Achieving a step change in route knowledge management

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ABSTRACT

Route knowledge is the information required to predict, identify and interpret route specific cues to complete an operational railway task safely and effectively. Route knowledge in the rail industry is defined, trained and assessed in different ways at different companies and there was an opportunity to develop the Rail Industry Standard in this area to improve consistency. The objectives of this project were to review route learning processes within Great Britain and Europe, consider the implications of future technologies and define and validate a structured approach to route learning (the route story approach). The route story approach draws together a sequential list of route cues and details what the learner needs to know for each cue. It provides the minimum set of required route cues for safe operation and covers both route cue information and route risks for normal, degraded and emergency operations. This approach was tested in scientific trials with three train operating companies and case studies with a freight company and infrastructure contractor. The new approach was compared to existing approaches in terms of both usability and competence development. The trials indicated that the new approach is more usable than existing approaches and that it facilitates a more tailored approach to competence development, allowing companies to optimise their training time. The new approach has four key stages. 1. Define essential route cue types: a structured risk-based approach to determine essential route features 2) Create the route story. 3) Select materials/training formats and effectively assess competence. 4) regulate effectiveness of training processes.

KEYWORDS

Route knowledge, Train driver, Competence

Introduction

An initial study was carried out to review the requirements for route knowledge by the Rail Delivery Group (RDG) which involved 1:1 discussions with individual Train Operating Companies (TOCs) and Freight Operating Companies (FOCs). This initial project identified key issues and inconsistency with the way route knowledge is trained, assessed and refreshed. This inconsistency is partly due to ambiguity in the Rail Industry Standard (RIS) for Management of Route Knowledge for Drivers, Train Managers, Guards and Driver Managers (RSSB, 2014). RSSB were subsequently requested by the RDG to carry out research to build on previous RSSB research project T150 (RSSB, 2006) on route knowledge requirements for train crew.
The objectives of the project were to:

1. Document a description of what route knowledge currently is, from a task-based human factors perspective, by considering best practices in GB and other European practice.

2. Review technologies which can support route knowledge and novel approaches to competence development.
3. Draft a new approach for route knowledge competence development and retention. The new approach considers: the fundamental route knowledge information and proposals for optimised approaches to competence development including training, assessment and refresher training.
4. Based on practical trials, demonstrate that the new approach to route knowledge can be applied effectively in an operational environment and deliver benefits.
5. Develop a document which defines the new approach to route knowledge with supporting evidence and guidance accumulated throughout the project.

This project spanned three years and the detailed results from the project are available on SPARK (RSSB, 2018a).

Method

There were five phases of the project.

1. Review of route knowledge practices within GB and Europe.
Data were collected from eight GB case study organisations selected as a sample of the different types of railway undertaking. Data were also collected from three European countries (Germany, the Netherlands, and Switzerland). European case studies were selected because they have shorter route learning times than the GB average and different approaches to route knowledge training, including the more extensive use of technology. A range of data collection methods were used for the case studies including:

- Initial site visits to understand company structures, operating materials and route knowledge training processes.
- Focus groups with drivers of varying experiences to identify the variety of route knowledge requirements across different driver types (n = 21).
- One-to-one interviews to provide more in-depth information from drivers (n = 32).
- Cab rides to supplement the focus group and interview data with knowledge stimulated by being in the in-cab environment.

There was also a review of a route with Operations, Human Factors and Engineering specialists based on a talk-through of the route maps to identify which route cues would be used to control train speed and how they are used for a selected route.

2. Review of the impact of future technologies.
Train drivers have different route knowledge requirements in colour light signalling compared to when they are driving with other systems. Emerging technologies such as the European Traffic Management System (ERTMS) and Driver Advisory Systems (DAS) will impact on route knowledge requirements. There are also technologies that can be used in training such as tablets, heads up displays and simulations. The methodology for this phase of the work was a review of technologies with engineering and operations specialists, visits to five suppliers providing technology, a workshop to review a selection of key technologies from a multi-disciplinary perspective (operations, engineering, human factors and risk) and a blue-sky workshop to consider novel approaches to route knowledge. These workstreams concluded that the timescales for delivery of these new technologies meant that more immediate benefits can be derived from better describing route knowledge requirements for existing colour light signalling and optimising competence management processes before new technology is available.

3. Development of the framework for the route story approach.

This stage of the project comprised three activities which included a literature review of route knowledge, wayfinding and aviation literature, analysis of the role of route knowledge in incidents using the incident factor classification system (RSSB, 2018b) and creation of a framework for a scientifically-based approach for deciding the requirements for route knowledge initial training, assessment and refresher training.

4. Trials of the route story approach.

There were 3 trials completed with TOC's and case studies completed with a FOC and Infrastructure Contractor. The method for each trial is shown in Table 1.

Table 1: Methodology for trialling the route story approach

Trial company	Number of participants	Data collection method	Route details
TOC 1	8 trainee drivers	Regular interviews, questionnaires, competence measures (drawing exercises)	A busy commuter service
TOC 2	9 qualified drivers	Interviews, workshops, questionnaires throughout trial	19 mile route, 40 minute route with nine stations.
TOC 3	9 qualified drivers and 4 mentors	Workshops	98 mile route on the fast lines with differing stopping patterns
FOC	2 Operations Managers	Interviews	Not applicable
IC	1 Operations Manager	Interviews	Not applicable

Each company had different process for determining route knowledge requirements. The trials with TOC 1 and TOC 2 involved developing route learning materials, measuring competence development and drivers being assessed through their usual assessment process. The trial with TOC 3 was a usability study to gather feedback on the training materials. The interviews with the FOC and IC were to understand how the route story approach could be adopted into their operations.

The results from the trial with TOC 2 will be presented in this paper. The objectives for this trial were:

1. Driver route knowledge competence is measured throughout the trial in order to understand how it develops.
2. Route knowledge competence development is compared with Northern's existing processes.
3. The usability of materials are assessed.
4. Drivers route knowledge competence is assessed at the end of the trial.
5. Drivers, trainers and competence managers give feedback on their opinions of the trial.

The route selected for the trial was 19 miles and 40 minutes in duration. The current procedures for learning this route were an initial route brief and provision of route maps. Drivers then completed 11 trips over the route and spend 9 hours at a complex station. Any additional learning was down to each individual driver. Route competence was assessed using a multiple-choice test and an assessment with a driver instructor. It took between 4 and 8 days for participants to learn the route.

The route information for the trial were developed in interviews with 6 experienced drivers. The route story and materials were validated with experienced drivers and managers at the TOC. The route learning materials provided to participants during the trial were route maps (interactive and paper based), route booklet, and a blank printed map that could be annotated with drivers' own notes. The pre-trial phase involved briefing participants about the trial and materials and collecting background information. The trial phase was designed to monitor and record participants' competence development, and their feedback on the materials. Finally, the post-trial phase involved debriefing the participants, and collecting some final information from them about the trial.

5. Develop the final guidance for the route story approach.
The final guidance on the route story approach was developed in collaboration with industry representatives and is currently being incorporated in to Rail Industry Standard (RSSB, 2014)

Results

Development of the route story approach
"Abilities are relatively stable individual differences that are related to performance on some set of tasks, problems, or other goal-related activities" (Murphy, 1996) and, as wayfinding depends on a number of spatial and cognitive abilities (Muhlhausen, 2006) it is difficult to improve a person's wayfinding ability. Instead, other factors, such as task design and the information available should be taken into consideration to improve overall wayfinding task design, so that it is achievable by people with different wayfinding abilities. Currently, driver selection processes assess cognitive skills such as perception, memory and attention, which are important components of wayfinding, but not within a wayfinding scenario. Therefore, it could be postulated that drivers have different wayfinding needs and abilities.
The legibility of a route is the ease with which relevant cues or features needed to guide movement direction can be organised into a coherent pattern and is related to good wayfinding design. There is evidence to suggest that storing large amounts of route information in memory can impair a taxi cab driver's ability to carry out tasks involving the formation and retention of new associations involving visual information (Woollett & Maguire, 2008, 2011). While the findings are yet to be tested in a rail context, this could be relevant as high route knowledge requirements on staff may impair their ability to carry out safety-critical activities.

There are a number of different types of wayfinding task for train drivers: a journey, where the driver knows the start and end point and become familiar with the route through repetition and infrequently travelled unfamiliar routes. This means that there are different information needs for different journey types, where more external information may be required if a driver is less familiar with a particular route.

The aviation industry takes a different approach to route knowledge, compared with the rail industry, due to the fundamental differences between the industries. However, there are parallels that can be drawn. These include categorisation of airports based on complexity and tailoring training to reflect this, and pre-flight briefings to ensure pilots are confident with the route and the complex areas they will face throughout the journey.

The finalised definition for route knowledge developed throughout the project (validated in the literature and with subject matter experts) was: the information required to predict, identify and interpret route specific cues to complete an operational railway task safely and effectively. The required information must be available when needed for the task(s) being carried out, whether it is provided by long-term memory (through knowledge and experience) or through documentation/verbal advice.

It is important to consider route knowledge in the wider context of human performance and company/industry systems. System and driver performance models were reviewed and combined to produce the model presented in Figure 1. These models included the onion model (Wilson & Sharples, 2015) and a simplified model of the knowledge, cognitive functions, and processes that underlie locomotive engineer performance (Roth & Mullter, 2007). The rectangles at the centre of the framework essentially represent the member of train crew and the process that they go through in order to complete their tasks. As the project is taking a task-based approach it is important to recognise that these train crew elements of the model will vary by task. So for different tasks, route knowledge requirements and decisions will be different. The model highlights that route knowledge is one part of a task, which is combined with other skills and abilities for successful task performance. The outer layers describe the wider organisational context which impact on the task and route knowledge, including regulation, competence management systems, team working and company rules/procedures. The framework can support the standardisation of route knowledge competence management processes and was used to develop and deliver training materials as part of the live trials.

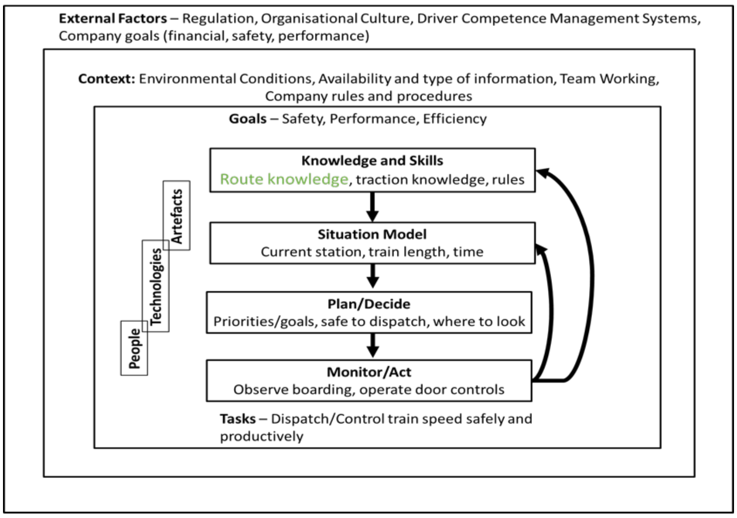

Figure 1: Route knowledge in the context of driver performance

Route story is the term given to the new approach to route learning developed based on the framework in Figure 1. A route story defines route knowledge requirements by drawing together a sequential list of route cues along a specific route, and detailing what the learner needs to know about each one. The knowledge requirement for each cue is based on the knowledge the driver needs about the cue to support a driver task, which may be to drive the train or for emergency and degraded modes. This is a significant step forward on previous practice, which defined the cues which drivers should know, but not necessarily why they needed to know about them from a task-based perspective. This is done for each line on a route and aims to be the minimal set of route cues required for safe operation. The route story covers both route cue information (e.g. station names) and route risks (e.g. irregular signal spacing) required for task. This approach was established in line with the Taking Safe Decisions (TSD) safety risk management framework (RSSB, 2018c) requirements.

Trial with a train operator

This section outlines the trial results with TOC 2. The trial aimed to provide quantifiable evidence that using the route story approach, drivers could reach the required competence for the route. Participants' competence was measured daily throughout their time route learning. This was done by self-rating their competence across different cue types, and answering a question set that were based on the route story. Driver competence increased each day during the trial and there were specific cues that were learned first with others built up during the trial. This supports the route story approach of building up route knowledge in stages. Some of the data even indicated that competence development began to level off, indicating that some drivers may be able to learn the route in fewer trips.

Self-ratings of competence development were compared between trial participants and experienced drivers. Experienced drivers' self-ratings were based on their memory of learning the route. The trial participants' ratings were significantly higher than the experienced drivers' ratings at the middle and end of route learning. It can therefore be concluded that route knowledge competence is acquired more quickly with the new approach, although it should be noted that this is based on subjective self-ratings. This finding was supported by the company route knowledge assessment, which all of the trial participants passed.

A total of 14 drivers (trial participants and experienced drivers) completed usability questionnaires about the new and existing route story materials. The route video, route story booklet, and printed map scored the highest, and their scores were significantly higher than existing route learning materials from that company. These materials were followed by the layered PDF map which was liked in theory, however drivers did not have access to mobiles or tablets when route learning so was not as practical as paper materials. The Excel route story list and the blank printed map scored the lowest. Different participants preferred different materials, therefore it is beneficial to offer a range of different materials and allow drivers to use the ones that suit them.

The trial concluded that 11 trips was a sufficient length of time for learning this particular route, and that some drivers may be able to learn the route in fewer trips. This is due to individual differences in drivers' learning preferences and ability, and different circumstances of route learning, such as how often a driver can drive the route, and the quality of information given by the other driver in the cab etc. This trial also highlighted that the timing of drivers' briefings can impact how quickly drivers' competence develops. Drivers that received their briefings on the first day of route learning scored higher in the daily probe questions. This indicates that for a route like this, it may be optimal to brief drivers as close to the beginning as possible. Drivers also reported that there was too much time spent at stations, which indicates another opportunity to condense the route learning.

The findings of the trial highlighted the variability in individuals' learning preferences and ability, and the differences in route learning experiences, thus indicating that a more flexible approach to setting route learning times may be optimal. As different people acquire competence at different rates, the amount of time set for route learning should reflect this and allow for drivers who are able to learn more quickly. Further assessments will need to be undertaken by this TOC to determine whether drivers were competent and would pass their assessments earlier during route learning

The trial achieved its main goal and provided quantifiable evidence that using the route story approach, drivers could achieve competence over the route and pass their assessment. All 9 participants passed their assessments and were deemed competent to drive over the route. However, there were some limitations on the trial. Firstly, participants could not be issued with tablets and therefore the electronic materials could not be used during a route learning shift. To mitigate this, the electronic materials were emailed to the participants and laptops were left in the depot. Feedback from participants indicates that the electronic materials were not used as much as if there had been tablets. The qualitative feedback highlighted the drivers' interest in using tablets, as several participants indicated that the layered PDF maps would have been more useful if they had access to tablets.

The route story approach incorporated into the final guidance

The final route story approach developed has four stages. The first stage is to define essential generic route features i.e. what cue types should be included in route knowledge training using a structured risk-based approach. This stage of the approach has been completed for train drivers under colour light signals as part of this project and an approach developed for other operational roles and signalling systems. Examples of the essential route features identified for train drivers in colour light signalling are junctions and station names. However, signals that are on the left-hand side in the direction of travel (or oriented consistently throughout out the route), located on plain line, clearly sighed, consistently spaced, post mounted, AWS fitted with no read through potential or route knowledge associated SPAD history would not comprise essential route knowledge. This omission will help drivers focus on the aspects of route knowledge that most effectively control risk and reflects how experienced drivers currently operate. It should be noted that a full risk management process will need to be done after making changes to route knowledge competence processes.

Once the essential route features have been established, a route-specific route story needs to be developed. This identifies the specific information for each cue. For example, junctions were identified as an essential route feature for train drivers. The development of the route story would then need to identify the associated information for junctions such as Haultwick Junction: no junction indicator required. Route stories can be started using existing materials but need to be validated with frontline staff or their managers (if they have experience completing the task) to ensure the correct information is provided. This validation is essential because the information contained in the route story is the basis for all the other learning materials.

The most commonly used training materials in route learning are route maps, videos and booklets. The route story approach includes the provision of these materials in both paper-based and interactive form. The use of interactive materials can utilise non-driving time. The interactive maps in the trials had a layering function which allowed competence to be developed by route feature. Learners could select or hide the different categories of information on the maps to simplify them initially, and build up the complexity over time. This means that the information that is visible can be customised to individual learners' pace and learning style. This approach provides guidance on a variety of training and assessment methods. This allows individual companies to select the most suitable training and assessment methods. However, the trials demonstrated that route learning assessment and monitoring processes can reflect the difference in pace of competence development by measuring when an individual has reached the competence level required as opposed to having a fixed time before assessments.

Companies can build up evidence bases for refresher requirements by assessing driver's route knowledge after longer periods of not driving a route. Memory fade does exist, and individual and task differences make the prediction of route refreshing requirements one where this project could not currently provide definitive limits. There should be a culture where drivers can raise the need for refresher training and also robust company systems to track when drivers have not driven routes for a period of time. Measuring competence accurately/frequently means that it can be accurately recorded when refresher training is needed. For example, whether route refreshing is required can be determined by using: quick assessments or cab rides to check on skill fade, quick discussions with the individual to establish confidence and competence, feedback from instructors and managers, written and/or verbal tests, self-rating confidence to drive the route, Driver requests for route refreshing.

There are three steps to monitor whether route learning processes are working as they should outlined in this approach: planning monitoring activities (and the data that can be used to monitor route knowledge activities), collecting and analysing the data and evaluating this data to determine if changes to route knowledge processes are required. The Taking Safe Decisions (TSD) safety risk management framework (RSSB, 2018c) provides guidance on the types of data, how data is collected and how it should be analysed.

Discussion

This project has identified good practice from GB and Europe, identified the implications of future technologies on route knowledge requirements, defined route knowledge and an approach to optimise the requirements, training and assessment and trialled this approach in live operational environments. The concept of the route story was easy to grasp by the trial companies. It provided a single and consistent description of route knowledge requirements and the feedback showed that the route stories contained all the necessary information to drive the routes safely and effectively. The trial companies found that the approach brought focus to the risk assessment process to ensure that the required information is included in route training. Inclusion of frontline staff into the development of the route stories ensured that the learning materials were accurate and reflected the way that routes were actually driven.

The trials in this project supported an approach of providing a suite of training materials to cater for individuals with different learning styles. The introduction of layers and interactive materials provides an opportunity to utilise non-cab time in route learning. The layered maps received particularly positive feedback due to their functionality to customise the information that is visible on the map. The route story is the basis of all the other training materials. This ensures that the different route learning materials display consistent information.

This approach introduced the concept of monitoring competence development continuously or at fixed time points during route learning. This means that learning is tracked and when the route learner is ready, an assessment can be undertaken. This was achieved during the trials through questionnaires and short 10-minute interviews. Adopting this approach to assessment allows for learners who develop competence more quickly or who require extra time to have their assessment when competence has been reached. Monitoring route knowledge development during learning also builds up the evidence base of the time it takes individuals to learn routes. This evidence base can be used to modify learning time allocations given to learn certain routes.

Overall, this approach provides clarity on what route knowledge should comprise and a comprehensive and robust approach to route learning which will bring consistency in route learning processes and standards across the industry. This approach has been trialled in industry and is therefore evidence based. The route story approach is currently being applied to the role of a guard and is being trialled for guards. The Railway Industry Standard is being updated to reflect the findings of this research.

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