Understanding the impact of ETCS on driver 'route knowledge' competence

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SUMMARY

Train drivers must have extensive knowledge about the features on each route they drive, called 'route knowledge'. The upgrade of signalling systems from lineside signals to in-cab signalling changes key driving tasks and the requirements for route knowledge. This project sought to understand the route knowledge requirements for drivers under the in-cab signalling system European Train Control System (ETCS) and to update the industry guidance.

KEYWORDS

Competence, rail signalling, train driving, risk assessment, hierarchical task analysis

Introduction

There are several schemes underway to replace older signalling technology with digital signalling. Some of these projects involve removing lineside signalling and replacing it with the European Train Control System (ETCS). Conventional lineside signalling mostly comprises of colour light signals to control the safe movement of trains. ETCS brings signalling into train drivers' cabs and provides continuous information throughout the journey through a display in the cab called a Driver Machine Interface (DMI). ETCS has several levels of functionality depending on the system and trackside infrastructure, this project focused on ETCS Level 2 (L2) infrastructure and functionality. ETCS L2 constantly supervises train movement and provides continuous communication between the train and trackside creating a safer railway. ETCS L2 uses fixed-block technology which divides the track into sections so that only one train is running per section or block and at a safe distance. The system provides a Movement Authority (MA) which grants the train a distance to travel and is shown on the DMI. The ETCS sections or blocks are usually indicated through lineside signs called 'block markers'. In ETCS Overlay, drivers have to abide by both colour light signals and block markers and their corresponding MA.

The introduction of ETCS has an impact on many aspects of driver competence as it fundamentally changes the driving task in several ways. Route knowledge is a core aspect of driver competence that is impacted. For conventional lineside signalling, drivers must learn about the geographical features and cues along each route that they drive, such as location and name of stations, linespeeds, level crossings, and gradients. This is because the driver needs to anticipate route features before they become visible, for example they may start braking for a station several miles in advance.

ETCS provides the driver with certain information about the route through the DMI and may therefore reduce the need for drivers to memorise as much information for their route knowledge. This includes consideration of normal and degraded modes of operation. The aim of the project, therefore, was to understand how driver route knowledge will change for an ETCS railway compared to a conventionally signalled railway.

On the GB rail network, the current route knowledge requirements for lineside signalling are set out in Rail Industry Standard (RIS) RIS-3702-TOM 'Management of Route Knowledge'. However, there is no evidence-based, agreed understanding on the route knowledge requirements for operating under ETCS. Research is therefore required to define and validate route knowledge requirements for drivers operating under ETCS, in normal and degraded modes of operation, as well as transitions between signalling systems, i.e. between ETCS and conventional lineside signalling.

The project was split into two phases, the first phase aimed to produce a list of route knowledge requirements for a specific ETCS scheme on the South section of the East Coast Mainline (ECML). This was driven by the timescales of the ECML ETCS rollout, and the desire for it to be a template for other ETCS schemes across GB. Phase 1 of this project took the specific ETCS scheme design decisions of the ECML rollout into consideration and produced a set of route knowledge requirements for drivers operating over that route. The South section of the ECML runs between London King's Cross and Peterborough, and it is operated over by several passenger and freight companies, also known as Railway Undertakings (RUs).

Phase 2 of this project took the requirements from Phase 1 and identified how applicable they are to future wider ETCS implementations. While industry aims to create consistency between different ETCS schemes, there are already differences emerging in how ETCS is rolled out in different locations. Different schemes may decide to include different information on the DMI, and this will impact driver route knowledge requirements. Phase 2 explored the different ways in which ETCS can be implemented and how these different features may impact the Phase 1 route knowledge requirements. A set of operational criteria and guidance was then developed to enable railway operators to customise the Phase 1 requirements to their specific ETCS scheme.

Phase 1 Methodology

Phase 1 aimed to identify and validate the route knowledge requirements for driving with ETCS on the ECML, therefore it was necessary to understand the driver tasks when driving under ETCS, and how they differ from driving under conventional signalling. It was also important to understand the ETCS signalling system, and how it has been implemented in different schemes (including the ECML scheme). This was achieved through:

Understanding driver tasks. A detailed list of all driver tasks carried out under ETCS was compiled through:

1. Review of industry documentation such as Risk Based Training Needs Analyses (RBTNA), route knowledge training documents, cognitive task analyses, to build up a list of driving tasks for ETCS.
2. Cab rides and simulator visits were carried out with several RUs to observe driving tasks for different ETCS rollouts and in different geographical areas. The task list was partially validated and added to through observations from simulator visits and cab rides.

The driver tasks list was compiled and organised into groups within a spreadsheet. The list of tasks included all tasks undertaken by the driver during normal, degraded, and emergency operations under ETCS. The task list included transitions between signalling types, different ETCS levels and modes, and Overlay as well as No Signals.

Hierarchical task analyses were also produced and validated for a deeper understanding of certain key driving tasks that have been impacted by the introduction of ETCS. HTAs were completed on five key tasks from the initial task list to provide a more detailed understanding of how they are performed. These tasks were selected either because they were identified as being likely to significantly change under ETCS, or because they are heavily reliant on route knowledge. The

HTAs were validated by industry stakeholders and SMEs. HTAs were conducted on the following tasks:

1. Transition between conventional and ETCS signalling
2. Perform a shunting manoeuvre
3. Train at station (arriving & departing)
4. Transition from degraded ETCS mode back to normal operational mode
5. Train stopping at End of Authority (EoA)

Systematic Analysis of Tasks. Systematic review of ETCS driving tasks was undertaken to determine if they are underpinned by route knowledge. This was carried out through workshops with Human Factors, Signalling, and Operations specialists and resulted in a preliminary list of route knowledge requirements for ETCS. The questions posed in the systematic review included:

1. Is the task underpinned by route knowledge (considering passenger and freight)?
2. What route cue/requirement is needed?
3. What are the credible consequences of removing the route knowledge for this task?

The preliminary list of ETCS route knowledge requirements was then compared to the industry route knowledge requirements for conventional lineside signalling (which are stated in RIS-3702-TOM). It was also compared to RU specific ETCS route knowledge requirements that had been developed in isolation. This comparison activity was used to determine if there were any missing requirements which had not been discovered through the previous activities.

Risk Assessment Workshop. A risk assessment workshop was held to validate the proposed requirements with industry stakeholders and Subject Matter Experts (SMEs). These included:

- Driver managers and assessors from a range of passenger and freight RUs
- Driver, union, and infrastructure manager representatives
- Human factors, operations and signalling specialists

The workshop helped to identify which proposed route knowledge requirements are necessary by understanding the credible consequences of a lack of route knowledge for specific driving tasks. The workshop aims were to consider the potential route knowledge requirements for drivers under ETCS and to identify risks associated with removing these requirements. The next step was to remove requirements, where doing so introduces zero or negligible risk, and to either retain those introducing unacceptable levels of risk, or to endorse further analysis/study of proposals. Where possible, the workshop considered the specific ECDP trackside scheme design. The workshop systematically examined each potential route knowledge requirement by looking at:

1. Possible consequences of removing proposed route knowledge requirement under conventional colour light signalling
2. Possible consequences of removing proposed route knowledge requirement under ETCS (normal and degraded working, No Signals and Overlay).
3. Risk controls in place (including ETCS and route knowledge).
4. Deciding whether the proposed route knowledge requirement should be retained, removed, or analysed/studied further.
5. Any possible future risk controls.

Further analysis was conducted for requirements where an agreement could not be reached in the workshop.

Phase 1 Findings

Two lists of ETCS route knowledge requirements were developed and validated: one list for ETCS Overlay and one list for ETCS No Signals. There was significant overlap between the new ETCS route knowledge requirements and the existing lineside signalling requirements, however there were three key areas that they differ:

Linespeed. During discussions in the risk assessment workshop it was suggested that with ETCS L2, it may not be as important for drivers to memorise every change in linespeed along a route. This is because information about linespeed that drivers must memorise under colour light signalling will be provided to them under ETCS in multiple ways on the DMI.

It should be noted that ETCS does not provide speed information to drivers in degraded modes, however the maximum speed a driver is allowed to drive in degraded modes is 25mph. Therefore, the project concluded that drivers need to have a general awareness of the speed profile along a route but no longer need to memorise every speed increase and decrease. They do however still need to know all linespeeds below the maximum degraded ETCS speed.

This is a significant change for drivers, who previously had to memorise every linespeed increase and decrease. To put this into perspective on the South section of the ECML, there are currently approximately 170 linespeed changes that drivers need to memorise between London King's Cross and Peterborough. When applying the new route knowledge requirements, this number reduces to approximately 40. These figures were calculated using LNER route maps and counting the total number of speed changes and the number of speed changes under 25mph.

Junctions. During the risk assessment workshop, it was discussed that drivers may need to memorise less information about junctions due to linespeed being shown on the DMI and the train speed being supervised by the system. Under colour light signalling, the GB rail network operates under route signalling principles: the driver is told where the train is being routed to and expected to know the speed for that route. They therefore need to interpret junction indicator signals to ascertain where they have been routed to, and remember the associated speeds for that route. This will change under ETCS which is designed around speed signalling principles: it tells the driver how fast the train is permitted to go not where it is being routed, which is a significant cultural shift in GB rail. There are consequently proposals in many ETCS schemes to provide drivers with routing information through text messages on the DMI for some junctions. Drivers will therefore need to know when to expect and how to interpret these messages.

Taking all this information into consideration, and applying the same logic as with linespeeds, the project therefore recommended that drivers require a general awareness of junctions along the route including location and whether they can go over them. They no longer need to memorise the associated speeds (unless the speeds are less than 25mph). In the new ETCS requirement, drivers also need to be able to interpret routing information through text messages if necessary.

While the amount of information drivers need to memorise about junctions is also less under ETCS than under conventional signalling, the introduction of text messages for routing information was identified as a risk in this project. It is explored further in the risks section of this paper.

Signalling Information. Under colour light signalling, drivers are required to memorise all high risk or irregular signalling infrastructure and be able to interpret many different types of signals. This will be simplified under ETCS No Signals when colour light signals are removed and will consequently reduce the amount of information drivers need to remember. For example, there are

approximately 30 high risk signals that drivers must currently memorise on the South section of the ECML which will be removed when the route transitions to ETCS No Signals.

However, drivers will still need to know where to find irregular or high-risk block markers when driving under ETCS, and they will also need to be aware of transition points to ensure they are in the right level and mode of ETCS.

The project concluded that drivers need to know high risk or irregular block markers, signalling and Electrical Control Room (ECR) boundaries, transition points (location and what signalling systems they are travelling to and from), and Position Light Signals (PLS). The route knowledge for signalling information is simplified under ETCS, but it does introduce new tasks for drivers to anticipate and respond to transitions between conventional and in-cab signalling systems.

One key takeaway from Phase 1 was that the introduction of ETCS potentially places more importance on non-technical and functional skills and relieves some of the need for underpinning knowledge stored in long-term memory. Driving under ETCS requires drivers to manage their attention between the DMI and in front of the train. It also requires them to understand and interpret more information from within the train cab. By providing more information within the train cab, the need for drivers to memorise information (such as every linespeed change) decreases, and the need for drivers to understand the system and interpret this information increases. RUs will also need to consider how drivers can maintain their competence under ETCS, particularly when they only need to use some elements of route knowledge infrequently during degraded working.

Phase 2 Methodology

Phase 2 aimed to identify how applicable the route knowledge requirements identified in Phase 1 would be for other ETCS rollouts. The key steps included:

Consultation with ETCS rollouts. Discussions were held with RUs either currently operating under ETCS or planning for ETCS operations, to understand the differences between national and international rollouts. A variety of implementations of ETCS on the GB network were considered to better understand differences in design decisions between rollouts. The project also explored examples of international ETCS schemes to highlight the different ways it has been designed. The consultation with other GB and international ETCS schemes highlighted that there are many differences between rollouts that could have an impact on driver route knowledge. While it is important to learn from other international rollouts, it is more important to ensure there is a consistent approach across the GB rail network.

Classify Applicability of Phase 1 Requirements. Through internal workshops with human factors, signalling, and operations specialists, the Phase 1 requirements were reviewed systematically to determine their general applicability to other ETCS schemes. These sessions were also used to brainstorm what other factors or functions (e.g. technologies or procedures) might impact the applicability of the requirements. For each requirement the following questions were answered:

a. Which ETCS functions may affect the applicability of this requirement?
b. What other factors may affect the applicability of this requirement?
c. Is this requirement therefore generally applicable to all ETCS schemes or will it require review and customisation?

Some requirements from Phase 1 were deemed to be generally applicable in any foreseeable future ETCS scheme because there were no potential features of ETCS that could provide information about that route cue or remove the driving task. However, some requirements were identified as having the potential to be met by the ETCS system rather than through driver memory. This is because it was determined that there are potential ETCS features that could provide information

about that requirement or remove the driving task. These requirements could be reviewed by future ETCS schemes and RUs to determine to what extent they can be met by the signalling system and to what extent drivers need to retain information about them in their long term memory.

The initial classification was shared with industry stakeholders and SMEs. They were then taken forward to the Phase 2 Workshop for further review and validation from the stakeholders and SMEs. This workshop included the same roles as the Phase 1 workshop.

Develop and Test Guidance and Operational Criteria. After classifying the requirements and identifying which ones could be reviewed and customised, the project team determined what factors would need to be considered when reviewing these requirements. A set of six operational criteria and accompanying guidance was developed to support stakeholders in tailoring these requirements for their ETCS scheme design and to help ETCS scheme designers to understand the impact their decisions have on driver route knowledge.

The operational criteria concern if and how information is displayed on the DMI, and whether that information is reliable and distinct enough to be used as a method of providing route knowledge. If the ETCS scheme design meets all of the operational criteria for a particular route knowledge requirement, it may be possible to fulfil that requirement through the signalling system rather than relying on drivers' long term memory.

The development of the operational criteria started by asking the question: what would it take for drivers to be able to use information presented on the DMI for their route knowledge, as opposed to their long term memory? Out of that question, certain criteria emerged that were then grouped into the six final criteria. Guidance was drafted to accompany these criteria to help operators determine whether each criterion can be met.

To test and review the operational criteria and proposed guidance, a workshop was held with industry stakeholders and SMEs. Workshop attendees participated in a structured review of the guidance and operational criteria, testing and validating them through scenario testing. Workshop attendees were split into small groups to read through and discuss the proposed operational criteria and guidance. Each group then worked through a worksheet that provided a structured approach to reviewing the criteria using different ETCS scheme scenarios. The scenarios were selected because they each represent a function of ETCS that could have an impact on the applicability of a Phase 1 route knowledge requirement.

Phase 2 Findings

The output for Phase 2 was a set of operational criteria and accompanying guidance to support the review and customisation of ETCS route knowledge requirements. The guidance has been developed for two main audiences:

1. **ETCS scheme designers and Network Rail strategic roles.** Those involved in the design and development of an ETCS scheme, may use the guidance to understand the impact of certain design decisions on driver route knowledge. The guidance can help design an ETCS scheme with drivers at the centre and ensure that ETCS is optimised for driver needs.
2. **Driver competence managers and trainers.** Those involved in planning route knowledge training following an ETCS rollout, can use the guidance to decide whether any of the route knowledge requirements in RIS-3702-TOM can be met by the signalling system rather than through a driver's long term memory. To use the guidance for this purpose, the ETCS scheme design should be complete and decisions about the rollout made.

The guidance is specifically focused on driver needs in relation to route knowledge. While it considers some driveability considerations, wider driveability work and engagement with drivers is

needed when designing ETCS schemes. Additionally, it is vital that different ETCS schemes work collaboratively to ensure a consistent approach to ETCS across the whole of the GB rail network.

The operational criteria are:

1. The route cue associated with this route knowledge requirement is shown on the DMI.
2. The information needed for this route knowledge requirement is easy to understand on the DMI and never misleading for the driver.
3. The amount and type of information displayed inside the cab is manageable for the driver to maintain 'heads up' driving.
4. The information needed for this route knowledge requirement appears on the DMI in enough time for the driver to act on the information.
5. The information needed for this route knowledge requirement is detailed and accurate enough to support the driver in completing their tasks.
6. The route cue associated with this route knowledge requirement is shown in every scenario the driver may need to know it, either on the DMI or through another way.

As well as producing requirements and operational criteria, this project highlighted several risks associated with the introduction and deployment of ETCS on the GB rail network:

Routing Information through Text Messages. The introduction of ETCS No Signals will eventually lead to route indicators being removed at junctions and ETCS will be able to show text messages to inform drivers of routing information in some locations. By removing these route indicators under ETCS, drivers will not know where they have been routed until it is too late to challenge it. Careful consideration needs to be given to how and when routing information is provided to drivers, and what is expected of the drivers upon receipt.

Consistency between ETCS Schemes & driver route knowledge. A key risk that has been identified throughout this project is how ETCS schemes may differ from each other. While it is expected that driveability assessments are carried out for each scheme, there may be a gap in understanding the risks of transitioning between ETCS schemes, where operational rules and scheme design can be different and the impact this will have for drivers. This risk should be considered to ensure there is a level of consistency across the GB network and not every scheme is bespoke. This is relevant to driver route knowledge because drivers, particularly within freight RUs, may travel over several schemes, all with differing infrastructure, systems and nuances.

Transition Points. During the migration period between conventional lineside signalling and ETCS, drivers are exposed to a potentially more complex system of dual operation. In many ETCS implementation schemes, drivers are exposed to several types of transition between conventional signalling, ETCS Overlay, and ETCS No Signals. They will also increasingly be exposed to transitions between different ETCS schemes. There is already anecdotal evidence to suggest that these transitions can be confusing to drivers and lead to a potential increase in incidents. Operators should be aware of this risk, and efforts should be made to prevent confusion at transition points through comprehensive driver training and briefing, and through simplified design.

Overloading DMI. A risk was raised that ETCS implementation could bombard the driver with too many alerts and indications, distracting attention from other tasks and diluting the value of critical alerts. More information is not always better and if driveability is not considered through the design process, drivers can be overloaded with information that is not necessarily relevant or useful. It could also be confusing and misleading for drivers if different ETCS schemes take different design

decisions that affect driver tasks and the information they see on the DMI. This issue raises the importance of ensuring robust driveability assessments are undertaken to identify and mitigate risk.

Migration to ETCS. The migration from conventional signalling to ETCS signalling is a significant shift for the GB rail industry that will take many years. Trust in the ETCS system will be built over time for drivers as they experience different rollouts and grow accustomed to the new system. Driver confidence and trust in the system are essential to the success of ETCS. RUs should be mindful of this and ensure that the changes introduced by ETCS are gradual and handled carefully. For example, ETCS presents opportunities to supplement and support driver route knowledge and reduce the burden of retaining information in their long term memory. However, trust and reliance on ETCS to provide route knowledge information takes time and rushing this process may be detrimental in the long run.

Conclusion

This project aimed to facilitate a standardised approach to route knowledge under ETCS. It did this by producing a list of route knowledge requirements for a specific ETCS scheme, and then determining the applicability of this list to future ETCS schemes. The project developed tools to help operators review and customise the route knowledge requirements to fit their specific ETCS scheme and ensure a consistent approach across the industry.

The key outputs of this project are two lists of route knowledge requirements for ETCS: one ETCS Overlay and one ETCS No Signals, and a set of operational criteria with accompanying guidance to customise these requirements if needed. This project also highlighted a number of wider industry risks relating to driver competence and ETCS implementation which have been documented and can be escalated through further work. The outputs of this project will be published by RSSB and integrated into the RIS-3702-TOM for adoption across the GB rail industry.

Future research may also explore the route knowledge requirements needed for Automatic Train Operation (ATO) which was out of scope for this project but will become increasingly widespread in future years.

The introduction of ETCS impacts on many aspects of GB rail culture and practices. This is because it changes the industry risk profile by greatly reducing certain risks while introducing new risks elsewhere. ETCS also changes the driver task, therefore impacting driver competence, including route knowledge. It is important for industry to acknowledge these changes and support drivers' transition into ETCS by ensuring their competence requirements are understood and updated. This needs to be done on an industry wide level to ensure consistency across different railway undertakings and ETCS schemes. This project supports this industry goal by providing the foundation for robust route knowledge across the GB rail network.