Safety with ERTMS under scrutiny

Heidi VAN SPAANDONK

ProRail, The Netherlands

Abstract. EU goals for future railway operations result in a system that allows us to safely operate cross-borders, in a uniform and safe technical environment. In the European Railway Industry we face similar challenges and risks and can therefore benefit from the lessons learned in other countries. This paper gives insight into railway safety under ERTMS and that the expected improvement of safety is not self-evident. With current incident numbers, the intended safety improvement with ERTMS implementation might become a myth.

Keywords. ERTMS, SPADs, Human error, Safety

1. Introduction

According to the European Commission (EC, 2017), European Rail Traffic Management System (ERTMS) is the standard railway management system of the future that enables interoperability between countries, increase capacity and improves the rail safety level in Europe. Several countries have published reports showing implementation of the system shows to be a challenge and the system is less uniform and user-friendly as perhaps desirable (Halcrow Group Limited, 2012) (RailEngineer, 2015). National Values determine the configuration of the system to local requirements in each country. The day to day train operations in the Netherlands at railway yards requires a more flexible use of the system than it may have been initially designed for. This paper discusses the lessons learned from Signal Passed At Danger (SPAD) incidents on ERTMS track in the Netherlands. SPADs are seen as the primary incident with high risk to result in a train collision. Compared to the kilometres of tracks fitted with the Automatic Train Protection (ATP) system (6600 km, 79 SPADs) the SPAD numbers on ERTMS tracks (400km, 19 SPADs) are high. When considering safety features of the ERTMS system it is often a comparison between levels. However analyses of incidents show that the safety level is more often than not dependent on the mode in which the train operates and this may very well result in the train driver being the last barrier. In Full Supervision mode the system provides a high safety level because of the constant speed supervision, however SPADs do happen. Also Full Supervision, Shunting Mode, Staff Responsible and other modes each provide a different level and sometimes kind of supervision and control resulting in challenges for train drivers and therefor railway safety.

According to the ministry of Infrastructure and the Environment the implementation of ERTMS is expected to enhance rail safety, improve the railways’ interoperability and reliability, and increase their capacity and speed. The system offers the following advantages in terms of rail safety:

- Drivers of ERTMS-equipped trains see on their DMI maximum speed allowed on a given stretch of track.
ERTMS keeps trains from exceeding the maximum speed, and automatically applies the brakes when necessary.
ERTMS gives a train’s exact location and allows drivers to see on their DMI if the track ahead is free.
ERTMS decreases the likelihood of a train passing a red signal.
Like the current system, ERTMS only works when both track and trains are operating with compatible on-board equipment (Mobility, Public Transport and road safety).
To support technical decisions and investments for nationwide implementation of ERTMS, ProRail is developing a tool with the purpose to re-evaluate infrastructure layout at yards to limit SPAD evoking circumstances. The tool, Route Risk Register (RRR), calculates risks for certain routings under specific technical circumstances. This paper will give more insight into this tool.

2. Methods

A SPAD resulting in a train collision in Amsterdam in 2012 (The Dutch Safety Board, 2012) changed the way we investigate and analyse SPADs in the Netherlands. Now all SPADs are thoroughly investigated, often in cooperation with the Railway Undertaking (RU) and a yearly analysis is done for trends and Human Factors. Also for SPADs taking place under ERTMS.

The definition of a SPAD used under ERTMS is as follows:

**Level 1:** A rail vehicle passes a red signal without permission that:
1. is a direct responsibility of the traffic controller; or
2. is a signal on the main line.

**Level 2:** A rail vehicle passes a Stop Marker Board (SMB) without a movement authority (MA), or without permission of the signaller.

A qualitative analyses of SPAD incidents on ERTMS tracks provides us with valuable data to learn from, see Figure 1. The following lines are ERTMS-equipped and used in daily operations:

- the Betuwe line and Port of Rotterdam line;
- The Port of Rotterdam;
- the High Speed Rail Link South;
- the Hanze line and Amsterdam-Utrecht line (both also equipped with the class B system).

These tracks add up to approximately 400km of the total of 7000km track in the Netherlands.

*Figure 1: SPAD numbers on ERTMS tracks in the Netherlands*
After a report of a SPAD a safety advisor of ProRail collects all the relevant data relating to the incident. At the same time all relevant information is collected at the side of the train operating company and the two advisors share information and decide on the next step in the investigation. The data collected are: logging files from the traffic management system, the on board computer loggings of the Juridical Recorder (JRU), interviews with train drivers and traffic controllers and the actual schedule for the SPAD train and surrounding trains. We include track works and if applicable changes in track use or signalling, technical specifications of train type and local operational specifics. In addition all SPADs are geographically plotted on a map and this helps to get more focus on location specific issues. On an annual basis all the information is analysed by a safety and human factors expert and shared with the railway sector in the Netherlands and the Ministry of Infrastructure and the Environment. The investigations and analyses of SPADs on ERTMS tracks has shown us valuable information of the system and Human Factors. The benefits that the ERTMS system offers in terms of rail safety depends strongly on the mode the train is operating in, the route knowledge, communication with the signaller and system knowledge of the train driver and signaller.

Both levels, ERTMS level 1 and level 2, provided useful data for SPAD analyses. The levels and operational modes are basic concepts of the ERTMS system. Operation modes can be defined as different conditions required for managing various situations regarding the status of the trackside equipment and the train itself (EC, 2017).

Table 1: A definition of the, for this paper, relevant levels and modes (UIC, 2008):

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involves continuous supervision of train movement while a non-continuous communication between train and trackside (normally by means of Euro-balises). Lineside signals are necessary and train detection is performed by the trackside equipment out of the scope of ERTMS.</td>
<td>Involves continuous supervision of train movement with continuous communication, which is provided by GSM-R, between both the train and trackside. Lineside signals are optional in this case, and train detection is performed by the trackside equipment out of the scope of ERTMS.</td>
<td>Provides continuous train supervision and communication between the train and trackside. The main difference with level 2 is that the train location and integrity is managed within the scope of the ERTMS system, allowing an optimal train separation without train detection systems on the track side. Train integrity is supervised by the train if the train is complete.</td>
</tr>
</tbody>
</table>

There are two more levels defined: Level 0, which is meant for ERTMS equipped trains on non-equipped lines; and Level STM/NTC (Specific Transmission Module/National Train Control), which is meant for ERTMS equipped trains on lines where the class B system needs to be operated. In STM/NTC level ERTMS acts as an interface.
The European Transport Workers Federations (ETF-Europe) describes the ERTMS levels as follows: The levels are associated with train-trackside communication, ERTMS modes are related to the operational circumstances of the line or the on-board equipment status. Where the train is operating in ERTMS, the preferred method is to issue movement authorities:

- **Full Supervision (FS)**
  The main ERTMS mode is Full Supervision. The ERTMS on-board equipment will be in Full Supervision mode when all train and track data, which is required for complete supervision of the train, is available on board. In this mode, the on-board ERTMS equipment is responsible for train protection.

However there are operational situations and infrastructure conditions where the train cannot be driven in Full Supervision. Or even where the train is operated on lines not controlled from the signalling system (e.g. yards). Therefore the system provides solutions with a variety of partial supervision modes that can also be used in areas which are controlled with the signalling system (EC, 2017). The management of the activity in other modes than Full Supervision (permission to move, extent of movement, confirmation of position on infrastructure, etc.) involve operational rules, site personnel or the provision of lineside signals/indicators. The system is programmed with the conditions in which this is possible (specifications are set by National Value). However Level 1 gives less options to control the conditions than level 2. This paper will discuss these partial supervision modes relevant for the SPAD analyses in this paper.

- **On Sight (OS)**
  The mode of ERTMS that gives the driver full responsibility for the safe control of the train at an enforced and limited speed (National Value) when the ERTMS system enables the train to enter onto a track section that could already be occupied by another train, or obstructed by any kind of obstacle.

- **Staff Responsible (SR)**
  The mode of ERTMS that gives the driver full responsibility for the safe control of the train at an enforced and limited speed (National Value) in an equipped area.

- **Shunting Mode (SH)**
  A mode that allows the train to enter an occupied section under driver responsibility and only supervises the maximum speed (by National Value). Shunting is an activity where trains are prepared, moved, split or combined in preparation for service. This can occur at a number of locations and for a number of operational reasons. Shunting Mode enables a train to reverse which is not possible in FS/OS or SR modes. Again, without supervision of the movement by the safety system. Once SH is entered, the trackside has very restricted functionality available to manage the train movement or to restrict it from entering an operational line potentially leading to a train collision. Shunting Mode has an operational advantage that it does not require the driver to enter full train data which can be an advantage when trains are being combined or split, and when parts of the train have isolated brake systems.
3. Results

We have learned from incident analyses that these modes and the required operational rules and standards provide the Human Factor challenges in daily operations, see Figure 2. Currently over 40% of the SPADs take place during a shunting movement, the following 40% takes place at or close to the yards under different, non-standard, operational circumstances that require unscheduled or unexpected train movements. The Dutch inspectorate has decided on categories for primary and secondary causes to create uniformity in incident investigation and analysis.

Figure 2: ERTMS SPADs in the Netherlands by primary causes

The following scenarios have multiple occurrences in the discussed period:

**SPADs under Level 1:**
- Technical circumstances: when a signal fails (no light) driving in Shunting Mode does not provide you with any protection that forces you to stop. The last barrier is the train driver and visual observation of the signal which does not give-off any light.
- Visual observation: last minute routing was requested and the signaller gives a part of the route, enabling the train to depart in Shunting Mode on amber till the next signal. Train driver is expecting whole route and does not anticipate a stop. All actions of the train driver are set to accelerate, there is no expectation and therefore no intention to stop at the second signal.
- Distraction: train was en route in Full Supervision for the last hours. When arriving at complex and busy yard and needing to switch to Shunting Mode as infrastructure demands. Train driver is busy (in his mind) with finalising long trip and parking train at designated track. The driver has no cognitive awareness of differences in protection when switching modes.
- Expectation: last minute routing was requested and the signaller gives a part of the route enabling the train to depart in the partial supervision mode (SR) on amber till the next signal. Train drivers expects the whole route and passed the red signal.
Communication between signaller and train driver contributes to create these expectations.

**SPADs under Level 2:**
- Distraction: due to technical issues on board the train driver was distracted and missed the SMB. Shunting Mode did not provide the necessary safety net.
- Expectations: due to disruptions en route the train needed to be redirected and for this the locomotive coupled on the other side of the train. The train driver expects a new route and not a partial one. Driving under Staff Responsible the train gets a TRIP (system applies emergency brakes). The train driver overrules the system assuming a system error and continues the route. Due to previous comparable experiences the train driver chooses the wrong handling strategy. There is no system support for the driver.
- Procedure train side: due to construction works the locomotive needs to be relocated. The train driver confuses Staff Responsible mode with On Sight mode. Unfamiliarity with OS en SR modes due to infrequent usage and limited training results in confusion.
- Technical circumstances: train is operating without the required brake pressure. When arriving at a busy railway junction the train needs to stop. Full Supervision does provide brake curve protection however this is based on the mandatory brake pressure, not the actual brake pressure. So when, due to circumstances, the train does not meet the required brake pressure, the system does not alert the train driver.
- Expectation: The test train is running in Staff Responsible mode and is not connected to the RBC and therefore has no movement authority or active train protection. Unclear communication provide the wrong expectations, resulting in unauthorised passage of SMB.

### 3.1 Analyses

When we analyse the SPAD incidents from the last 4 years we are, in most cases, confronted with Human Factor related causes. System design envisages an operational application of the system which does not correspond with actual daily operations. The flexibility of the partial supervision modes, specifically Level 1 Shunting Mode, leads to the system being used in a way for which it was not designed. Also the underestimated role and influence of the signaller in daily operations plays a significant part in incidents. Communication between signaller and train driver lead to confusion and misinterpretation in many occasions. Although the train driver is trained for working with ERTMS the signaller is often not or insufficient. Train drivers are confronted with messages on their Driver Machine Interface (DMI) which they have difficulty interpreting or last minute re-routing requests all require contact with the signaller. The signaller will try to help the train driver with limited or non-existing system knowledge, resulting in unwanted outcomes. Not intentionally, but in the effort to maintain a punctual and steady operation going. A good comprehension of the system proves to be a necessity for both.

### 3.2 System as designed and system used

One of the reasons we have SPADs under Level 1 with Shunting Mode can be explained by the gap in work as designed and work as done. Shunting Mode under ERTMS was created to give Railway Undertakings the opportunity to reverse/combine or split in specific shunting operations. However the system mode provides more benefits. In Shunting Mode it is not mandatory to put in the train characteristics like brake pressure, length and weight and one can drive in the mode without entering the train number in the DMI. Also current
infrastructure design at yards demands driving in Shunting Mode at locations for which it was not originally designed. In the design stage this may have seemed as a minor issue with hardly no impact on safety, however when the technology (ERTMS) is used differently than the intended design, in reality opens up a world of potential hazards. In everyday operational life minimizing start up time (process time) is a huge benefit for a train driver and the opportunity provided by the system (input of data not mandatory) will be used. As Erik Hollnagel describes in the ETTO principle, efficiency trade-offs are made by people at the sharp end in daily operations, usually just to get the job done (Hollnagel, 2009). Thus resulting in un-designed use of Shunting Mode. The process time with ERTMS is significantly longer (60 to 90 seconds) than with the current class B system. This will provide additional planning challenges. When developing the system, the hazards for un-intended use were not thoroughly taken into consideration.

Design and implementation of ERTMS has created operational hazardous possibilities and mitigating measures have not been put in place by technique or operational rules and procedures. It also has specifications that require a different infra structure layout at railway yards as the current system to be able to maintain the safety level in all operational conditions, e.g. start of mission mode. Past and current incident data provides a valuable insight on how the system functions in daily operational conditions and gives us a better understanding of the strengths and weaknesses of ERTMS. Introducing new technology is not manipulating a single variable, but a change that reverberates throughout a system transforming judgements, roles, relationships and weighting on different goals (D. Woods, 2000). To support technical decisions and investments for nationwide implementation of ERTMS we are developing a tool, together with CQM, a consultancy firm specialised in quantitative methods, in which we calculate risks for certain routes under specific technical circumstances.

The Port of Rotterdam is currently equipped with a variety of ERTMS infrastructure designs. To support infrastructure design decisions we are developing a tool which combines ERTMS system specific behaviour, infra-layout and timetables to assess hazards and identify risks, see Figure 3. The Route Risk Register (RRR) is intended to be used in the planning phase of the annual timetable. An innovative way to balance safety, capacity and accessibility. The tool also allows you to research how to reduce the specific risk by a selection of mitigating measures in the digital toolbox.

![Figure 3: Screenshot RRR (Roosendaal)](image-url)
3.3 ERTMS remains a system which is still in development.
The implementation of ERTMS demands radical adjustments in trains, infrastructure, communication systems and user processes. It is of huge importance that all systems, processes and procedures of ERTMS and other systems to link properly to provide a well-functioning railway system. Train drivers advocate for further standardization beyond technological rules by affecting operational aspects in order to minimize operational uncertainties to train drivers. (M Giaccone) In addition, the training and education of train drivers, signallers, maintenance staff and incident investigators are an important part of the programme in the Netherlands. There are issues and questions that require more analyses and investigation, like the implementation of ERTMS at busy railway yards/stations and the necessary required capacity of the wireless communication. To this end, the ERTMS programme in the Netherlands does extended research to find an optimal solution. Also lessons are learned from other countries who have and are still working on the implementation of ERTMS; like Denmark, Austria, Belgium, Switzerland and others.

4. Discussion and Conclusion

According to the European Commission, ERTMS is the future standard railway management system that intends to promote interoperability between countries, increase capacity and significantly improve the rail safety level in Europe (EC). It is a system change which comes with challenges. In cooperation and collaboration with Railway Undertakings, government and unions we implement ERTMS in stages in the Netherlands. The process will take years and in the meantime there will be many transitions between systems with a variety of challenges. The technical specification of ERTMS have been laid down in European Commission Decision 2012/88/EU. However, as highlighted by Schuitemaker, the ERTMS specifications leave room to implement ERTMS functions differently by countries, resulting in different operational rules (K. Schuitemaker, 2017). Companies configure the national systems on the basis of national requirements. The uniformity and inter-operability the European Union was aiming for might therefore turn out to be a myth (UIC, 2003).

4.1 What does this all mean for railway safety
To maintain a comparable safety level as the current ATP system, with ERTMS a different infra structure layout is required at railway yards. Analyses of incidents has shown that the approach to compensate deficient technical supervision with user guidelines and operational standards is not a safe option resulting in Human Factor related issues. Train drivers have limited comprehension of the system and therefore do not fully recognize the operational system circumstances. The challenge that lies ahead is to find an affordable solution for ERTMS to solve technical and Human Factors issues without loss for performing normal daily operations whilst creating a safer and interoperable system.

The day to day train operation requires a more flexible use of the system than it may have been initially designed for. The system is complex on its own and for the users. There are the technical challenges on board and in the infrastructure but also for the users like the train drivers and signallers the transition period will be a challenging one. ERTMS and the current ATP will often provide them with similar operational issues as the current ATP system, however they require different solutions. The complexity of the system and the relative inexperience of the train drivers and signallers have shown a good foundation for misconceptions resulting in unwanted actions and unforeseen hazards.
When considering safety features of the system it is often a comparison between ERTMS level 1 and level 2, however analyses of incidents in the Netherlands show that the operation in partial supervision modes in which the train operates is an important factor to be taken into consideration. Shunting Mode, Staff Responsible and other modes each provide a different and sometimes minimal safety level, leaving the driver as the last barrier resulting in Human Factor challenges for train drivers and railway safety. Considering that several countries are implementing ERTMS now for the first time this is not just a Dutch challenge.

4.2 Conclusion

The Dutch railways include some of the European most intensively used railway lines. The current control and safety system, with all its added mitigating measures, meets the existing requirements, but as it dates back to a time when fewer trains were using the tracks, it is rapidly aging and offers little room for future improvement. The transition to ERTMS will take place gradually and in phases, so as to keep inconvenience to passengers to a minimum. This means that in the following years the infrastructure will have several system transition points at an increasing number of locations. These transitions are not just a challenge for the system but also for the train drivers and signallers.

Although the national definitions of a Signal Passed at Danger (SPAD) may slightly differ throughout Europe, everyday operational risks are very much the same. The need for a system that allows us to safely operate cross-borders, in a uniform and safe technical environment, is shared. In the Railway sector we face similar challenges and can therefore benefit from the lessons learned from each other in an attempt to close the knowledge gap before European wide implementation of ERTMS. The European Transport Workers Federations (ETF-Europe) envisages that cross-border rail transport will be provided by replacing former cross-border cooperation among railway companies by competition between new and existing companies. These developments, which are currently under way, necessitate solid European standards for working conditions. Differences in National Values configuring the system preferences is not beneficial to interoperability (ETF-Europe).

The intention of the European Union to improve railway safety by implementing ERTMS in Europe is not self-evident. ERTMS has its limitations. Introduction of the system is a complex process and it differs significantly from the current system in the Netherlands. Providing training for the users is a must but by itself likely to be insufficient. To use the system to its full potential and maintain or increase our current safety level we should pay close attention to the weaker parts of the system, e.g. longer process times, different configurations due to National Values, system characteristics and operational use. Focus on the imperfections and differences with the current ATP system can help us determine what measures to implement to use the system to its full potential and also maintain and/or increase current safety levels.

The challenge that lies ahead is to implement ERTMS in such a way that the discussed technical and Human Factor issues are solved without loss for performing normal daily operations whilst creating a safer and interoperable system.
References


Transport: https://ec.europa.eu/transport/modes/rail/ertms_en

https://ec.europa.eu/transport/modes/rail/ertms/what-is-ertms/levels_and_modes

EC. (n.d.). Roadmap to a single transport area: Towards a competitive and resource efficient


learnt.pdf

Publishing.


Government of the Nethelands: https://www.government.nl/topics/mobility-public-
transport-and-road-safety/rail-safety-ertms

https://www.railengineer.uk/2015/08/28/ertms-a-reality-check/

Dutch Safety Board: https://www.onderzoeksraad.nl/en/onderzoek/1841/collision-
between-intercity-and-sprinter-amsterdam-21st-april-2012

UIC. (2003). Implementing the European Train control system ETCS. *UIC ERTMS
Conference* (p. 38). Leipzig: UIC.