Digital Simulation Modelling providing a platform for ETCS Driveability Assessments

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ABSTRACT

The development of a true-to-life, cutting-edge Digital Simulation Model of a train drivers experience operating with a future European Train Control System (ETCS) system has provided a platform for robust Human Factors analysis and has proven to be a success with the driver stakeholders.

KEYWORDS

Digital, Simulation, Model, Visualisation, Rail, Driveability, ETCS, Look-and-Feel, Innovation

Introduction

The digitalisation of the UK's Transpennine railway will see a transformational shift from conventional manual operations of train signalling to a semi-automated operation through introducing enhanced technology offering system protection control. ETCS is an in-cab signalling system allowing trains to run closer together, safely and to travel at their optimal speeds.

A driveability assessment has been carried out during the concept design phase of the Transpennine Route Upgrade (TRU) ETCS project to assess the route from the train driver's perspective in the new operating environment and conditions.

The cost and time for implementing digital signalling is under heavy scrutiny since Network Rail initiated their 'Target 190' industry-wide program to provide the capability to enable safe, affordable, and deliverable signalling to meet the future demands of the railway, (Network Rail, 2023). Digital simulation models can have multiple benefits to the rail industry. TRU project identified set of opportunities to harness the technology in conducting the driveability assessments, as presented in Figure 1.

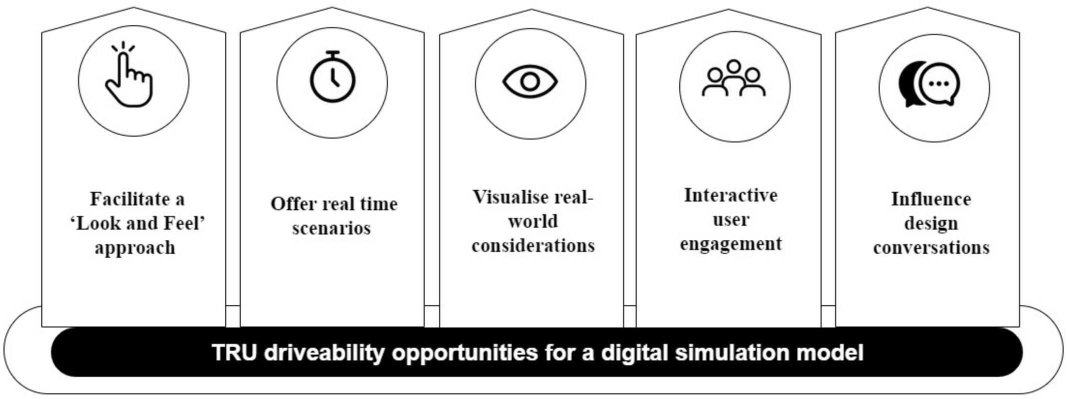

Figure 1: TRU driveability opportunities for a digital simulation model

The digital simulation model, Rail Signalling Visualisation Tool (RSVT), was developed by Arup UK on behalf of Network Rail to replicate the future state and present a representative 'look and feel' of the train driver's in-cab view. The RSVT allowed for virtual design reviews for the TRU in-cab signalling project. As a cornerstone of the driveability assessment approach the RSVT provided a multitude of benefits to the project analysis in operations, human factors, safety, and performance.

A traditional signalling design review process based on drawings is sub-optimal, significant signalling system experience is required, otherwise it can be very difficult for engineers and operators to interpret. The RSVT, a next generation digital simulation model of the rail environment provided a high-quality resolution rendering of the real world, whist augmenting the future state infrastructure using BIM (Building Information Model) digital models. The use of an off-the-shelf simulation package meant that the train movements could be calculated to represent the operational line speeds and motions over various operating scenarios.

The generation of RSVT, provided a valuable signalling concept design reference tool for stakeholders integration throughout the project user engagements. During the early project design utilising the innovative tool enabling understanding and acceptance without significant experience of operating cab signalling systems.

RSVT modelled scenario recordings benefitted the human factors task analysis and human error analysis methods applied to the project to best identify the preconditions in the concept design that give rise to errors before they occur. A detailed systematic review of the driver to rail system interactions could be conducted to understand the ETCS demands and potential task conflicts across the board harnessing the flexible replay and time-based specific functions particular to the RSVT.

Method

The TRU project driveability study set out to review the risks introduced by the conceptual ETCS safety system and determine how they should be appropriately managed through the design functions. It involved the development of the RSVT digital simulation model, a series of stakeholder engagement workshops, and an evaluation of the proposed future driving task with ETCS in operation.

RSVT Development

The RSVT model aimed to provide the complete future state route in a virtual design environment with the visual perspective of the in-cab driver. The tool set out to offer the ability to map the driver Driver Machine Interface (DMI) screen to the external environment. A mature visualisation tool was possible by inputs by connecting the environmental BIM modelling, high quality 3D rendering, and route specific train simulator technology.

Design development of the RSVT digital simulation model required an interactive and iterative process. It was imperative that the detail of the future route and driver DMI was accurately portrayed and any discrepancies with the proposed scheme plan concept could be eliminated. The tool design followed a review process which ensured it captured the proposed signalling scheme plan, existing route information, and future operating conditions to ensure visualisation validity. The operating condition are part of the ETCS reference design requirements specification, (European Railway Agency, 2007).

Driveability Workshops

Stakeholder driveability workshops were conducted to engage with train operators and experienced drivers. A common systematic approach was implemented to all workshops across the impacted areas. The future state train driving operating scenarios were followed and discussed in terms of the hazard precursors, (Rail Industry Standard, 2018). Documentation of any potential impacts identified from the workshop engagement were captured considering the following:

- Signalling information provided
- Display of signalling information
- Positioning of information in relation to driver's field of vision
- Time available to the train driver to comply with operating requirements.

The workshops provided a platform the discuss the current risk mitigations and explore potential mitigations with driver representatives offering a perspective of the effectiveness of the proposed considerations. The RSVT offered the opportunity to view the environment in real-time, pause and play back during key discussion points. It offered a richer level of engagement with the end user group in comparison with the traditional approach where signalling diagrams are reviewed.

The tool allowed the project to model the transitions between ETCS and conventional signalling, the visibility of trackside signage, and to review the route environment to identify any conflicts.

The driveability workshop presented a set of human factors (HF) issues based on simulation scenarios to capture in the project HF issues log. This was to further assess the risks, assumptions, issues, and dependencies identified from the discussion with stakeholders.

Evaluation of proposed future driving tasks

A literature review of the driveability analysis of ETCS, (Rosberg et al, 2021), and the transition to/from ETCS operations, (Rail Safety and Standards Board, 2016), provided examples of structured approaches to evaluate the future driving task considering the technology proposed to be introduced. RSSB produced a task analysis and a list of plausible driver errors for transitions across different signalling systems.

For TRU, a tabular task analysis captured the current driving duties in the impacted section and the driving duties in the proposed future design for normal and degraded operations, including the level transitions. Each task was decomposed to its lowest level of action, based on the information available to the project. These individual action were considered in terms of the sensory, cognitive, or psychomotor activity, required by the driver to achieve the task.

All plausible human errors from the task analysis were systematically reviewed to determine the measures required to mitigate the error producing conditions and minimise the consequences. Having the ability to share physical evidence from the RSVT results, dissemination of the identified risks with the designers and drivers was a more transparent, simpler validation process.

Results

Driveability Workshops

A summary of the driveability workshop findings particularly benefiting from the RSVT simulation model can be found in Table 1;

Table 1: Summary of driveability workshops considerations utilising the RSVT

Consideration Type	Consideration Description
Signalling information provided	Timing of the ETCS transition announcement indicator conflicts with existing Automated Warning System (AWS) acknowledgement information. ETCS indications expects not interfere with existing demand, shown in Figure 2.

Display of signalling information	DMI-monitored speeds should be aligned to the available trackside speed boards. The review should consider if any change to the speed board is required due to the identified potential overspeed.
	A release speed may be mistaken for an Movement Authority extension.
Positioning of information in relation to driver's field of vision	First signal at the transition point from ETCS to non-ETCS not visible due to track infrastructure and geography.
	Sighting of degraded Stop Marker Boards should be unrestricted to ensure drivers do not overspeed the maximum permitted speed under degraded working, as shown in Figure 3.
	Neutral Section additional driver warning needed. Driver is instructed to follow the instructions from the DMI, lineside signage would reconfirm the upcoming neutral section.
Time available to the train driver to comply with operating requirements	Consistency of the upcoming ETCS transition indication announcement timings with other ETCS applications across the network.

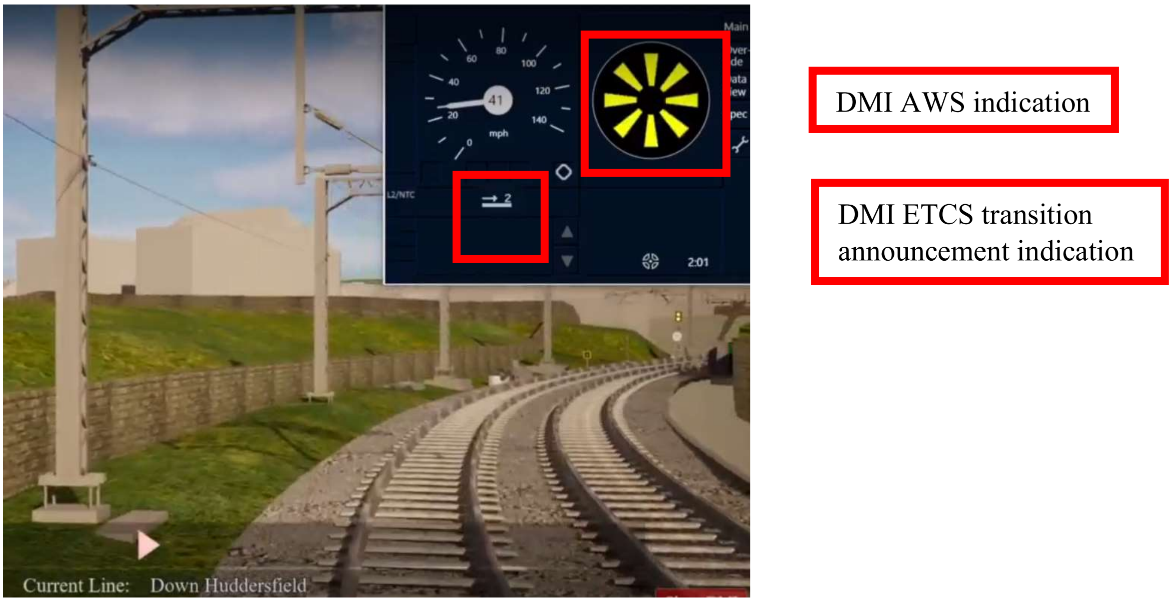

Figure 2: DMI ETCS transition announcement indicator and AWS task conflict

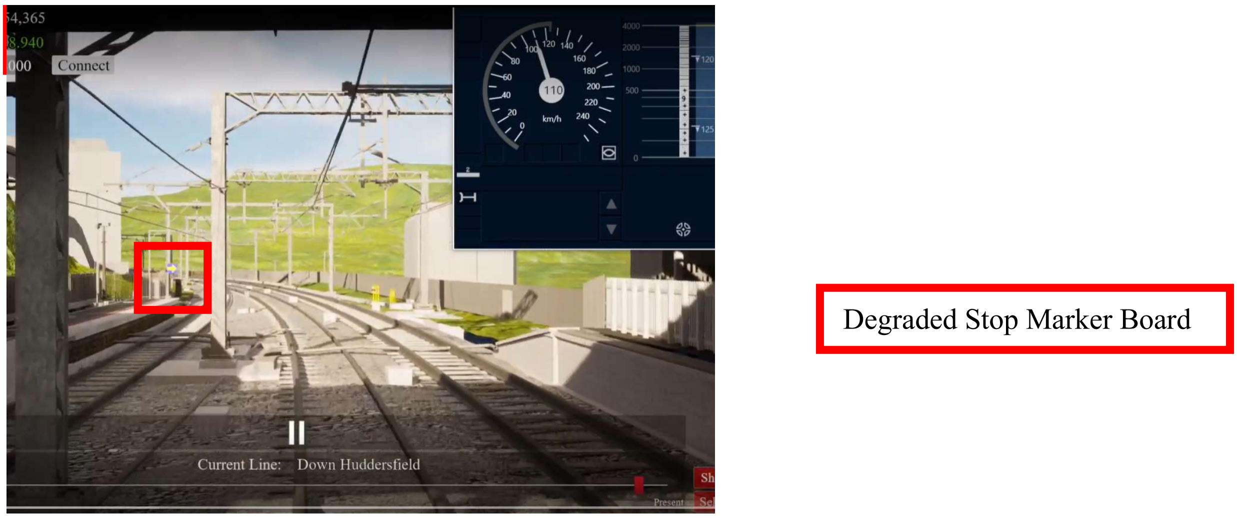

Figure 3: Degraded Stop Marker Board restricted sighting

Evaluation of proposed future driving tasks

The RSVT was used to review the future normal and degraded driving tasks whilst considering the existing driving functions to remain. Further physical and cognitive task conflicts were identified in addition to those captured in through the stakeholder engagement driveability workshops. Figure 4 and Figure 5 show two key considerations identified in the task analysis through the RSVT include;

Figure 4: DMI speed change indication distraction of station stopping duties

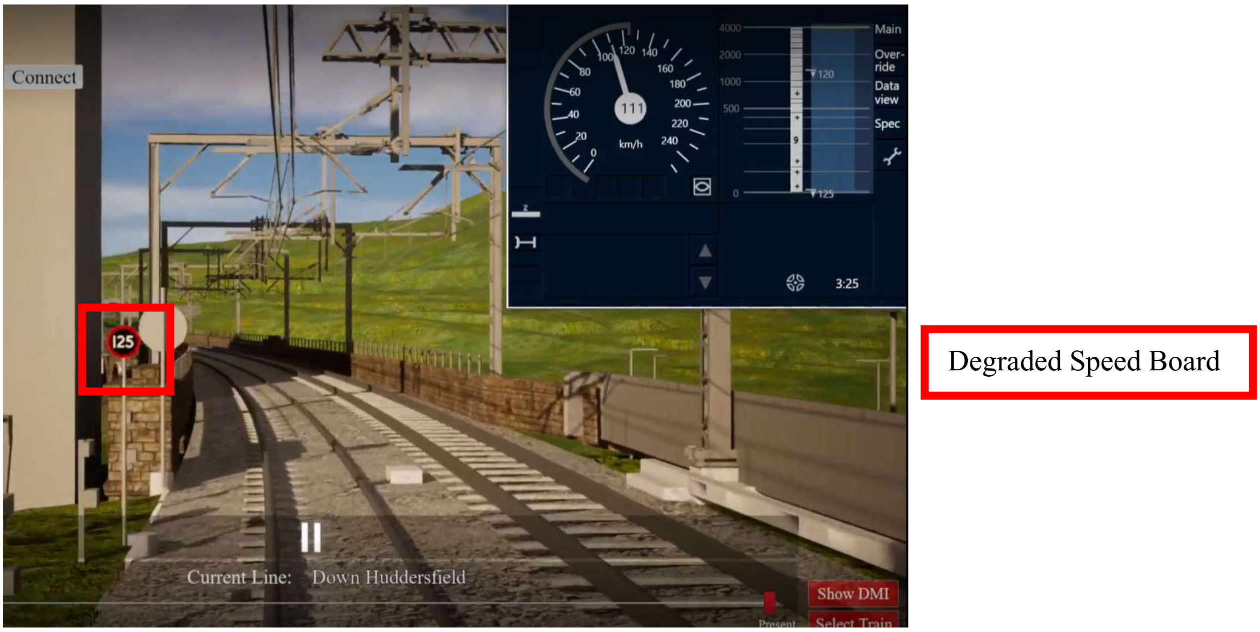

Figure 5: Presentation confusion of Degraded Speed Board

The human error analysis identified a set of plausible errors from the systematic review of the proposed future state driving task in the RSVT. A summary of key task conflicts or design limitations to potentially effect operations detected from the RSVT review are listed in Table 2. The table outlines the task impacted; the potential plausible errors; the TRU context specific error producing conditions; any safety or performance consequences; recovery opportunities available to the driver; and recommended project design and organisational measures to mitigate the error risks.

Task	Plausible Error	Error producing conditions	Consequence(s)	Recovery opportunities	Measures
Normal Operation					
Hear/sight ETCS speed change information on DMI	Information not obtained - Missed indication or not seen Check omitted- Driver fails to process the indication Operation mistimed	Conflict between the speed change indication presented at the same time as preparing for station duties. At location x speed change ETCS information estimated 15 seconds prior to speed change lasting 20 seconds. The indications expect to be present until approx. 10 seconds after location x. Drivers attention may be focused on approaching station duties and fail to process the information demands and operate the train faster / slower than the new limit permits.	Performance: Driver not prepared/anticipating speed change, and associated control required. Performance: Sudden braking from the system could result in harsh jolting of the train and impacting the passenger experience.	Both audible (beep beep) and DMI indicator presented. In some locations Driver's station duties expect to involve braking aligning with the intentions of the speed change indications. Once the speed limit has changed the hook will constantly show the new limit.	Suitable spacing of speed change indications away from approaching station. Driver competency assessment. Driver route knowledge.
Visualise approaching speed change in planning window	Information not obtained - missed speed change indication Operation mistimed	Internal focus on DMI speed indicator different to existing conventional speed change task. Speed change positioning prior to location x conflicts with Driver's demand to brake for the station. Speed increase missed by driver due to station duties.	Safety: Driver misses the prompt to decrease speed resulting in sudden braking from driver risking passenger safety. Performance: Service brake intervention control input stopping train and slowing the service.	Service brake intervention will prevent the driver from overspeeding. Station duties will require the drive to reduce the speed. Route knowledge of the speed change and station positioning not expected to change unless station proximity has changed.	Suitable spacing of speed change indicator from stations . Driver competency assessment. Route Krowledge.
Degraded Operation					
Sight degraded Speed Board (kph)	Check omitted Wrong information obtained	No speed board signage provided for the degraded trains after speed reduction in identified locations. Driver continues to operate at lower speed that permitted. Driver confusion as to where the permitted speed changes and increases the speed too early.	Performance: Driver continues to operate at a lower speed instructed. Delay to operations impacting network performance. Safety: Train exceeds the permitted speed risking train derailment.	Written order instructs driver to operate at a permitted speed unless instructed otherwise. Driver route knowledge expected to return to permitted speed at certain locations. Communication to signaller available to confirm changes in linespeed if Driver is unsure.	Signage design to be considered and positioned to signal sighting guidelines. Clear written order communication of the permitted speed.
Sight Km post	Wrong information obtained Wrong information communicated	Driver confusion between km posts and mile post coexisting trackside in ETCS areas.	Safety: Drive misinterprets the nearest signage when communicating the train location to the Signaller in degraded/emergency scenarios. Impact on signalling movements of train into potentially occupied track.	Design differences between the km posts introduced and the existing mile post. Yellow background and Km text to be included.	Signaller and Driver to confirm the train location unit. Consider the removal on Mile Posts in ETCS areas to avoid confusion. Route Krowledge.

Table 2: Summary of plausible human errors identified from the RSVT review process

Discussion

The driveability workshops and driver task evaluation design considerations prompted a series of risks mitigation design development hazard analysis reviews. A key ETCS design aspect is the positioning of the level transition from ETCS to non-ETCS train operation modes is required to offer the driver visibility of the first signal. The simulation model offered an opportunity to investigate how fit for purpose the design is from a drivers perspective. The RSVT demonstrated limitations of the concept design in a specific TRU context, due to the trackside infrastructure and track geography. The visualised early detection has led to the project reviewing the risk to driver and explore potential improvement opportunities in the advance project stages.

The results from driveability workshops identified the difficulty to sight degraded Stop Marker Boards in specific locations where the track curvature restricted the approaching driver's line of sight. Traditional concept design driveability reviews would likely fail to capture the risk where representative visualisation of the section would be absent. The project can utilise the RSVT during the development with the ability to trial repositioned boards in the virtual world before finalising locations. A similar approach is available with other physical ETCS assets introduced such as Cab Boards, degraded Speed Boards, Km Posts.

The participating stakeholders feedback was of an enhanced sighting experience through the accurate representation of the real-life rail environment. By making the simulations 'Look and Feel' so realistic it harnessed the personal ability and knowledge from the drivers, improving the collaboration and input to design through numerous context specific risk consideration generated.

The model provided a mechanism to accurately breakdown the proposed driver workload and demand in the design of future state operating conditions and produce a set of error vulnerabilities identified for driving in ETCS. By enhancing technical understanding of the functional changes for the train operators, the model uncovered design considerations of split attention and overloading around level transitions. The analysis has provided a mechanism to development the TRU specific signalling design and outline specific system design requirements.

RSVT will play an important role in the development of digital twins. There is an expanding industry need for digital twins for the railway and this is a trend that will only grow. RSVT allows change development, testing and visualisation within the digital twin first. This means solutions can be tested quickly and effectively, and thereby reducing the cost and time for deployment on the real railway.

Study Limitations

The application of the RSVT digital simulation model on TRU has three notable limitations. First, the RSVT driver interface information provided did not contain the full current and future state in-cab messaging, alarms and communications requiring the drivers demand and attention during the driving task. Secondly, the level of simulation fidelity varied across the TRU scheme impacting the representation clarity of the trackside environment in sections. The quality of the RSVT is reliant on consistent and accurate data inputs. Third and finally, the observer expectancy effect. The perceived expectations of the future operation can influence the people observing the set RSVT simulated scenarios. False positives portrayed in the scenarios could have influenced the stakeholders expectations and may have led to an unconscious bias.

Conclusion

The driveability assessment approach on the TRU project was enhanced by utilising the digital simulation model RSVT. The resulting design development considerations identified through stakeholder engagement and human factors analysis methods were enriched by the capabilities of

RSVT. It is recommended to apply such methods of technology to future signalling design reviews, both to detect valuable design risks in the early project stage and to improve the stakeholder engagement experience.

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