Checkpoint systems and their integration into solid state interlockings for automatic train supervision

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SUMMARY

The introduction of the new ÖBB management operation system has to result in an increase in reliability and quality. At the same time, operational costs are to be reduced. These goals can only be achieved by concentrating the responsible staff on a few locations. Consequently, the traditional train supervision has to be replaced by a technical solution, the so-called Checkpoints. Checkpoints can be defined as trackside locations where trains are examined to detect any deviation from nominal condition. In February 2003, the project "Checkpoint systems and their integration into solid state interlockings for automatic train supervision" was officially started. It is supported by the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit). In autumn 2004, the Checkpoint prototype has gone into operation on the railway line between Vienna and the Austrian-Hungarian border.

1. MOTIVATION

As a result of the ongoing reduction of station inspectors, the railway system has lost a decisive link of well-established organisational and technical processes. The consequences of this development were mitigated against by the introduction of technical solutions. The new processes are subsequently less labour-intensive and more efficient. The role of the traditional train supervision is, however, a good example to demonstrate that technical solutions, currently available on the market, do not provide the whole solution (Figure 1).

Figure 1: Traditional train supervision

Originally, station inspectors were not the only employees among those responsible for the operation of trains who had to deal with train supervision. Interlocking, block and/or level-crossing attendants had to monitor the condition of the rolling stock, too. The locations for this task had been defined alternately, thus enabling train supervision to be carried out on both sides of the track. The disappearance of mechanical signalling equipment led first to a reduction of posts for the supervision of trains. Technological progress resulted in a further acceleration of this trend. By introducing management operation systems, the network of posts to observe trains, which was initially very dense, was reduced again.

Due to the gradual implementation of this strategy, aiming at a higher productivity, manual train supervision will not exist in the near future. Therefore, this task has to be taken over by technical systems. With regard to their future locations, there is a choice of two concepts:

1. Whenever traditional train supervision is to be replaced, a technical equivalent has to be installed.
2. The number of locations and/or systems necessary for conducting train supervision can be optimised provided that they are based on cost-benefit-considerations. In this case, the number of locations should be lower.

An approach for the second concept has been developed within the framework of a thesis submitted at the department of Railway Engineering, Traffic Economics and Ropeways at the Vienna University of Technology[1)]. First evaluations for the core network of the ÖBB have shown that potential risks can be reduced to such an extent that the safety level is not affected and the expenditure for replacing the traditional train supervision by sensor components is not too high.

Technical systems for automatic train supervision are able to check both sides of the train at the same time. Their locations do not have to be set up according to the original locations for traditional train supervision. These advantages will result in a lower number of locations needed for automatic train supervision. In addition to that, the technical systems used for automatic train supervision are able to detect faulty conditions of the rolling-stock which can not be discovered even by well-trained station inspectors. Therefore, these technical systems are very important with regard to early accident identification and will bring about higher productivities, too.

2. SENSOR COMPONENTS

Checkpoints can be defined as trackside locations containing an accumulation of technical systems, which are required to enable the substitution of the traditional train supervision. From today's point of view, seven sensors are needed for this task. They can be divided into two groups: Damage-reducing and/or event-avoiding systems. For both groups, all environmental requirements have to be met taking into consideration that these systems will be passed by trains with a speed of up to 250 km/h. Even under harsh environmental conditions, these systems have to supply reliable information regarding the train state. In addition to that, all data collected must be processed in the shortest time possible by using appropriate tools for analysis.

Figure 2 (left): Dynamic scale at the Checkpoint prototype. Manufacturer: SCHENCK PROCESS GmbH, Darmstadt (Germany). Figure 3 (right): Dynamic scale at the Checkpoint prototype. Manufacturer: Hottinger Baldwin Messtechnik GmbH, Vienna (Austria), on behalf of ÖBB Infrastruktur Bau AG, Vienna (Austria).

Several dynamic scales are currently passing the transition phase from a prototype development to a series production (Figures 2 and 3). As a rule, these systems obtain the necessary data from strain gauges, which are positioned either on the rail or in the sleeper. Their distortion can be used for the calculation of the rolling-stock's weight and/or the detection of displaced cargo. Moreover, certain dynamic scales can detect flat wheels and various other irregularities in the contact area of wheel and rail. Hot box detection systems, including an add-on for stuck and/or disc brake detection, were installed on a large proportion of the Austrian high-level network during the last few years (Figure 4). The system used can measure the temperatures of wheels, disc brakes and wheel bearings by means of infrared sensors. These installations are to be integrated into the Checkpoint concept, as well as already existing train gauge monitoring systems. Objects exceeding the train gauge profile are detected by optical measuring systems (Figure 5).

[1)] Schöbel, A.: Zur Frage der Standortwahl von Zuglaufüberwachungseinichtungen. Thesis. Institute of Railway Engineering, Traffic Economics and Ropeways, Vienna University of Technology, 2005.

Figure 4 (left): Hot box detection system at the Checkpoint prototype. Manufacturer: ÖBB Infrastruktur Betrieb AG, Vienna (Austria). Figure 5 (right): Train gauge monitoring system at the Checkpoint prototype. Manufacturer: ASE Industry Services AG, Bruchsal (Germany), on behalf of ÖBB infrastructure Bau AG, Vienna (Austria).

Manual inspection of halted trains is facilitated when surveillance cameras are available along track sections dedicated for the processing of alarms. Derailment detectors are required in particular in front of sections comprising tunnels or other dangerous elements of the infrastructure. Systems for the detection of fire are to be used, too. But they have to be mounted outside tunnels. Due to the fact that there are currently no marketable solutions for derailment detectors and systems for the detection of fire, they are subject to a separate R&D-project.

Sensor systems for the detection of fire are a good example of the fact that for the identification of certain irregularities onboard solutions are more effective, especially when it comes to passenger safety. In spite of these advantages, a trackside approach is preferred because a full Checkpoint network can be established more easily than equipping all units of the rolling-stock with the necessary sensors. The large number of wagons and locos – in Europe, there are more than half a million – and a rather complicated installation procedure are the main reasons for this commitment. Onboard solutions have an additional disadvantage. Infrastructure operators would be obliged to check not only the existence, but also the operational status of the sensor systems. To fulfil this task with reasonable funds it would be necessary to elaborate and publish standards, which have to be valid throughout Europe. At the moment, such a document is not in sight.

If sensor components are positioned where the necessary data can be obtained very easily, the result will be a mixed system, which would increase the complexity of integrating the relevant information into existing data networks. This risk is clearly lower in case of a pure trackside solution. All investment can be assigned to the infrastructure operator. The costs for purchasing and/or maintaining the Checkpoints have an influence on the calculation of the track access charge. This fee has to be paid by the railway operators who will benefit from an increased availability of the network and the opportunity of simple data procurement. Nevertheless, the use of onboard sensor systems is appreciated provided that they bring additional safety for passengers and cargo.

3. THE TECHNICAL CHECKPOINT CONCEPT

Hot box detections systems can be considered as the Checkpoints' ancestor. With regard to its technical implementation they vary in three essential issues from a full Checkpoint system for automatic train supervision.

1. The collected data is – lacking additional technical systems – not linked to the data of other sensor components.
2. Hot box detection systems are in fact connected to a central unit, but there is no sub-system supervising the evolution of temperatures over several Checkpoints.
3. Currently, an alarm is simply visualised on the so-called operational level. The necessary actions have to be taken by the station inspector manually. By strictly following given instructions, it might be possible that considerable delays will arise. They can be avoided by automatically forwarding alarms to control systems and/or solid state interlockings.

The technical Checkpoint project takes into consideration all three of the above-mentioned issues.

3.1 Conjunction Of Sensor Data

Each sensor system is used for the supervision of one or several train conditions. The significance of a single measurement can be increased by the conjunction of collected data. The average temperature of an intact wheel bearing is, for instance, related to the wheel load. In case the wheel load is high, a higher average temperature of the bearing and/or a faster increase of it have to be assumed. To avoid misjudgements of the actual bearing's condition, this physical correlation can be shown by calculating and evaluating a weight-compensated bearing's temperature. This means that stricter limits will be applied to bearings with low wheel loads. Consequently, the contrary will be carried out if the wheel load is high.

The core of each Checkpoint is the so-called data concentrator. A dedicated software package is available for the above-mentioned functionality. Data, which are transmitted from sensor components to the data concentrator after passage of a train, are converted into a uniform format. If necessary, additional sensor and/or environmental information are added. In doing so, abstract data objects are generated. Together with positioning data, they are displayed onto the train model, which serves as the basis for data conjunction. Then the results are compared with rules. In case a threshold is exceeded, actions defined by the infrastructure operator have to be set. The range of alternatives comprises a short message to the owner of the rolling stock, but also a signal showing a stop indication. This step can only be executed by means of the control system and/or the solid state interlocking. Assuming that a single sensor registers the exceeding of a threshold, the whole procedure will then be shortened. In this case, immediate measures are initiated.

3.2 Networked Checkpoints

In contrast to solid state interlockings, all sensor components mentioned in section 2 do not achieve the necessary reliability values. This shortcoming can be compensated by redundant or diverse measurements. An increase in data quality and an early detection of faulty conditions can be achieved by networking the various Checkpoints, too. In this case, all data concentrators are directly linked to the Checkpoint centre. There, important data of trains are analysed and stored whereas current and already finalised train routes are distinguished. The advantages of networked Checkpoints are obvious.

1. The technical Checkpoint concept is highly modular. Based on cost-benefit-considerations, the range of sensor components can vary from one Checkpoint location to another. Therefore, new or additional sensors can easily be integrated into the already existing structure. The same applies to data of virtual sensors. Assuming that Checkpoint B has no dynamic scale, data, which was collected at Checkpoint A, can be transmitted to the data concentrator of Checkpoint B via the Checkpoint centre. At Checkpoint B, this data can be used for conjunctions, too. This feature is limited to values, which are subject to no or not more than small changes, only (e. g. the weight of the rolling-stock).

2. Trend analysis is another feature of networked Checkpoints. On the one hand, critical situations can be detected at an early stage. This target can be achieved by supervising the evolution of important measured characteristics of a train while passing the infrastructure's network. On the other hand, these analyses enable a check to be made of the plausibility of data by comparing single measurements with the appropriate series.

3. In contrast to decentralised single systems, networked Checkpoints have a big advantage. The status of all data concentrators and their connected sensor components is permanently supervised. In case of troubles and/or failures, short messages are generated and automatically sent from the Checkpoint centre to the central trouble management system. The latter is responsible for arranging and managing all measures, which are required for the removal of the problems.

4. There are various other reasons for justifying networked Checkpoints. Software updates and the use of the collected data for the calculation of track access charges are considered to be another two important examples but they will not be discussed in this paper.

3.3 The Integration Into The Control System And/Or Solid State Interlockings

When finalising the introduction of management operation systems and using sensor components for the supervision of rolling-stock, a small number of station inspectors will be responsible for a relatively large number of data concentrators. The idea of visualising alarms via the control system is rejected by the infrastructure operator. During peak time, it might be possible that the necessary measures cannot be initiated on time. Therefore, the integration of Checkpoints into the control system and/or solid state interlockings is a very important goal.

Alarms requiring rapid intervention are transmitted from the data concentrator directly to the control system. In certain cases, these alarms can prevent the automatic continuation of the route setting. After the train has stopped, the station inspector will decide on the measures to be taken. Given that the train gauge has been exceeded, this procedure applies to possible oncoming trains, too.

All used sensor components have to meet the requirements set by the infrastructure operator. This is a prerequisite for a successful integration of Checkpoints into the control system and/or into solid state interlockings. Problems with railway operators have to be expected in case the number of failures is too high or alarms not being registered correctly lead to accidents. Events like these will result in a critical analysis of the investment. Therefore, as a first step, all alarms are to be displayed on the operational level. The development of the data concentrator is clearly orientated to the integration of Checkpoints into the control system and/or into solid state interlocking. This target is to be achieved as a second step (Figure 6).

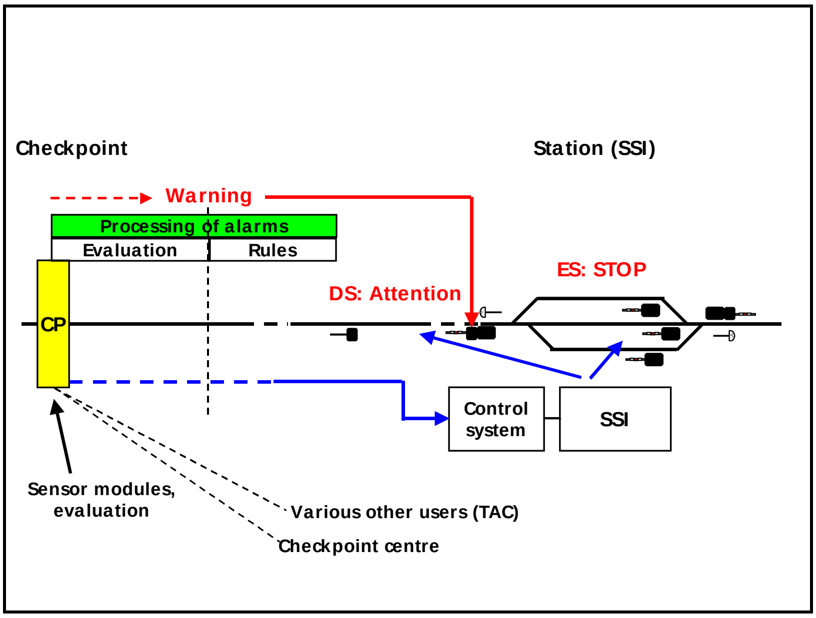

Figure 6: Technical Checkpoint concept: Integration into the control system and/or into solid state interlocking.

4. THE PROJECT

The implementation of this project, which is supported by various R&D-programmes of the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit), was started in February 2003. The project team comprises employees of Alcatel Austria AG, the ÖBB Infrastruktur Betrieb AG, the Institute of Electrical Measurement and Circuit Design and the Institute of Railway Engineering, Traffic Management and Ropeways. Both institutes are located at the Vienna University of Technologoy. In autumn 2004, the Checkpoint prototype was put into operation between Vienna and the Austrian-Hungarian-border. All sensor components, which were introduced in section 2, are subject to a 12 months test programme. The emphasis is put on the interaction of the various sensors and their reactions under a wide range of different climatic conditions.

Figure 7: Test train on May 10th, 2005 at the Checkpoint prototype: System for monitoring the train gauge and for the detection of fire.

For this programme, ÖBB has provided a test train. Its wagons have defined faulty conditions (Figure 7). In addition to that, the data of all regular trains are processed. After a sufficient level of calibration has been achieved, regular trains will be stopped to verify the faulty conditions. This task will be carried out by employees of the ÖBB responsible for the rolling-stock. Cargo trains will have a dedicated area at the central shunting station east of Vienna. Faulty conditions on passenger trains will be checked either at Vienna west or south station. The development of sensors for the detection of fire and derailed wagons is driven forward in a parallel project by using synergies.

The results, which will be available in spring 2006, play an essential role for the evaluation of the sensor components. The findings are considered to be an important source of information for the planned product development. Thereafter, a marketable solution should be possible.

5. CONCLUSIONS

Comparing Checkpoint systems with traditional train supervision, the technical solution provides a number of benefits.

1. In contrast to all employees involved in train supervision, sensor systems are able to check both sides of the train at the same time.

2. As result of their functionality, Checkpoints do not have to be set up according to the original locations for traditional train supervision.

3. Certain sensors used in the project are able to detect faulty conditions of the rolling-stock which cannot be discovered even by well-trained station inspectors.

The positive impact on the Quality of Service (QoS) concerning the rail network of a particular infrastructure operator is obvious:

1. In the long run, the availability of the rail network will increase as a result of earlier identification and/or elimination of damaged rolling-stock. Assuming that there will be no train supervision at all under the current circumstances, the number of accidents will probably rise. In addition to that, there will be more units of rolling-stock in operation causing damage to the track by various irregularities. Consequently, the number of slots, which can be sold to railway undertakings, will decrease due to constant construction work. An increase in the network's availability can only be achieved provided that the reliability and availability figures of the sensor systems used meet the requirements of the infrastructure operators. This applies in particular to the number of false and/or undetected alarms. Having achieved this target, Checkpoints can then be integrated into solid state interlockings to reduce the processing time of alarms.

2. A lot of data collected by sensor components can serve as the basis for calculating a fair and transparent train access charge. In contrast to the current price regime, infrastructure operators will then possess the necessary data to introduce the polluter-pays-principle. They can charge for damage caused to the track but also earn additional income, which is currently not paid by railway undertakings due to wrong declarations. The whole business case improves considerably by taking into consideration the possibility that certain data can also be sold (e. g. railway undertakings, rolling-stock lenders, etc.).

As a result of this perspective, Checkpoint systems are urgently required by infrastructure operators. There is no doubt about it that they will form an integral part of a modern railway infrastructure in the foreseeable future. In Europe, the first invitations to tender, in which Checkpoint systems have to be quoted, are expected to arrive in the next few months.