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APPROACH FOR MONITORING OPERATIONAL SAFETY

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Abstract: *This paper deals with the results from a national founded project in Austria. Aim of this project was to describe the complex dependencies in the field of railway safety from a technical point of view in a simplified way for practical usage of infrastructure managers and railway undertakings in their safety management system (SMS).*
Key words*: *cause-consequence-analysis, operational safety, wayside train monitoring

INTRODUCTION

In railway systems, there are many different fault states which can occur during operation. For safety reasons, these well known fault states have to be prevented by train monitoring. But fault states may also have dependencies among each other, which are not sufficiently known yet or used for fault state prevention. Thus, in a first step an abstract approach has been developed for the description of dependencies. Based on this and as systematic description of all relevant states and their dependencies a fault state matrix has been created, which is considered in this paper.

The railway system has a lot of dependencies between different fault states. In general, faults state can lead to another fault state which might be worse than the one before. Thus, in an abstract approach fault states can be interpreted as causes and the resulting fault states can be interpreted as consequences (Figure 1).

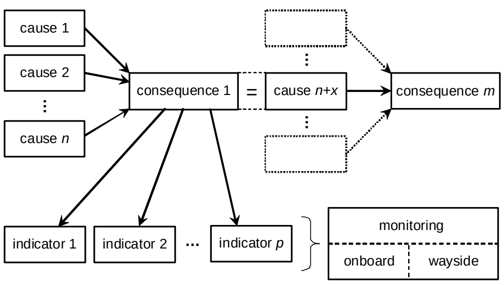

Fig. 1 Abstract approach of causeand consequence relation

If there are no measures for recognition, the final consequence of many fault states is a derailment. Therefore it is necessary to prevent the long-lasting occurrence of all critical fault states. Because of the movement of the train, most of the relevant fault states can not be observed directly. Thus, suitable indicators have to be measured, which can be done by onboard or wayside monitoring systems.

FAULT STATE MATRIX

Based upon this abstract approach a matrix was created to point out the dependencies in a customer-friendly way (Figure 2). For each fault state a description was developed accordingly to UIC dictionary. Some examples are listed below [1]:

Derailment (1): A derailment of an axle or of the whole bogie often takes place in the marshalling yards. Generally such derailments are quickly detected by railway staff and the resulting damage of the infrastructure is low. But on the free line, a derailment stays often unrecognized over several kilometers, because drivers have no possibility to detect this fault state. In such cases, the consequences are an enormous damage of the superstructure and extremely high repair costs.

Hot Box (2): As the result of missing lubrication or of mechanical damage of parts of an axle bearing, the increased friction heats the bearing during the drive. Hence, a good and proven

	Cause \ Consequence	Derailment	Hot Box	Blocked Brake or Wheel	Faulty Flash Guard	Faulty Elements of Brake System	Broken Axle	Breakage of Stub Shaft	Broken Wheel	Faulty Running Surface / Wheel Spot	Faulty Flange of Wheel
1	Derailment						1		2		3
2	Hot Box							9			
3	Blocked Brake or Wheel	11							12		
4	Faulty Flash Guard										
5	Faulty Elements of Brake System			15							
6	Broken Axle	16									
7	Breakage of Stub Shaft	17									
8	Broken Wheel	18									
9	Faulty Running Surface / Wheel Spot						19		20		
10	Faulty Flange of Wheel	22									
11	Faulty Suspension and -component	23					24				
12	Faulty Frame	26					27				
13	Unbalance (during vehicle´s run)	28									
14	Displacement of the Load										
15	Overload (continuous)						32		33	34	3
16	Violation of Clearance Gauge	40									
17	Faulty Car Opening (Doors, Loading Trap, etc.)										
18	Faulty Load Fixation and Fastener										
19	Insufficient Lubrication of Buffers										
20	Faulty Buffer	49									
21	Overriding of Buffers	52									
22	Faulty Electrical Car Equipment										
23	Broken Pantograph										
24	Fire on/in board										
25	Objects within the Clearance Gauge	54									
26	Enlarged Width of the Track Gauge	55									
27	Track Distortion	56									
28	Faulty Rail Surface									57	5
29	Faults inside Rail										
30	Worn Rail										
31	Aged Rail Material										
32	Broken Rail	66								67	6
33	Faulty Elastic Rail Pad										
34	Faulty Rail Fastening / Ironmongery										
35	Aged Timber Sleeper										
36	Cracks in Concrete Sleeper										
37	Insufficient Track Bed	73									

Fig. 2 Cause-Consequence-Matrix

indicator for damaged bearing during the run of a train is the temperature of the box itself.

Blocked Brake or Wheel (3): Due to failures in the control value of the pneumatically driven brake system, the brake shoes or blocks of an axle may not release. Mostly, the friction is not high enough to block the whole axle. Hence, there will be a continuous heating of the brake discs (for disc brake systems) or of the wheel (for block brake systems). Moreover, the blocked brakes can cause fires in the bogie construction due to sparks. These sparks can also enkindle vegetation besides railway lines. In the residual cases of massive friction the axle won't rotate and will sliding on the rails.

Broken axle (6), *Breakage of Stub Shaft* (7): There can be two types of broken axles identified. A cold axle breakage is influenced by metallurgic reasons (material defects, etc.). In contrast to the cold type, if there is a massive heat exposure, the properties of the material can be affected negatively. In combination with high mechanical stress, such a weakened axle can break (warm axle breakage). In both cases the guidance property, which is obligatory for rail-bound traffic, is lost.

Faulty Running surface / Wheel spot (9): The term defects describe many different irregularities, which can occur on the running surface of a wheel. For instance, flat spots are flattenings of the round wheel, whereas reweldings are similar to little metal bumps. Beside there are out-of-roundnesses, and material eruptions. All lead to short force peaks with increased amplitudes during the run of the train and effect additional stress in the rail and in the wheel. Thus, such wheels can damage the rail and should therefore be rejected.

Violation of Clearance Gauge (16): The risky situation of clearance profile exceedings can be divided into three categories: if the exceeding is on the outer side, a collision with pylons for overhead contact wire is possible. If the exceeding is on the inner side on a double track section, there is a higher risk of crashing with other trains or with signal posts. If the exceeding is above, flashovers from contact wire may take place.

For the conceptual design of the inspection system it is important to know, what kind of elements will be expected to exceed the clearance profile. Besides massive exceedings done by displaced cargo or by derailed wagons, which do not require fast or sensitive measuring, also loose fastener of cargo can exceed the clearance gauge. Another low-loader wagon specific problem of clearance gauge violation concerns truck antennas. In detail, low-loader wagons offer the transportation of trucks on railways. A well-known operational problem of low-loader wagons are modern radios in the trucks. To gain good reception, radio antennas are extending autonomously during the transportation on the low-loader wagons. Due to the fact, that in tunnels the contact wires are lowered, the possibility of flashovers is rising significantly. For detection of such small exceedings, appropriate measurement principles and sensors have to be used.

For the reasons of the analysis and the validation of the supposed logical connections between different safety related fault events and states in the railways, a network of technical train monitoring components must exist. The data acquisition can be done on the vehicle-side or wayside or both together. The key issue by the observations is the evaluation of the proper correlation of the collected data (allocation of fault state to vehicle number). If this practical problem can be solved, a huge database of monitored parameters and therefore of particular detailed information about important fault states and events will be available.

IMPLEMENTION

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 compensated 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.

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:

Whenever traditional train supervision is to be replaced, a technical equivalent has to be installed.

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. The application 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. 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 [2].

Based upon the experiences on wayside train monitoring which ÖBB made since the prototype of a checkpoint solution was installed in their network in the year 2003, this topic became part of the collaboration memorandum between NRIC and ÖBB.

For NRIC three major fault states were identified and therefore they have to be monitored by some equipment:

- Overload
- Wheel unloading
- Faulty boxes

After the identification of risks caused by car related fault states and the general check for the economic feasibility risk reducing measures have to be designed. Fundamental risk reducing measures can be divided by functionality:

- Event-avoiding
- Damage-reducing
- Rescue-supporting

Event-avoiding measures aim of preventing hazardous events. Important here is the coordination of the responsibilities of railway undertakings and infrastructure managers. But it is not possible to reach sufficient protection by preventative measures only, because it will not be financially feasible. Therefore damage-reducing measures also have to be planned, to minimise loss in case of an accident.

After one accident has happened, rescue measures become important for saving people. Wayside train monitoring systems are related to the event-avoiding and damage-reducing sector of risk reducing measures.

For the three mentioned fault states the requirements were defined in the last workshop which can be used to prepare a tender. Basic requirements are:

- Costs (purchase, installation, maintenance)
- Availability, reliability
- Allowed passing speed
- Car identification
- Accuracy
- Applicable on different superstructures
- Short evaluation time

To share the experience on wayside train monitoring between NRIC and ÖBB components provided by ÖBB have been offered to NRIC which shall prevent accidents caused by car related fault states identified as critical for the Bulgarian infrastructure manager.

Fig. 3 Test installation at Zimnitsa

OUTLOOK

In the last years several sensor systems were developed to detect fault states. A disadvantage of such monitoring solutions is their design as stand-alone system. Furthermore, most of them do not provide interfaces to other systems respectively customer-specific interfaces. So if these systems shall be integrated into a higher-level system, first new interfaces have to be designed.

Based upon this situation an Austrian project was founded to create a concept for an overall system. One design criteria was the ability to integrate different existing sensor systems for monitoring all kind of potential fault states on a moving train. In detail a generic interface was designed to allow communication with different types of sensors. The specification of this interface is free available and can be used by any manufacture of sensor systems to forward measured data to the Checkpoint. Thereby the problem of different stand-alone systems without appropriate communication capabilities could be solved.

For the network of Austrian Railways the installation of a Checkpoint network until 2013 is planned. This network consists of Checkpoint concentrators along the tracks and a so called Checkpoint Master Node which is the centre of all wayside systems. This situation is the base for all subsequent considerations.

In countries without any systems for automated train monitoring, it will be quite simple to define specifications for the interfaces to a Checkpoint network. But if there are already some systems installed, three scenarios can be designed, which refer to the level of IT in the neighbouring network. In case of having stand-alone systems for train monitoring, it will be straightforward to extend such a system with suitable network capabilities. But if there is already an existing network of sensors, which is not equal to the Austrian Checkpoint-solution, properties and degree of usability of existing or planned interfaces have to be determined. Based upon this task generic interfaces have to be designed. The third scenario deals with existing systems with architectures, which look like those of the Checkpoint system. In this case there is only the need for an extension of a further interface according to available system architecture specification.

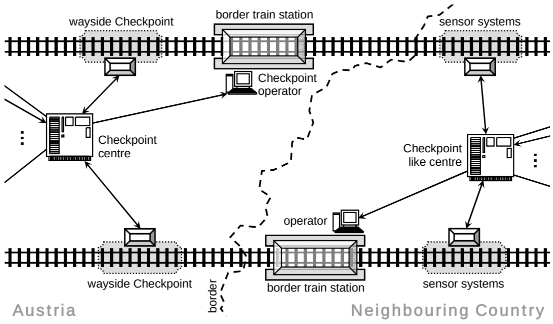

Fig. 4 Cross border data exchange on wayside train monitoring systems

The improvement of cross-border railway traffic is one of the most important tasks to be done in the new member states of the European Union. Thereby the quality of service on corridors should be increased by enhancing the quality of service and shortening the average dwell time at border stations.

The presented approach allows in case of realisation a more efficient fault state monitoring of cross-border railway traffic by shared use of data. This results in a reduction of costs due to lowered efforts for system installation and maintenance.

Independently from the level of installed components for monitoring and because of the absence of fault state information of entering trains at border crossing, manual inspection has to be done at border stations by examiners. Thus, presented approach allows saving further costs for operation as a result a reduction of staff for such inspections.

Due to the loss of human inspections, the efficiency of operational handling of trains will increase, because without dwell times a higher operational capacity can be achieved. Moreover, with an interoperable train monitoring system, wagons with fault states can be identified before arriving border stations. Thus the detachment of such wagons can be better prepared and the resulting delay can be reduced.

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ПОДХОД ЗА УПРАВЛЕНИЕ НА БЕЗОПАСНОСТТА ПРИ ЕКСПЛОАТАЦИЯ

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АВСТРИЯ

Ключови думи: *експлоатационна безопасност, състояния на неизправност, функционални вериги, управление, системи от датчици*

Анотация: *Настоящата статия разглежда резултатите на австрийски проект с вътрешно финансиране. Целта на проекта е да опише в опростен вид сложните зависимости в областта на железопътната безопасност от техническа гледна точка за практическите цели на инфраструктурните мениджъри и железопътните предприятия в системата им за управление на безопасността.*