SAFETY STANDARDS OF MODERN RAILWAY LINES IN EUROPA – DECISION MAKING WITH RISK-BASED APPROACH

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ABSTRACT

The proposed presentation begins by discussing two different major European rail accidents from recent years, underscoring the importance of a continued focus on safety. Subsequently, European efforts towards establishing common safety standards for the entire continent are discussed. The presentation concludes by using the specific situation on Austrian railways as an example for state-of-the-art safety measures.

Despite the mentioned accidents, railway is by far the safest means of transport in Europe. The number of fatalities per passenger and kilometre is in fact 20 times lower than for road users. Besides, the annual number of train accidents is steadily declining (70 % decrease between 2004 and 2011). The presentation will address the work of the European Railway Agency, which was established in order to draw up a common European railway safety concept (Directive on Safety on the Community’s railways 2004/49/EC) and common Technical Specifications for Interoperability (TSI) including a unified train control system (ERMTS). Moreover, a set of Common Safety Methods (CSM) was developed.

In Austria, it is the declared goal to continuously reduce the probability of train accidents. For this purpose, certain installation and infrastructure measures are applied to the entire network. The presentation will cover a number of these measures, including train control systems (new ETCS Level 2 vs. old control systems), hot-axle-box detection identifying defunct carriages, maintenance schemes and tunnel safety.

Keywords: Train accidents, railway safety, risk-based approach, risk assessment models, risk-based decision-making

1. EXAMPLES OF RAILWAY ACCIDENTS

1.1 Derailment at Santiago de Compostela 2013

In the summer of 2013 a very grave train accident occurred near the Spanish town of Santiago de Compostela. A high-speed train derailed on a bend about 3 kilometres outside of the train station at Santiago de Compostela. 79 people died and more than 140 persons were injured.

<u>Circumstances of the accident:</u>
Shortly before the accident the train driver took a call on his mobile phone from the train attendant while the train was travelling at 200 km/h. Almost simultaneously he received the acoustic signal that the new high-speed track section was joining the old conventional section and that, according to specific rail instructions, the train had to be slowed down to a speed of 80 km/h before passing the main signal. Distracted by the telephone call, the train driver failed to brake in time and the train derailed at the start of the tight "A-Grandeira curve", travelling at a speed of 180 km/h.

Tragic background – in the call, the train attendant asked the train driver to take the train to a platform at the next train station where it would be easier for a family travelling with children to get off the train. But train drivers are only permitted to make telephone calls in emergencies.

Figure 1: Derailment at Santiago de Compostela

<u>Cause of the accident:</u>
The railway line between Ourense and Santiago de Compostela is designed as a high-speed route almost over its entirety and is equipped with the European Train Control System ETCS Level 1, which ensures that the permitted velocities are not exceeded, regardless of signal intervals. On the last kilometres, the new high-speed stretch joins the old track section. From this point on, the line is equipped with an older, inductive train control system where the train driver has to brake manually to the posted speed before passing the main signal. The accident occurred exactly at the interface between to different train control systems due to human error of the train driver.

<u>Consequences:</u>
As a consequence the Spanish railway company RENFE revised the communication rules for the train drivers in the driver's cabin, the control centres and the train crew as well as for any other

calls. In addition, a new balise was installed 5 km before the slow-speed stretch, in order to ensure that the maximum posted speed is not exceeded, if necessary by forced braking.

1.2 ICE Derailment and crash into bridge in Eschede 1998

In 1998, the community of Eschede in Germany was the site of the most disastrous train accident in the history of the Federal Republic of Germany at the time. The derailment of the ICE train resulted in the death of 101 people, and 88 people were seriously injured.

Circumstances of the accident:
The ICE was travelling at about 200 km/h some 6 km outside the village of Eschede, when a steel tyre on a wheel of the first carriage broke on account of material fatigue. At the first of two consecutive switches, about 200 m before a road bridge, the loose wheel sets derailed. At the second switch the entire train derailed and the carriages were twisted perpendicular to the rails, sending the carriages careening into the pylons of the road overpass, causing its collapse. The subsequent carriages jack-knifed into the collapsed bridge in a zigzag pattern.

Figure 2: Derailment / crash into bridge – Eschede

Cause of the accident:
As the original monoblock wheels of ICE type 1 began showing metal fatigue relatively quickly, in 1991 it was decided to test rubber-cushioned wheels. After only a brief testing phase it was decided to introduce the new type of wheels for the entire ICE fleet in 1992. The permitting authority for railway carriages had previously pointed out that, prior to approving serial production, numerous tests would be necessary which would at least take another two years.

Later it was found that the structural analysis had not paid sufficient attention to dynamic, recurring forces when performing the structural analysis of the wheels, which meant that the wheels had not been dimensioned with sufficient safety margin. After introducing the rubber-cushioned wheels regular checks were not performed.

Consequences:
As catastrophic as the Eschede derailment was, it could have been worse if an oncoming train had crashed into the accident site. One of the measures was to publish UIC leaflet 777-2R "Structures built over railway lines – Construction requirements in the track zone" in 2002. It serves to assess the risks to structures built over railway lines arising from train derailments and to protect trains against impacts with bridge structures.

2. RAILWAY – THE SAFEST MEANS OF TRANPORT

Despite the horrific accidents, it must not be forgotten that railway accidents are extraordinarily rare. A study conducted by the European Transport Safety Council (2001) revealed that the railway is absolutely the safest means of transport. When comparing road and rail transport, the number of accident victims shows that travelling by rail is 20 times safer than travelling by car.

Motor cycle	6 million km
Pedestrian	13 million km
Bicycle	16 million km
Car	125 million km
Ferry / ship	300 million km
Aeroplane	1,250 million km
Railway	2,500 million km

Figure 3: Statistical distance to be covered for occurrence of a fatal accident (Europe)

2.1 Railway Safety in Europe

Europe has a great variety of trains and train control systems – from the remnants of the Communist era in Eastern Europe, to modern high-speed trains, e.g. in France, Germany or England. All in all, the safety standards are among the highest in the world. Accidents like the one in Spain are thus incredibly rare.
According to EU statistics, the number of train accidents per year in the 28 countries of the European Union is declining steadily. In the period from 2004 to 2011 a decrease of train accidents of about 70 percent was registered.

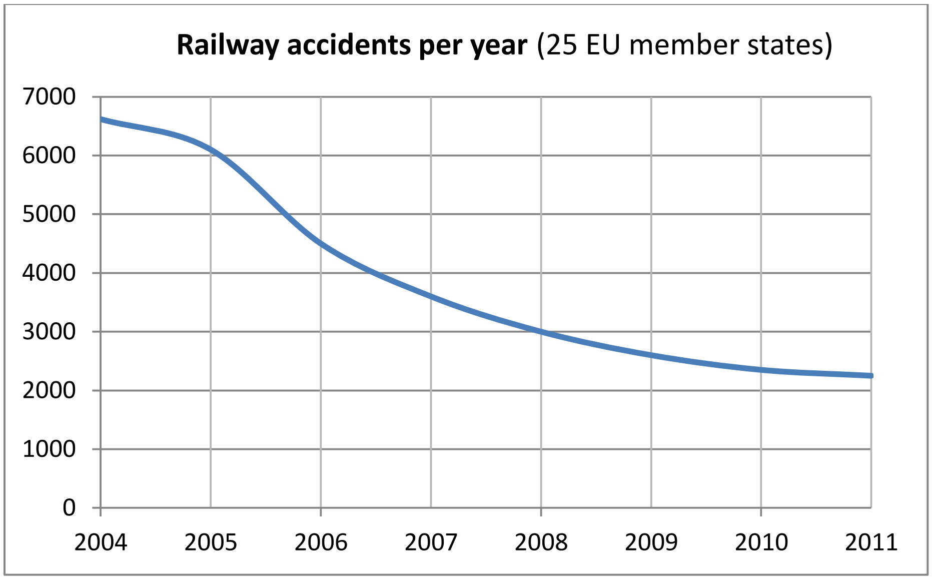

Figure 4: Decrease of railway accidents in the EU since 2004

2.2 Common safety policy

Up until about the year 2000, the EU member countries developed their own railway safety regulations and standards independently from each other. Over the years the economic integration and the rapid increase of trade and commerce in the EU led to an increased demand for rail transport. That is why the development of a safe supranational railway network has become on the top priorities in the EU. To this end, the **European Railway Agency (ERA)** was established, to define a pan-European approach to railway safety (**Railway Safety Directive 2004/49/EG**) and **Interoperability (TSI guidelines)**. The main task of the ERA is to develop economical, common technical specifications (TSI), including a consistent solution for a standard train control system (ERTMS - European Rail Traffic Management System), as well as harmonised safety approaches and/or safety management systems. The efforts of the agency primarily aim at promoting the development of rail transport by means of harmonising the safety and permitting procedures. For this purpose, a harmonised approach to risk assessment of railway systems (**CSM – Common Safety Methods**) was established. The joint approach facilitates access to the market and permits mutual recognition of the results of risk assessments.

2.3 Measures to increase railway safety

Europe has a very high level of safety in railway transport which is generally determined by the provision of specific track-side assemblies and infrastructure measures over the entire rail network and defined as per legal requirements. Despite the high safety level, appropriate safety management measures aim at further reducing the probability of train accidents.

The reasons for train accidents can be summed up in two categories – those whose cause can be attributed to technical failure and those that can be traced back to human error. The technical causes include defects on the track bed, construction defects and production defects as well as defects in the rolling stock. Disregarding regulations and loading rail vehicles incorrectly are human mistakes. For instance, in case of derailments, some 60 % can be attributed to technical causes and 40 % to human causes.

2.3.1 Improvements in the train control system

The latest technology in train control according to interoperability principles is finding its way into Europe. In accordance with the **interoperable European Rail Traffic Management System (ERTMS)**, on all new railway lines the **ETCS (European Train Control System)** is already being used. It is a digital radio-based signalling and train control system that sends information to the train, which means that the cab display continuously shows the driver the permitted speed and the line profile ahead. All trains automatically transmit their exact position and direction of travel to the Radio Block Centre (RBC) at regular intervals. Together with information about speed and route details, travel permit data are continuously transmitted to the vehicle via GSM-R. The Eurobalises are only used as passive locating balises which serve as «electronic milestones».

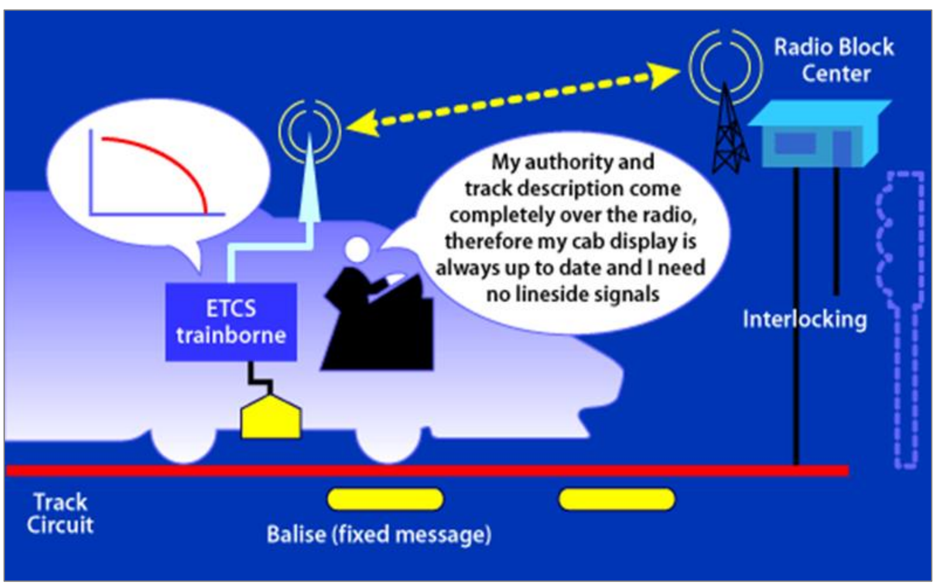

Figure 5: Principle at ETCS (Level 2)

Currently the major portion of the existing European rail network is still operated with an inductive train control system. At defined points, depending on the position of signals ahead, information for controlling the train movement is transmitted. In case of imminent danger (e.g. rapid approach to a red signal, speeding) the system triggers emergency braking until the train has stopped.

2.3.2 Improvements in the operation of railway lines without automatic train control system by means of technical support

For single-track railway lines with little traffic there are also operation modes in Europe without automatic train control. This simple operation mode is based on communication by phone between the train operator and the train driver. The operational safety is therefore the sole responsibility of the acting persons.

Technical support of the train control serves to locate the train driver, transmitting his position via a permanent GPRS-link to the computer of the train operator. This increases the safety of the train operation by reducing the risk of passing or ignoring signals and unauthorised entering of track sections that are not free of traffic.

2.3.3 Improvements in the detection of defective rolling stock (track-side checkpoints using Austria as an example)

Until the year 2013 the entire rail network of the Austrian Federal Railways was continuously upgraded with hot box and brake detection systems. In a next step, the installation of additional sensors at track-side checkpoints is planned at strategic points of a railway line. Track-side checkpoints serve to provide comprehensive technical supervision of trains. Previously train supervision was carried out by railway staff, in the future surveillance will be effected by means of applied technical systems. In a first step, track-side checkpoints will be equipped with a weight and structure gauge measurement system.

2.3.4 Improvements in maintenance

In general track systems have to be kept in a condition that will prevent any inadmissible effects on passengers, transported goods, vehicles and the track itself. Continuous surveillance and maintenance of the track bed as per the criteria of driving safety and passenger comfort are some of the most important tasks of the railway line operator. Using track recording vehicles, track beds and rail profile are recorded at speeds of up to 250 km/h by means of optical gauge measuring systems. Regular visual checks, inspections, functional tests as well as fault elimination and repair and replacement works ensure that the above mentioned condition is maintained.

3. RISK-BASED ASSESSMENT MODELS FOR ENSURING SAFE OPERATION IN THE FUTURE

The target system contributes decisively to implementing the three primary targets of the transport mode *rail* and constitutes the central prerequisite for long-term and sustainable safeguarding and further development of the competitive position of rail transport (Figure 7).

3.1 Target system

3.1.1 Strengthening of the market position

Further developing the quantity and quality of the infrastructure facilities serves as a basis for increasing the demand for rail transport. Expanding and upgrading the infrastructure facilities shall focus on those relations where there is high market potential for inducing further modal shifts. It is only by ensuring that the infrastructure measures are effective, i.e. high potential transport gains can be achieved with given financial means, that the market position of rail transport can be strengthened.

3.1.2 Increase of cost effectiveness

An efficient infrastructure is a decisive factor for the success of rail transport. That is why the objective is to be able to cover the infrastructure costs (costs for operation and maintenance) predominantly through market profits. This requires measures both with regard to costs and profits – the corresponding strategy recommendations of the target system can contribute significantly to increasing the cost recovery of the infrastructure.

3.1.3 Continued development of operation safety

The very high degree of safety – especially as compared with road transport – is an essential characteristic of rail transport. Maintaining and further developing the safety performance is only possible if the infrastructure meets state-of-the-art criteria. In the target system measures are therefore intended for retrofitting and renewing the existing system and safeguarding its state of the art.

Figure 6: Long-term strategy for rail infrastructure – the target system

3.2 Operation safety through risk-based assessment approach

Operation methods, facilities and systems complying with regulations ensure safe railway operation with an acceptable risk. Depending on their functions, transport volume as well as on their facilities and systems, railway lines and train control centres pose specific hazards which determine the risk. On account of transport and traffic development and changing infrastructure these hazards may change so that the risk increases or decreases. In order to use risk mitigating systems and facilities effectively, the railway infrastructure operator may apply incident-specific assessment models which provide a basis for decision making for planning measures from the perspective of safety as follows:

1. **Current state**
   The assessment model depicts the risk of defined infrastructures (overall network, certain railway lines or danger points) based on relevant hazards with regard to defined incidents.
2. **Development**
   For defined incidents and infrastructure the development of the risk due to changing relevant hazards (transport development, change of infrastructure) is depicted.
3. **Target from the perspective of safety**
   The risk for defined incidents and infrastructure is compared to the corresponding target of the rail infrastructure operator.
4. **Requirements for risk mitigating measures**
   Comparing risk and target serves to provide requirements for risk mitigating measures from the perspective of safety. The effects of risk mitigating measures are depicted in the assessment models.

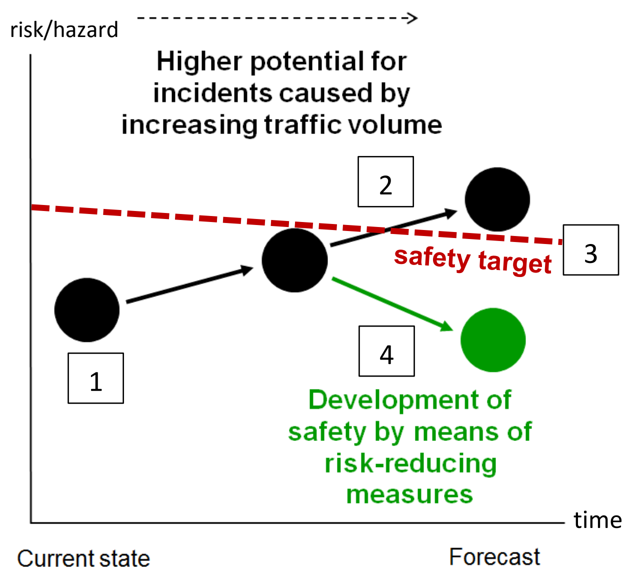

Figure 7: Implementation of risk-reducing measures to meet the safety targets

Using the assessment models serves to support the planning processes of the railway operator from the safety perspective as follows.

3.2.1 Strategies and assessment of measures

Models applied throughout the network assess railway lines with regard to defined incidents. Based on the results of the models those railway lines can be identified where risk mitigating measures have a great effect with regard to the considered incidents, and requirements can be derived for planning suitable measures.

3.2.2 Determination of required measures in case of changes to the infrastructure

Specific assessment models are applied when planning changes to defined infrastructure systems. They assess railway lines, train control centres and certain danger points (hot spots) with regard to defined incidents and evaluate the need for risk mitigating measures from the perspective of safety.