum 10 near miss collisions, it is easy to conclude that from the aspect of overall risk, the most important task of the obstacle detection system is to recognize moving objects in the area next to the free profile [7].

2.2 Risk-based approach

Real risks on public railways cause more complex operational requirements for the obstacle detection system than just recognizing the category of an object at a certain distance. An obstacle detection system would have to be able to detect ,i.e. recognize, not only the type of obstacle, but also the level of risk.

More detailed operational requirements for the obstacle detection system were defined by Russian Railways (RDŽ) [4]. Their classification of obstacles that should be recognized by the obstacle detection system is more detailed and includes moving objects in the belt next to the tracks (Fig. 1). In addition, it defines the basic type of risk related to an individual category of obstacles.

Until now, RDŽ has performed tests in the so-called GoA 3+ level, which means that the train was controlled remotely from the command center. For that case, this level of risk determination is sufficient because after the detection of an obstacle by the system, the dispatcher takes over the control of the train, i.e. defines the way of reacting to the obstacle.

№	Class	Subclass	Status or description	Threat to an obstacle	Threat to a vehicle
1	Pedestrians	Adults	Standing, moving, sitting, lying	Yes	No
		Kids	Standing, moving, sitting, lying		
2	Animals	Big animals (examples: cow, horse, moose)	Standing, moving, sitting, lying	Yes	Partially (at high speed)
		Medium and small animals (examples: goat, dog, cat)	Standing, moving, sitting, lying	Yes	No
3	Train units	Locomotives, train cars, maintenance vehicles and etc.	Standing, moving	Yes	Yes
4	Road vehicles	Cars, trucks	Standing, moving	Yes	Yes
		Motorcycles, bicycles		Yes	No
5	Static obstacles	Big (cross section area in the plane perpendicular to the rails is more than 0.5 m²)	Violation of the clearance gauge : building construction, fallen tree, tilted posts and other constructions	No	Yes
		Medium (cross section area in the plane perpendicular to the rails from 0.1 to 0,5 m²)	Boxes, shrubs, parts of building constructions	No	Partially
		Small (cross section area less than 0,1 m²)	Brake shoe	No	Yes
			Stones, rail tools and mechanisms	No	Partially
			Various items (boxes, wood boards and etc.)	No	No
6	The defects of infrastructure	Sun kink, a drawdown of the track, broken rails		No	Yes
		breakage, sagging of catenary		No	Yes
7	Natural phenomenon	Flooding of tracks, undermining of tracks		No	Yes
		Fire		No	Yes
		Snowdrift		No	Partially
		Landslide, mudflow		No	Yes

Fig. 1 RDŽ classification of obstacles for the obstacle detection system [4]

For a fully automated level GoA 4 train control system, the risks related to the obstacles defined in this way may not be sufficient. Therefore, within the SMART 2 project, more detailed operational requirements for the obstacle detection system were defined [8]. The two most related to the recognition of all necessary characteristics of the object that represent obstacles and determination of the associated risk levels are:

OR-RAM-04 - The OD&TID system shall provide the necessary data for train control/TMS systems to make a proper control decision to avoid collisions with objects/obstacles or restrict severity of collisions to the extent that the operational risk is assessed as acceptable.

OR-SS-02 - The system algorithm shall calculate the hazard rate associated with a detected object and communicate the hazard rate and detection information to other systems.

The operational requirements for the obstacle detection system defined in this way allow that with the GoA 4 level of automation, all risks associated with obstacles in the train path train can be successfully controlled.

3. Conclusion

The complete automation of railway traffic at the GoA4 level implies that many control functions previously carried out by people/engine drivers will be taken over by technical train control and management systems. To adequately define operational requirements for such systems, it is better to apply the so-called risk-based approach rather than the usual project-based approach. This is especially valid for the obstacle detection system because the correct way of reacting to the appearance of an obstacle depends not only on the obstacle type but also on the related risk for every specific case. In addition, the risk-based approach enables the assessment of requirements in terms of preventive action, i.e., potential obstacles, which is not the case in the so-called project approach.

REFERENCES

1. Hyde P., Ulianov C., Liu J., Banic M., Simonovic, M. and Ristic-Durrant, D., 2021. *Use cases for obstacle detection and track intrusion detection systems in the context of new generation of railway traffic management systems*. Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, p. 09544097211041020
2. P. Singh, M. A. Dulebenets, J. Pasha, E. D. R. S. Gonzalez, Y. -Y. Lau and R. Kampmann, 2021 "*Deployment of Autonomous Trains in Rail Transportation: Current Trends and Existing Challenges*" in IEEE Access, vol. 9, pp. 91427-91461, doi: 10.1109/ACCESS.2021.3091550.
3. https://smart2rail-project.net/, accessed on 24.10.2021
4. IRRB Webinar Autonomous Technologies in Rail – Anticipating Expectations, 2021, https://uic.org/events/spip.php?action=telecharger&arg=2513
5. Ristic-Durrant D.; Franke M.; Michels K. A., 2021 „*Review of Vision-Based On-Board Obstacle Detection and Distance Estimation in Railways*“. Sensors, 21, 3452. ttps://doi.org/10.3390/s21103452
6. U.S., Federal Railroad Administration, „*Florida's Train Whistle Ban*“, 2nd edition, September 1992
7. Rosic S., Stamenkovic D., Banic M., Simonovic M., Ristic-Durrant D., Ulianov C., 2022, *Analysis of the Safety Level of Obstacle Detection in Autonomous Railway Vehicles*, Acta Polytechnica Hungarica Vol. 19, No. 3, pp 187 – 205
8. D1.1. *Obstacle Detection System Requirements and Specifications*. SMART project. Published online 2017. http://smart.masfak.ni.ac.rs