



## WAYSIDE TRAIN MONITORING SYSTEMS FOR THE SECOND TRACK DIVAČA KOPER

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### Abstract

The ongoing construction of a second track between stations Divača and Koper in Slovenia will increase the capacity of this important railway link to the harbour in Koper. To ensure availability of the second track wayside train monitoring systems are a main contributor. Of course, prevention of incidents on this neuralgic section has highest priority. Therefore, checkpoints will be installed to check passing trains before they will enter the Divača-Koper line. Lessons learned from other comparable projects e.g. Gotthard Base Tunnel, Channel Tunnel and Koralm Tunnel were included in the choice of detectors as well as existing technologies were considered. Finally, the authors of this paper developed a proposal for company 2TDK to make sure that operational safety will be achieved by the right combination of various wayside train monitoring systems. Our approach combines detectors before trains enter the Divača-Koper line as well as derailment detectors and fire recognition on the line itself.

*Keywords: wayside train monitoring, railway tunnel safety, derailment detection*

### 1 Introduction

On 9 January 2023, the Directorate of the Republic of Slovenia for Infrastructure signed a contract for the implementation of the project “Installation of systems for detecting irregularities on railway vehicles on the public railway infrastructure”. The project execution period is 48 months from the date the Contractor was introduced to the works, which took place on 14 February 2023; consequently, the project completion deadline is 14 February 2027. The reason for implementing the project “Installation of systems for detecting irregularities on railway vehicles on the public railway infrastructure” lies in the fact that traffic safety on the public railway infrastructure is of key importance. Railway traffic safety can be ensured through monitoring both railway vehicles and infrastructure. Incidents and accidents limit access to railway services, endanger lives, and cause damage to property, as well as to railway infrastructure and rolling stock. Approximately 60% of railway incidents and accidents are caused by technical failures, and approximately 40% by non-compliance with safety regulations.

By using appropriate detection systems, the railway infrastructure manager can detect most vehicle irregularities that cause such incidents and accidents and can consequently take timely and appropriate action. For safe, accurate, and efficient monitoring of the railway rolling stock, an appropriate number of systems for detecting irregularities on railway vehicles must be installed at selected locations [1, 2]. Prior to the implementation of the project for installing detection systems on railway vehicles on the public railway infrastructure, five checkpoints were established across the entire public railway infrastructure network, at which seven detection systems were installed.

Within the project for installing systems for detecting irregularities on railway vehicles on the public railway infrastructure of the Republic of Slovenia, the installation of additional detector systems and the upgrading of individual detector assemblies is planned at 20 locations (checkpoints), using already existing checkpoint locations on the public railway infrastructure network. Fault reports (alarms and detector operational irregularities) and other measurement data will be transmitted to a central control location and to the alarm management and tracking system (CVP), where appropriate measures will be adopted depending on the type of alert.

With the introduction of detection systems across the entire public railway infrastructure and the comprehensive implementation of remote traffic control on the public railway infrastructure, a unified approach to system operation and reporting will be established from the perspective of safety and traffic management efficiency. As a result, a new Central Supervision System (CNS) will be established, with server components located at CVP Maribor and CVP Postojna, and operational access provided at CVP Maribor, CVP Ljubljana, and CVP Postojna. A dedicated monitoring center will be established for system supervision, located at the premises of the SVTK Office in Celje.

## **2 Wayside train monitoring systems in Slovenia**

Within the project “Installation of systems for detecting irregularities on railway vehicles on the public railway infrastructure”, the following detection systems will be installed on the public railway infrastructure:

### **2.1 Hot box, hot wheel and hot brake detection (HBD)**

The hot axle and hot wheel or brake detector (HBD) detects and enables the timely removal from service of all unsuitable trains where overheated brakes or wheels or hot axles could cause fire or damage to railway vehicles and consequently lead to extraordinary events. Today, detectors for axle bearing temperature, wheel temperature, and brake temperature are combined into a single device. Detection of overheated axle bearings as well as hot wheels and brakes is based on non-contact temperature measurement. Infra-red (IR) sensors measure temperature-dependent electromagnetic radiation emitted by all objects. Based on radiation intensity, the temperature of the object is calculated. For early fault detection, sensors must ensure high temperature measurement accuracy. The measuring device is installed in the track zone and measures the temperature of bearings, wheels, and brakes during train passage. If bearings, wheels, or brakes exceed predefined temperature thresholds, a corresponding alarm is generated via the reporting unit.

### **2.2 Damaged wheel detector (DWD)**

The damaged wheel detector must be capable of monitoring and assessing the condition of the wheel running surface, which must not contain flat spots, surface corrugation, metal build-up, or other material deposits. A second monitored parameter of the DWD system is the detection of possible geometric wheel deficiencies (out-of-round wheels, different wheel diameters within a wheel set, wheel mismatch). These defects cause increased peak wheel forces or a higher ratio between maximum and minimum wheel load, which the system must detect. If predefined threshold values are exceeded, the system generates an appropriate alarm via the reporting unit.

### **2.3 Wayside weighing system (WWS)**

The wayside weighing system verifies whether wagons are loaded in accordance with line load capacity and, if not, enables their timely removal from service. Overloaded wagons impose higher loads on railway infrastructure. As a consequence of higher mass, stronger braking is required, which results in increased sparking and a higher risk of fire. The dynamic trackside weighing system must be capable of measuring the static axle load of a vehicle based on the detection of dynamic forces exerted by the vehicle on the rail, and calculating axle load, vehicle weight, and train weight.

### **2.4 Clearance gauge detector (CGD)**

The clearance gauge detector (DPP) detects whether the load or the wagon itself complies with the clearance profile requirements ensured on the public railway infrastructure. The detector must be designed to detect all objects protruding beyond the reference clearance profile, regardless of train direction, while the train passes the detector location. If an object exceeding the clearance profile is detected, an appropriate alarm must be triggered.

### **2.5 Pantograph condition detector (PCD)**

The pantograph condition detector is used to diagnose all raised pantographs of railway vehicles in a train, in order to prevent continued operation of vehicles with damaged or improperly adjusted pantographs and to prevent disturbances and damage to the overhead contact line. The purpose of the DSP system is to generate an image and 3D reconstruction of pantograph passing the detector location, including all necessary measurements and diagnostic elements required to determine pantograph condition in accordance with prescribed parameters. If pantograph condition does not comply with technical standards, an appropriate alarm is generated.

### **2.6 Dragging equipment detector (DED)**

The dragging equipment detector is used to actively detect and alert operators to objects being dragged under trains during operation. Various components are typically mounted beneath wagons and may partially detach under certain conditions. For example, vibrations during train operation may cause air hoses, pipes, or other components to be dragged beneath the train without the driver's awareness. Such objects can damage railway infrastructure (rails, switches, sleepers, crossings, signaling and safety equipment) and, in extreme cases, cause derailment.

### **2.7 Vehicle identification system (VIS)**

The vehicle identification system (IDV) performs intelligent analysis and reads the registration number of each railway vehicle. By using radio-frequency identification (RFID), the system automatically identifies all types of railway vehicles with high reliability, at high speeds, and in demanding environments. The system consists of trackside RFID readers and ID tags installed on railway vehicles.

### 3 Proposal for additional monitoring systems for Divača-Koper

Checkpoints are currently planned at the following locations:

- CP Merče (km 674.780)
- CP Neverke (km 650.778)
- CP Sermin (between km 27.317 and km 27.562; micro-location not yet determined).

Based on the checkpoints defined within the project “Installation of systems for detecting irregularities on railway vehicles on the public railway infrastructure”, it is assessed that the KT Merče location is optimal for the needs of the second track Divača–Koper section. It should be highlighted that in certain European projects, the practice of installing redundant checkpoints is increasingly being applied in order to provide higher availability of monitoring systems. This approach is already used in the Austrian Koralm Tunnel as well as in the Swiss Gotthard Tunnel or in the Eurotunnel (GB-F).

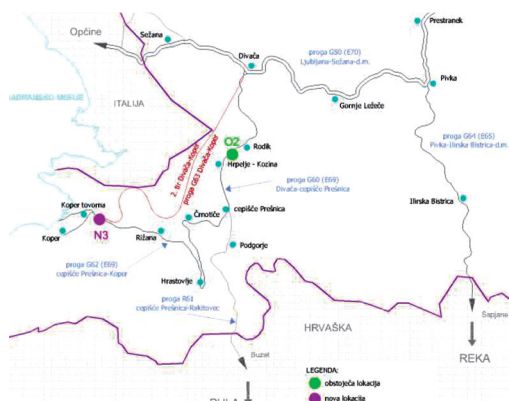


Figure 1 Locations of checkpoints around Divača-Koper

Based on the presented content, two proposed variants for upgrading checkpoints (CP) and introducing additional detection systems are presented to increase safety and operational availability on the new Divača–Koper line section [3]. Both variants also include proposals for additional systems for:

- derailment detection
- fire detection in tunnels and
- overheating monitoring (hot wheels or brakes and axle temperature).

Key features of variant 1 are:

- extension of CP Neverke by adding damaged wheel detector (DWD), wayside weighing system (WWS) and clearance gauge detector (CGD)
- extension of CP Sermin by adding hot box and hot wheel or brake detection (HBD) and dragging equipment detector (DED)
- CP Merče remains unchanged.

Key features of variant 2 are:

- establishment of a new checkpoint KT D. Ležeče (km 666.700) with the following systems: hot box and hot wheel or brake detection (HBD), damaged wheel detector (DWD), wayside weighing system (WWS) and clearance gauge detector (CGD)
- extension of CP Sermin by adding hot box and hot wheel or brake detection (HBD) and dragging equipment detector (DED)
- CP Merče and CP Neverke remain unchanged.

### 3.1 Additional systems for detecting irregularities

When train formations enter tunnels, where due to specific conditions such as reduced air flow, increased friction, and more intensive braking (e.g. towards Koper), it is advisable to appropriately inspect the condition of vehicles and loads before entering the tunnel, and if necessary, also within the tunnel. From the perspective of infrastructure management, a dangerous situation arises if a burning train does not stop before the tunnel. To prevent such situations, it is necessary to prevent potentially dangerous trains from continuing their journey or to prevent their entry into the tunnel. In addition to the detection systems already described for detecting irregularities, the following additional systems are proposed:

- derailment detectors
- detection system for chemical substances and fire in tunnels
- hot wheel or brake detection.

For the installation of additional derailment detection systems, the following is proposed:

- installation of a derailment detector at the beginning of the line, at approximately km 1.320 (figure 1), before the first tunnel in the Divača–Koper direction, serving as a preventive filter
- inspection of trains before entering the tunnel complex, enabling early detection of trains with technical defects before they reach critical sections
- rapid detection of derailments and limitation of consequences reduces the extent of potential damage and lowers the risk of fire
- integration with the control center is necessary so that detected irregularities automatically trigger actions such as: stopping the train, speed restrictions, or traffic rerouting
- data from checkpoints enable better planning of rolling stock maintenance and assessment of loading on the new line, which in the long term reduces costs.

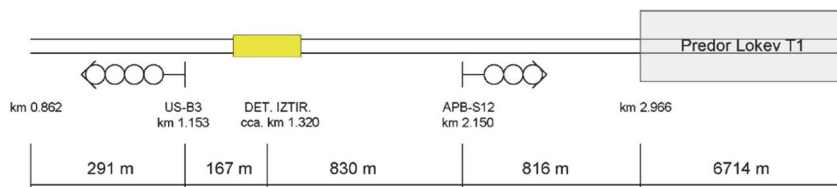
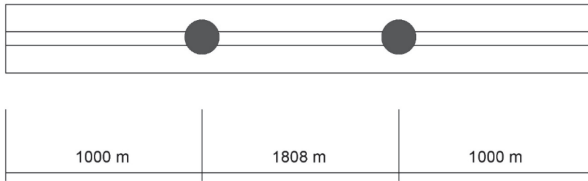


Figure 2 Proposed installation location of a derailment detector

The chemistry and fire detection system operates based on precisely defined parameters. The proposed installation on the new second track Divača–Koper line is as follows:

- installation location: Škofije Tunnel T8 (figure 2)
- the chemical and fire detection system consists of two identical measuring units, installed at appropriate locations within the tunnel
- measurement locations: exclusively inside the tunnel (external environment is not suitable due to unstable airflow)
- detector installation: at least 300 m from the tunnel entrance or exit, which reduces the influence of external disturbances
- minimum tunnel length for system application: 1, 000 m – the model is developed for longer tunnels
- distance between detectors: between 300 m and 1, 000 m, depending on the required localisation accuracy
- alarm triggering delay: 30–40 seconds after exceeding the alarm threshold on two consecutive measuring units, which prevents false alarms and increases detection reliability.



**Figure 3** Proposed installation of fire and chemical detection system in tunnels

The system is particularly suitable for long tunnels, where early measurements can significantly reduce the risk of fire or the release of hazardous gases. On open railway sections, the system is not implemented. The hot wheel or brake detection is proposed at the following locations:

- CP D. Ležeče (before Divača): installation of detectors for trains arriving from Ljubljana, before entering the second track section. This location enables early inspection of train formations before entering tunnels
- Črni Kal area (before the viaduct and railway station): possible additional installation of detectors due to the transition from tunnel sections to open environment, where temperature differences may occur
- CP Sermin: installation at the exit of the last tunnel and before arrival in the coastal area. This is a key checkpoint for inspecting train formations before entering the port terminal.

With the proposed detector placement, optimal monitoring of temperature along the entire new line section is achieved. Locations are selected to ensure early detection of issues (before tunnel entry), enable monitoring on critical gradient sections (before and after long tunnels), and ensure control before Koper, where freight traffic is directed into the port area.

## 4 Conclusion

Based on the conducted analysis, it is proposed to upgrade checkpoint Sermin and to upgrade checkpoint Neverke before Divača railway station. This will enable inspection of train formations arriving from Ljubljana in the direction of Divača and potential continuation of their journey onto the second track Divača–Koper. In addition, the installation of derailment detectors, brake temperature detection systems, and systems for early detection of hazardous gases and fire in tunnels is proposed, as these systems enable early recognition of critical events with a high level of risk to passengers, infrastructure, and the environment. Their implementation substantially improves response capabilities, increases operational reliability of the railway system, and reduces the risk of long-term traffic disruptions. Among the key advantages of such a solution are reduced costs of emergency interventions and maintenance, extended service life of infrastructure, and increased confidence of users and operators in the safety of railway traffic. In this way, the upgraded detection system not only ensures compliance with modern safety standards but also represents an important contribution to the sustainable and reliable operation of the new railway connection.

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## RAILWAY TRACK MATERIALS, PERFORMANCE AND NUMERICAL MODELLING

