The impact of transitioning to/from ERTMS operation from a train driver's perspective

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Abstract. The roll out of the European Rail Traffic Management System (ERTMS) will expose train drivers to transitions between ERTMS and conventional signalling operation during a journey or work shift. After the transition, there may be a period of adjustment before the driver is completely secure in the new method of operation which leaves potential for degradation in the effectiveness of the driving task. The objective of this research was to identify the safety/performance issues that can be attributed, directly or indirectly, to transitioning between train signalling systems.

Keywords. Railway, signalling, ERTMS, operations

1. Introduction

The European Rail Traffic Management System (ERTMS) is an interoperable signalling and train operation management system. It consists of the European Train Control System (ETCS) for automatic train protection, the Global System for Mobile Communications – Railway (GSM-R) system for voice and data transmission, the harmonised set of European operating rules and the European Traffic Management layer (ETML, yet to be defined). With ERTMS, movement authority information, including extent of authorised movement and speed profile information, is issued by the signalling system from Railway Operating Centres (ROCs) and communicated to trains by the ERTMS trackside equipment. At the start of a journey the driver enters train data, including train braking characteristics, into the ERTMS onboard system. The ERTMS onboard system uses the entered train data and the received movement authority information to calculate speed and distance supervision limits against which the train is supervised. The ERTMS onboard system will apply the brakes if the train exceeds these supervision limits. There are a number of different ERTMS operating levels but this paper only focuses on ERTMS level 2 and assumes there are no "overlay" implementations i.e. Level 2 with lineside signals. In ERTMS level 2, movement authority information is transmitted to the train via GSM-R and all information is provided to the driver through the Driver Machine Interface (DMI).

During ERTMS deployment in Great Britain, drivers will be exposed to transitions between ERTMS and conventional signalling during a journey or work shift. On the approach to a transition border, the driver will receive a notification that a transition to a new method of operation is going to occur. The driver will receive this notification at any time between a designed earliest and latest location on the approach to the border. When the notification is received, the driver is required to prepare to apply the rules for the new method of operation (ERA, 2015). Drivers may also have to acknowledge the transition via the driver machine interface (DMI).
After the transition, there may be a period of adjustment until the driver feels completely comfortable in the new method of operation. Consequently, there is potential for degradation in the effectiveness of the driving task which may impact on performance (if drivers reduce speed until they have adapted to the new method of operation) and safety (especially if the

transition border is located close to key infrastructure features and/or areas of high workload). Transitioning more than once in a journey may cause confusion about the train protection which is active and this may be exacerbated if transitions are occurring at a high frequency or at locations where a driver has a high workload. The objective of this research is to identify safety and performance issues that can be attributed, either directly or indirectly, to transitioning between ERTMS and conventional signalling systems with an aim to support the design of these transitions.

2. Methods

The first phase of the research was a literature review of relevant standards and research projects from Great Britain and Europe. There were six relevant themes identified in the literature which were: driver workload and confusion; automation and supervisory systems; change management and culture; driving styles; international deployments of ERTMS and incident analysis; driver training and how information is presented to a driver on the DMI. The project research questions were used to determine the themes used for the literature search.

The second phase of the research included interviews and observations with drivers who currently transition between signalling systems (Arriva Trains Wales, Eurostar, SouthEastern High Speed, Tyne and Wear Metro, London Underground and First Great Western) to understand what is involved mentally and physically for transitions between existing signalling systems.

The third phase of the research were two sets of Human Factors Risk Analysis workshops. The first set of workshops were held with train drivers from Train Operating Companies (TOCs) and Freight Operating Companies (FOCs) (16 TOC and 3 FOC drivers) to identify the risks associated with transitions at key infrastructure features (eg, level crossings and station stops). The second set of workshops were with operations managers from both passenger and freight companies (10 participants). The objectives of these workshops were to identify and evaluate mitigations for the hazards identified by drivers in the first set of workshops. The data from these workshops was used to estimate human error probabilities at key infrastructure features using the rail action reliability assessment (RARA) technique. An analysis of data from the RSSB safety risk model (SRM) was also undertaken to estimate the impact of transitions on fatality and weighted injuries (FWI).

3. Results

Driver experiences of transitions and attitudes towards new technologies

The introduction of ERTMS brings many safety and performance opportunities. However, a change (in general) can cause uncertainty, discomfort and worry for drivers (Calder, 2013). There were examples during the interviews of drivers disliking/distrusting new signalling systems (especially when they were first introduced). The reasons for this dislike were that the systems were new and unfamiliar, more restrictive and prone to technical issues where trains fail to transition correctly. An example of the perceived restrictiveness of the KVB system (KVB is a signalling system used at St Pancras International, which monitors and controls train speed) was expressed by one driver:

"I hate KVB with a passion…You know you can go 30 but can you?"

There were also examples of experienced drivers finding it difficult to adapt to a new signalling system:

"Going to XXX now I describe as like going to the dentist and pulling out all your teeth without any anaesthetic…It turned out to me that I absolutely hate it."

"You can't trust the system because it's only a computer at the end of the day"

In comparison, some of the less experienced drivers were generally more accepting of new systems. It does take some people longer to accept and adapt to change (Kübler-Ross, 1969). Research suggests that all individuals go through an emotional sequence of change but the speed at which we go through the stages differs between individuals. The 'adaptation to change curve' has four stages: rejection, resistance, acceptance, and commitment (Hiatt et al., 2010). A link has been identified between positive attitudes towards new technology at the 'pre-use' stage and the 'use stage' so 'pre-use' attitudes are important in determining if new technologies are accepted (RSSB, 2015).

An advantage of ERTMS is that it offers greater train protection but the DMI also generates alerts to prompt the driver to apply the brakes which some drivers find too restrictive. This may affect acceptance of the system. Research about the effects of automation are mixed. An increase in automation may reduce job satisfaction and a driver's ability to detect and correct errors and increase the likelihood of error (Merat et al., 2012). However, the reduced cognitive demands and workload associated with automation may also enhance decision making and prioritising skills (Porter, 2002). There was evidence during the interviews of drivers who were worried about the changes in their role that more automated signalling systems bring.

"Its essentially taken the thinking out the job as far as I'm concerned"

However, there were also drivers who embraced in-cab signalling:

"Cab signalling tells you what you have to do - you can't go outside the braking curve. Driving with TVM is easier because of the automatic train protection (ATP). ATP is a passive system but is a backup if you make a mistake."

This demonstrates the importance of change management in the deployment of ERTMS to overcome any initial distrust of the new system and how it affects the role of a train driver.

Driver workload and confusion about which train protection system is active

Drivers described transitions between signalling systems as a 'non-event' or something that was 'straight forward' and 'automatic'. However, drivers thought that issues could arise when something does not go to plan such as during degraded operations where workload is increased.

Drivers were asked about whether they changed their driving style in different modes of operation. Answers varied between companies because of the different signalling systems they deployed. In ERTMS, speed information and movement authorities are communicated to the driver through the DMI. The drivers with ERTMS experience said that when ERTMS was first introduced they adopted a more 'heads down' driving style as their attention was drawn to the DMI. A 'heads up' driving style is preferable because it means that drivers can monitor the visual scene ahead to identify hazards such as obstructions on the line. As experience of driving with ERTMS was gained, drivers reported to find the right balance between glancing at the DMI and looking out of the cab window. Drivers from other companies expressed concerns about adopting a 'heads down' driving style and getting distracted by the DMI. A study with drivers on the Cambrian line found that some drivers described themselves as being 'hunched' over the DMI so that their attention could be focused on the information being presented on the screen (Naghiyev, 2014).

Drivers stated a preference in the interviews and workshops to have transition locations away from areas of complexity because of the additional workload a transition brings. A simulation study in Holland assessed the impact of dual signalling. This research showed that 10-18% of drivers thought that they could become confused about the train protection system which is active on dual signalling routes (Zeilstra and Van der Weide, 2016). The report concluded that the chances of error are increased in dual signalling systems and the most likely cause of this is confusion about which train protection is active (Zeilstra and Van der Weide, 2016). Confusion about which train protection system is active was a common concern of drivers within this study in relation to multiple transitions during a journey.

The transition to/from ERTMS operation with no lineside signals has been estimated to have a high cognitive workload because of the change in supervision, driving style and metrics (between mph in conventional signalling and km/h in ERTMS Level 2) (Porter, 2002). The potential for peaks in workload at transition borders has been highlighted by previous research (Naghiyev, 2014). This has been supported by evidence from simulator trials which showed that transitioning does increase workload especially when transition borders are in areas with other demanding events (Zeilstra and Van der Weide, 2016). Drivers in this study felt that on approach to a transition border, they could increase their attention levels in order to transition safely and continue in the new mode of operation. However, when workload is increased e.g. during degraded operations, then the risk of error is increased.

Risks of transition borders close to infrastructure features

The effects of locating transition borders close to key infrastructure features (station stops, locally monitored level crossings, speed restrictions, neutral section and plain line sections) was examined within this project. Absolute Probability Judgement (APJ) and the Rail Action Reliability Assessment (RARA) (RSSB, 2012) were used to identify errors and their associated human error probabilities (HEP). APJ involves talking to subject matter experts (train drivers in this instance) and using their experiences to identify a range of errors and an estimation of their frequencies (Kirwan, 1994). Drivers in the workshops were asked to:

- List errors associated with driving for each key infrastructure feature (using task analyses and a structured error identification exercise using the guidewords outlined in the RARA technique)
- Estimate current error probability (calculated by dividing the number of times an error had been made by drivers by the estimated number of traverses of each key infrastructure feature).
- Estimate the impact of a transition or transition related activities on the likelihood of error. A seven point likert scale was used to assess the estimated transition impact on likelihood of error (significant decrease, medium decrease, slight decrease, no change, slight increase, medium increase, significant increase).

The two components of RARA are Generic Task Types (GTT) and Error Producing Conditions (EPC). GTTs ‘provide a generic description of a task, and an estimation of the human error probability for that type of generic task’ (RSSB, 2012). Every error was assigned a GTT using the current error probability figures (calculated from the driver workshops) and GTT descriptions. For example, at a junction the driver may brake late but recognise the error in sufficient time to apply the brakes. The average reliability in the workshops was 4.13E-05 traverses which suggests an R2 GTT. R2 GTTs are tasks which are completely familiar, highly practiced and routine with error probabilities between 0.00008 and 0.007. Reducing speed for a junction is a task conducted multiple times per day and had a reliability figure between the outlined figures so an R2 GTT was used for this error. Expert judgement was used to assign GTTs where the error probabilities and GTT descriptions differed. All GTTs were reviewed by an independent human factors specialist.

EPCs are ‘factors which are predicted to negatively influence human performance’. The EPC used in this analysis was In6: A channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information (RSSB, 2012). This EPC was selected because it was the most relevant to increases in workload. The assessed proportion of affect 'is a value between 0.1 and selected by the analyst, where 0.1 is a small affect and 1 is the full affect'. If drivers in the workshop thought that the likelihood of error was significantly increased due to the presence of a transition, then the full affect (value of 1) was assigned to that error (a value of 0.5 was assigned for a medium increase and 0.1 for a slight increase). The decrease ratings on the scale were outside the scope of the RARA technique and no drivers selected these ratings. The maximum effect of the selected EPC was 6. The following formulas were used to calculate the HEP figures:

Affect (A) = (Maximum Affect-1) x Assessed Proportion of Affect + 1

HEP = GTT x A

The results for a junction are displayed in Table 1. The results show that generally the HEP figures tended to be at the more reliable end of the human performance spectrum because the tasks affected by transitions are highly practiced and routine. Reducing speed too early on the approach to a junction was the most common error and failing to brake at all for the junction was the rarest error.

Table 1: HEP figures for a junction

Identified error	GTT	EPC	Transition impact	HEP
Reduced speed too early for the junction (approaching it too slowly)	R4	In6	Significant increase	0.01800
Reduced speed too late (but stopping in time for the junction)	R2	In6	Significant increase	0.00240
Reduced speed too late but unable to recover the error	R2	In6	Significant increase	0.00240
The driver does not brake or reduce speed for the junction	R2	In6	Medium increase	0.00140
Driver accepts the wrong route or fails to check/misinterprets the junction indicator	R2	In6	Significant increase	0.00240

The Safety Risk Model (SRM) 'is a quantitative representation of the potential accidents resulting from the operation and maintenance of the GB rail network' (RSSB, 2016). The SRM uses information from the Safety Management Information System (SMIS) and predictions where there is little or no relevant data available. The data from version 8 of the SRM were used in this analysis. The SRM considers the frequency and consequences of incidents and accidents. Consequences are quantified using fatality and weighted injuries (FWI) which weights injuries according to their severity (RSSB, 2014). For example, an FWI of 1 is equivalent to 1 fatality. For each error identified by drivers in the workshops, the relevant precursors were extracted from the SRM. There were occasions when the precursor did not map on to the error or where the SRM precursor did not separate out the proportion of the FWI due to driver error from other factors. In these instances, a proportion of the FWI was used following an analysis of a sample of incidents or through expert judgement. This means that these figures should only be used to prioritise the location of transition borders.

The EPC used in the RARA assessment was used as the multiplier in the analysis of SRM data. For example, the maximum affect for EPC In6 was a figure of 6. If drivers in the workshops thought that the likelihood of error was significantly increased, then the SRM figures relating to that error were multiplied by 6 to consider the effect of the transition on FWI/year. Medium increases were multiplied by 3.5 and slight increases by 1.5. The FWI figures were then summed to produce a FWI/year figure per infrastructure feature. Normalisers were applied to the data in the SRM to provide a relative scaling of risk figures. An example of a normaliser used for junctions is the number of junctions on the network. If the normaliser of the number of junctions was used in the calculations, the results would assume that there was a transition at every junction and this would not be the case. Therefore, additional figures were calculated to consider the number of traverses of junctions. The following data was therefore used to produce the final calculations:

- 577,326,429km covered by passenger and non-passenger trains per year (SRMv8)
- 14,506km length of route open for passenger and freight operators (ORR)

The latest available Department of Transport rollout plan for ERTMS deployment and Office Rail and Road (ORR) predictions of trains planned was used to estimate the number of transitions traversed per year. This data was extremely limited and would need to be updated as soon as further data is available. The figure of 562,651 train journeys affected per year by the deployment of ERTMS was derived. There are several assumptions that have been made to calculate this figure and these are:

- Each affected train will transition once per journey
- The number of trains translates directly in to the number of transitions
- The roll out plan has few starting points and then follows a process of steady expansion
- There is a match between the ORR data set for the defined TOC and the DfT defined route. For example, Virgin Trains for the West Coast Main Line.
- The number of planned trains is kept constant over time.

These figures should therefore be considered with extreme caution and be updated as soon as more data is available. Table 2 shows the estimated number of traverses of each infrastructure per year, the increase in risk if a transition was introduced (FWI per traverse) and the estimated increase in FWI/year for trains affected by a transition (the figure of 562,651 was used for this as outlined above). When linked to an estimation of the number of traverses, the analysis of RSSB Safety Risk Model data shows the greatest increase in FWI is associated with junctions and speed restrictions. The lowest increase in FWI due to the presence of a transition would be on plain line sections of track. Whilst these increases are very small compared with the overall safety figures in the SRM, it does show that locating transitions on plain line is preferable to locations such as junctions and speed restrictions.

Table 2: FWI figures for key infrastructure features

Infrastructure feature	Traverses/year	Increase in risk due to transition (FWI/traverse)	Increase in FWI for trains affected by a transition (FWI/year)
Junction	132,785,079	5.59E-09	0.0031
Speed restriction	45,769,019	5.02E-09	0.0027
Station stop	101,567,424	3.61E-09	0.0020
Locally monitored level crossing	3,701,321	3.25E-09	0.0018
Plain line section of track	444,541,350	2.21E-09	0.0012

4. Discussion and Conclusion

The results of this research project are based on the experiences of train drivers who transition between signalling systems. Evidence was found of some drivers distrusting new signalling systems because they were perceived to be more restrictive and prone to technical failures. This suggests that the introduction of ERTMS will involve a period of adaptation where change management will be particularly important.

Drivers felt that they adapted automatically to transitions between signalling systems. There is evidence that transitioning between signalling systems does increase workload and can lead to confusion about which train protection is active (Zeilstra and Ven der Weide, 2016). Drivers in this study reported they could increase attention levels on the approach to transition borders but did have concerns about degraded operations and the effects this could have on workload.

The location of transition borders at the following infrastructure features were considered in this project: station stops, locally monitored level crossings, neutral sections, junctions, speed restrictions and high speed plain line sections of track. The results of the RARA assessment showed that HEPs tended to be at the more reliable end of the human performance spectrum because the tasks assessed were highly practiced and routine. The HEP figures considered the impact of the error producing condition In6: a channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information.

The analysis of RSSB Safety Risk Model data shows that increases in FWI/year due to transitions are very small compared with the overall safety figures but do show that locating transitions on plain line is preferable to locations such as junctions and speed restrictions. The limitations of the available data mean that it is necessary to update these calculations when more up-to-date information is available.

The final output of this project was the development of a process for those responsible for designing or introducing transitions to consider the suitability and human factors issues associated with the transition design. The process is based on RSSB's Taking Safe Decisions and Common Safety Methods documents (RSSB, 2014). Further research to collect more objective performance data is currently in the proposal stage.

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