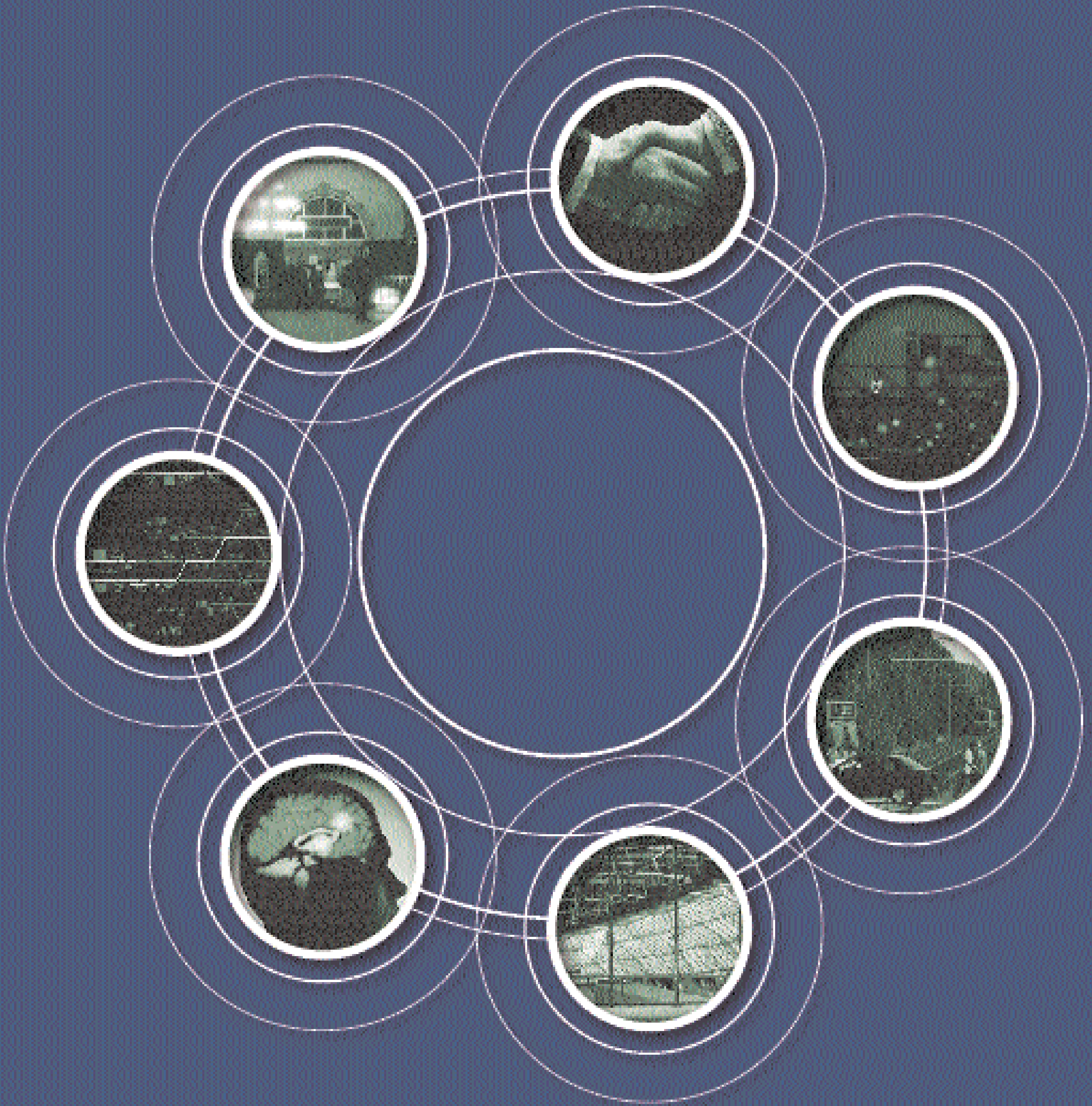
Rail Safety & Standards Board

Research Programme

Operations

Route Knowledge Study



Route Knowledge Study

Final Report

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Status of this Report

This report has been commissioned by Rail Safety and Standards Board as part of the Railway Safety Research Programme and produced by *Air Affairs (UK) Ltd*.

The findings, conclusions and recommendations contained in the report are those of *Air Affairs (UK) Ltd*.

Rail Safety and Standards Boards, on behalf of the rail industry, is currently considering the report's conclusions and recommendations, and what action needs to be taken as a result. A formal response will be issued shortly.

This report is strictly confidential and is not for copying and/or further distribution.

CONTENTS

ANNEXES

Executive Summary

Overview

This report presents the principal findings of a research study involving four separate work packages conducted for the Rail Safety and Standards Board (RSSB) into train driver route knowledge requirements. The report is intended to be used primarily by members of the railway industry involved in training, assessing or specifying requirements for drivers' route knowledge.

The report comments on current route knowledge training and assessment practices and describes training and assessment regimes appropriate to ensuring effective development of route knowledge. It discusses the relationship between route knowledge and driving performance, illustrating some of the potential consequences and causes of human error. Finally, it highlights some of the challenges posed by future technological advances to current route knowledge training.

Key Findings from the Study

1. The study's principal recommendation is that the rail industry should adopt a situation awareness based approach to the training and assessment of train drivers' route knowledge.

2. Analysis of incident data carried out as part of this study revealed that the most frequently identified route knowledge-related factor contributing to error related to the failure to monitor or observe relevant route information, i.e. not looking in the right place, for the right information, at the right time. Evidence identified that this is associated with a poor mental model[1] normally resulting from a train driver's:

   - lack of knowledge resulting from not having previously experienced the situation, such as driving in unusual climatic conditions
   - lack of knowledge associated with skill fade, having not experienced the situation for some time, such as driving a diversionary route
   - expectancy based on previous experience, such as over reliance on previous experience and expecting a signal to clear.

3. The study identified the training objectives (with associated knowledge, skills, behaviours) and cost effective media that could be used to train and assess route knowledge from a situation awareness perspective. In general it was found that the types of media currently used by train operators to train route knowledge could meet the additional training requirements, if used appropriately. Inconsistencies were found between operators, in terms of approaches to training and the media used, that could impact on the quality of route knowledge training. The following recommendations were made:

   a) Using route risk assessments to prioritise and guide route knowledge training is a sensible approach, but there is variation between operators in the methods used to conduct route risk assessments. Route risk assessment should be conducted to a common format, incorporating a standardised, systems-based set of risks (expanding on those identified in GO/RC 3551). Those responsible for assessing route risks would then be required to identify (and justify) specific risks as 'not applicable' for their operations or for specific routes. The report additionally recommends that results of this process should be used explicitly to inform the development of route maps and the route knowledge assessment process.

[1] Mental models are developed through training and experience, and provide a way to interpret and respond to information and situations. If a drivers' mental model is incorrect or inaccurate, this can lead to various errors.

b) Route maps are used by all operators in the training of route knowledge, and the study did not identify major problems with the content of route maps currently used by operators for driver training. In some cases, however, it was evident that drivers were being provided with excessive or unnecessary information about route features. In order to identify specifically what information to include or exclude, operators should first identify the target audience and explicit purpose of the route maps, and use the route risk assessment to prioritise the information contained within the maps.

c) Some of the cues currently used by drivers to prompt action do not meet the 'good cue' criteria developed as part of this study. Identification by drivers of braking cues are essential to the maintenance of situation awareness. Trainee drivers and route learners should be provided with information on the *characteristics* of good cues, to enable them to identify appropriate, route-specific cues when learning routes. Whilst the study did not conclude that guidance on specific cues should be provided during training, *if* cues are identified by instructors and mentors during initial training, operators should take steps to ensure that these cues are appropriate.

4. It is evident that retention of information on route features and route risks is in itself not sufficient to develop and maintain driver competence of routes. It is essential that assessment measures route knowledge from a situation awareness perspective, and that assessment is objective and consistent. Some train operators rely significantly on a driver instructor / assessor's subjective judgement and experience whilst assessing practical route driving, rather than ensuring that the assessment is undertaken against a pre-defined set of criteria. The following findings on the assessment of route knowledge from a situation awareness perspective were made:

a) The most cost effective methods for assessing situation awareness are:

- verbal protocol (whilst driver is driving a train)
- verbal protocol (whilst driver is conducting a train)
- instructors' use of pre-defined questions to assess real-time situation awareness (whilst observing the driver in a simulator or train).

b) Assessment of train driver route knowledge and situation awareness may require instructors and assessors to be provided with additional skills, to enable them to assess drivers' situation awareness effectively and consistently, during a cab ride.

Although the study focused on the current training requirements, consideration was also given to the impact of future technology on route knowledge and situation awareness. An outline process for assessing the likely impact of any new technology was described. Further work is likely to be required to quantify the risks to driver route knowledge and situation awareness from new technologies as their capabilities and operational characteristics become better defined. Information from studies conducted in other industries may be of use when considering the impact of new technology. A process for evaluating the relevance and applicability of information from other industries was developed and described.

The supporting data and copies of the work package reports 1 to 4 are to be made available on the RSSB Human Factors Research Catalogue CD Rom.

1 Introduction

1.1 Purpose of this Report

This report presents the principal findings of a research study conducted for the Rail Safety and Standards Board (RSSB) into train driver route knowledge requirements.

The report is intended to be used primarily by members of the railway industry involved in training, assessing or specifying requirements for drivers' route knowledge. It comments on current route knowledge training and assessment practices and describes training and assessment regimes appropriate to ensuring effective route knowledge development and retention. It discusses the relationship between route knowledge and driving performance, illustrating some of the potential consequences and causes of human error. Finally, it highlights some of the challenges posed by future technological advances to current route knowledge training.

This document describes the psychological nature and application of route knowledge sufficient to provide a basis for the results and observations reported. It does not dwell on the varied research, consultation and analysis processes conducted during the course of the study.

1.2 Further Reading

Those interested in a detailed explanation of the issues presented in this report should refer to the study's four technical reports, available from RSSB. These were produced during the course of the research, each reflecting activities performed in a study Work Package (WP), outlined below:

- The WP 1 Report (Ref 1) describes the tasks conducted to develop a psychological model of train driver route knowledge.
- The WP 2 Report (Ref 2) provides details of a high level training needs analysis, including assessment of current practice, specification of training objectives and evaluation of training media.
- The WP 3 Report (Ref 3) discusses the potential route knowledge-related risks resulting from introduction of major new technological initiatives.
- The WP 4 Report (Ref 4) presents an assessment of the relationship between route knowledge and driver performance, including analysis of the consequences of ineffective performance and the human errors involved in observable safety- or performance-related issues.

Copies of the above reports and supporting databases will be made available on the RSSB Human Factors Research Catalogue CD Rom (Ref 5).Each of these reports provides full details of research methods, industry consultation, results and analysis.

In addition to these reports, two software databases were generated:

- A database model of driver route knowledge, presenting collated evidence from industry and research sources in support of proposed model relationships.
- A literature database of research papers, incident reports, training materials and other documentation reviewed during the study, with keywords and reviewer summaries.

1.3 Industry Support

The study team wishes to thank the following companies and organisations, who provided invaluable support to the study by permitting interviews with key personnel, and providing comment, cab rides, technical and training information, route maps and incident data:

Table 1 – Companies and organisations that contributed to the study

Amec SPIE Rail (UK)	Freightliner Intermodal	Rail Training International
Amey Rail	GB Rail Freight	Scotrail
Arriva Trains Northern	GNER	Serco Railtest
Arriva Trains Wales	Grantrail Group Ltd	Silverlink trains
Association of Train Operating Companies	Halcrow	South Eastern Trains
Carilion Rail	Heathrow Express	South West Trains
Central Trains	Jarvis	Southern
Chiltern Railways	London Underground	Thameslink
CIRAS	Midland Mainline	Track Access Systems
Connex South Eastern	Network Rail	Transport Research Laboratories
Eurostar	ONE Railway	Virgin Trains
EWS Railway	Pennant	Visual Simulations Technologies
First Engineering	Primary Image	WAGN
First Great Western	RSSB	

2 Train Driver Route Knowledge Model

2.1 Introduction

Traditional approaches to route knowledge training focus primarily on memory and recall of route features and risks – signals, junctions, stations, line speeds and so forth. The Railway Safety Approved Code of Practice (RACOP) for train driving (GO/RC3551) identifies a theory-based training module, devoted to providing the sort of information that needs to be remembered about a route.

This focus on recall of static information about a route, however, doesn't tell the whole story. Consider the following example:

> *Drivers use route knowledge to recall the location of a signal. They also need to look at the signal as it comes into view, and correctly observe its aspect. They then need to use this information to add to their understanding of the current situation, and to plan for the immediate future (perhaps by slowing down or stopping, or by building a picture of events further up the line).*

The first bit of this example is pure route knowledge. The rest isn't really route knowledge, but clearly makes use of it, along with bits of rules and traction knowledge. The end result is an example of competent train driving.

It is broadly recognised that route knowledge is a fundamental constituent of train driving competence. GO/RC3551 uses the term *route competence* to reflect *'… the application of route knowledge, together with the knowledge, experience and understanding of the handling characteristics of the train and the underpinning rules and instructions, to driving over the route involved'.*

From the example above, and the description in the RACOP, it is clear that the demonstration of route knowledge is unavoidably related to the other components of train driving, including traction knowledge, rules and regulations. This means that route knowledge cannot be properly assessed without considering, or at least having in place, these other components.

Route knowledge assessment already acknowledges this. In addition to testing recall of route features, it also considers the *application* of route knowledge, or perhaps more accurately, route competence, whilst driving.

Route knowledge remains, however, very difficult to define – indeed part of this study has attempted to do this. Because it is so integrated with the other components of train driving, it is difficult to identify what the route knowledge elements actually are. This causes several problems:

- ❑ Standards and methods used for route knowledge assessment vary widely between train operators.
- ❑ Methods and media used to train and assess route knowledge vary widely, often with significant time and cost implications.
- ❑ Causes of safety-related incidents might be incorrectly attributed, and corrective actions incorrectly applied.

Referring back to the example above, it is clear that there is some other component of driving competence which is not route knowledge, traction knowledge, rules or regulations, but which draws on all of them. It uses this knowledge, together with information drawn from the environment, to provide an understanding of the current situation, to inform planning and decision making. This study uses the term *situation awareness* to describe this component.

2.2 Situation Awareness

Situation Awareness is a concept frequently used in other industries such as aviation, defence and road transport. It is also starting to be recognised in the rail industry. It is a practical means of describing and explaining some fairly complex psychological processes which underpin effective planning and decision making. The following definition and explanation of situation awareness is provided by Mica Endsley, a prominent researcher in this area:

> *Situational Awareness is the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.*

There are four main elements in this view of situation awareness:

1) **Extracting information from the environment.** This describes a *perception* process, in which an individual sees, hears, feels or otherwise obtains information.

2) **Integrating the information with relevant internal knowledge to create a mental picture of the current situation.** This describes a *comprehension* process, in which information is processed to create meaning.

3) **Anticipating future events.** This relates to using this information to plan and prepare (*projection*) for the immediate future.

4) **Using the mental picture to direct further exploration.** This shows that the process is cyclical, where understanding of the situation is used to inform the search for more information.

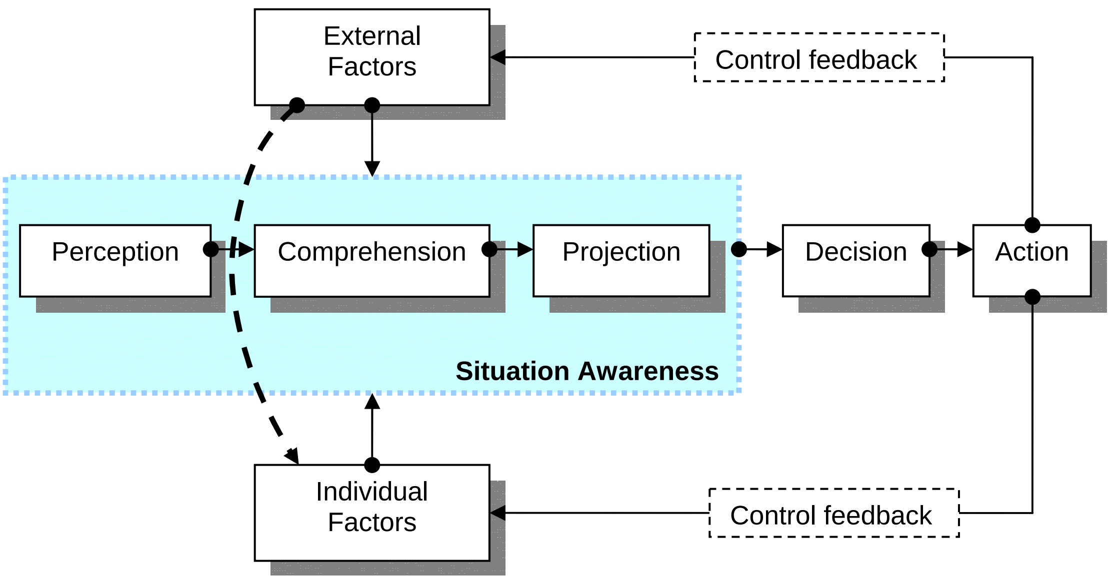
The job of train driving is made challenging and demanding by the need to use a significant amount of recalled knowledge, together with information about the current situation, to plan and make decisions, then to implement these decisions in a timely, effective manner.

Using this situation awareness based approach to describe some of the mental processes involved in train driving allows us to show how a range of information sources and other factors can influence the quality of decisions, which ultimately underpin driving competence. For the purposes of this study, it also crucially allows us to describe the role played by *static*, or unchanging, route knowledge – route features and risks – and *dynamic*, or changing, knowledge of the minute-to-minute state of the route being driven. It allows us to illustrate how situation awareness and decision making can be affected by a range of individual and external factors, and how inadequate static or dynamic route knowledge can directly relate to observable safety and performance issues. Finally, it allows us to identify sets of training objectives, with supporting knowledge, skills and behaviours, which together can form the basis of a route competence training programme.

2.3 Model of Route Knowledge and Situation Awareness

To develop a model of route knowledge and situation awareness (referenced in this report as the route knowledge model), the study team first prepared a structural model based on extensive research in this field. This resulted in the model presented in Figure 1. This model illustrates the three stages of situation awareness, their relationship to decision making and actions, and the potential relationship with individual[2] and external factors. Feedback is represented to illustrate that the process is cyclical.

Figure 1 – Route Knowledge and Situation Awareness Model



In order to test and populate this model, the study team undertook an extensive data capture exercise, involving:

- Interviews with train driving trainers, assessors and other experts drawn from across the rail industry.
- Series of cab rides, observing driver performance, and questioning the basis for decisions and actions both during and after cab rides.
- Video evidence from another study which used an eye-tracking device to record where drivers focused their gaze whilst driving.
- Reports and analyses from safety related rail incidents.

Analysis of this data resulted in the identification of driving decisions and actions which are informed by route knowledge and situation awareness, and a range of individual and external factors which might influence situation awareness (refer to Figure 2 for the finalised set of factors).

Information regarding the potential effects of the individual and external factors identified in Figure 2 on each other and on situation awareness were documented in the form of detailed statements. To illustrate this, consider the following example:

[2] Although not shown in Figure 1, relationships were also allowed *between* individual factors.

*The model identifies a relationship between the individual factors **Workload** and **Attention**. Sixteen statements were generated in support of this relationship, derived from research literature and interviews with rail industry experts. One statement extracted from research literature was:*

'When a train driver has a series of duties to perform at the same location, attention may get inadvertently directed away from a relevant lineside sign.'

Another statement, this time resulting from an interview with a train driving specialist, was:

'If a station is complex, drivers change their behaviour to be more attentive to what is happening around them'.

Whilst both of these statements describe characteristics of the relationship between workload and attention, the first identifies a negative consequence of high workload, whilst the second identifies a positive driver characteristic of increasing attention when required. These and other statements (more than 800 in all) were stored in a database which permitted them to be easily collated and reviewed. Each statement was coded to reflect its source (research literature, interviews, incident analysis), the type of effect described (negative, positive or neutral) and provided with a link to the source data. Confidence in the model relationships could be based therefore both on the detail of individual statements, and the breadth and quantity of corroborative sources.

Figure 2 – Route Knowledge Model Item Details

External Factors	External cues External environment Internal environment Onboard cues	Other people Service type Workplace organisation		
Individual Factors	Physical health Psychological state Stress	Attention Attitude Driving experience	Mental models / cognitive maps Recall of knowledge	Workload Personality Route experience
Decision	Control speed Move off Stop Communicate			
Action	Apply brake Apply power Reduce / remove brake	Reduce / remove power Operate voice communications	Operate non-voice communications Operate other equipment	

At the end of this process, individual and external factors were amended to reflect the findings of the analysis. Certain factors which research literature suggests should have an effect, such as driver aptitude (including perceptual speed, spatial ability), were not corroborated by interviews or incidence analysis. This observation is probably explained by the fact that the rail industry has careful selection and monitoring processes in place, which remove or significantly reduce the occurrence of certain factors.

2.4 Uses of the Route Knowledge Model

In itself, the model provides a description (with substantial supporting evidence) of the way in which diverse sets of information, including route knowledge, individual driver characteristics and external environmental factors, can influence situation awareness and performance.

The model also provided a structure for evaluating information from other industries, and comparing it with findings from rail industry sources. This should increase confidence in the applicability of information obtained from research literature, and mitigate some of the reasonable concerns that might be expressed regarding the relevance of, for example, airline pilot studies to train driving.

Relationship statements in the database were further assessed to identify those that supported, or could be mitigated by, any of the following six categories:

- training and assessment
- equipment design
- task requirements
- working environment
- selection
- workplace organisation.

This was done to support and focus subsequent study activities, including the identification of training objectives, conduct of error analyses and the identification of risk mitigation strategies.

3 Performance Analysis

3.1 Introduction

This phase of the study (Ref 4) involved analysis of the relationships between route knowledge, situation awareness and train driver performance. This was done to better understand how problems related to route knowledge and situation awareness might result in observable behaviours, ineffective performance and safety-related incidents. The analysis was conducted in the following stages:

- Identification of performance measures

  This stage involved the identification of the range of circumstances under which decisions identified in the route knowledge model (Control speed, Move off, Stop, Communicate) might be required. Once this was done, descriptions, or *measures*, of effective and ineffective performance were identified to define the scope of ineffective performance that might have a route knowledge component.

- Consequence analysis

  during this stage, a list of observable consequences of the ineffective performance was developed to enable consideration of the range of possible outcomes, and to enable prioritisation of the examples of ineffective performance for use in other phases of the study.

- Identification of causal factors

  This stage involved consultation with rail industry specialists and review of rail incident data to explain the possible real-world reasons, or *causal factors*, that might contribute to ineffective performance.

- Human error analysis

  This stage investigated the potential psychological mechanisms behind the identified causal factors. Having done this, the error mechanisms were mapped onto the individual factors and external factors identified by the route knowledge model.

3.2 Identification of Performance Measures

<u>Identification of Circumstances</u>

Circumstances were developed for each decision through consideration of the range of mainline train operations, review of relevant Railway Group Standards, task analysis data, and discussions with industry specialists. Consideration was given to the needs of different train operators (e.g. the need for passenger trains to stop at platforms and for freight trains to comply with Railway Group Standard GO/RT3973 – Conveyance of Exceptional Loads when controlling speed).

To illustrate this process, Table 2 provides an example of the circumstances associated with the Decision 'Stop'.

Table 2 – Circumstances under which the Decision to 'Stop' might be appropriate

Decision: Stop
At a red signal/stop sign

Decision: Stop
At a station platform
At a buffer stop
In an emergency
At a station not usually stopped at (i.e. not in planned stopping order)
In response to passenger operating emergency alarm
While engineers work
At a siding
At points fitted with indications
At incorrect route indications

<u>Identification of Effective and Ineffective Performance</u>

This process involved the identification, in consultation with industry specialists, of the effective and ineffective performance associated with each decision, under each of the circumstances under which that decision might be taken.

To illustrate this process, Table 3 presents the effective and ineffective performance identified for the decision *Stop* in the circumstance *At a station platform*.

Table 3 – Effective and ineffective performance associated with the decision '*Stop*' under the circumstance '*at a Station Platform*'

Decision	**Stop**
Circumstance	**At a station platform**
Effective Performance	**Ineffective Performance**
Stops train at appropriate stop point for train length.	Stops short of appropriate stop point.
	Selects inappropriate platform markers for train length/type.
	Stops beyond appropriate platform stop markers.
	Fails to stop at platform.
	Fails to stop at appropriate point to view platform monitors.
	Fails to inform passengers that this is not the appropriate stopping point.
Ensures that correct doors are opened in	Opens the incorrect doors for platform side.

Decision	Stop
relation to platform side.	
Ensures that platform length is appropriate to train length.	Fails to ensure that platform length is appropriate to train length.
Stops train in response to signal aspects along platform.	Fails to respond appropriately to signal aspects.
Stops train 2 metres from other train in platform.	Fails to stop train 2 metres from other vehicle.

3.3 Consequence Analysis

The consequence analysis identified a range of real-world, observable events that might result from inadequate route knowledge. The following list of consequences, each associated with one or more examples of ineffective performance, was developed through review of information sources and discussion with industry specialists:

- collision
- delays while correct position is achieved
- derailment
- loss of time
- passenger discomfort and/or injury
- SPAD
- station overrun
- station underrun.

These potential consequences were assessed and allocated as required to each ineffective performance measure identified. Table 4 provides an illustration of this process, showing the consequences associated with the ineffective performance measure *stops short of appropriate stop point*.

Table 4 – Consequences identified for the ineffective performance measure '*stops short of appropriate stop point*'

Consequences
Station Underrun
Passenger discomfort and/or injury
Delays while correct position is achieved
Collision

3.4 Identification of Causal Factors

To understand how ineffective performance associated with route knowledge can be addressed, it is first necessary to understand why it might occur.

This stage generated real-world descriptions explaining ineffective performance. These descriptions were termed ‘causal factors’. Two sets of causal factors were prepared, one through consultation with industry specialists, the other from analysis of rail incident data. An example of causal factors generated by industry specialists, associated with the ineffective performance measure ‘*stops short of appropriate stop point*’, is provided in Table 5.

Table 5 – Causal factors associated with the ineffective performance ‘*stops short of appropriate stop point*’

Causal Factors
The train driver thinks they are driving a train of length X, but are in fact driving a train of length Y. This could be due to presuming they are driving the train they usually drive at that time (e.g. off-peak trains operate with fewer carriages) or because they are driving a train they are not used to driving.
The train driver is aware that they need to stop at the next station, but selects the incorrect position to bring the train to rest.
The train driver is distracted by passengers on the platform.
The train driver has never stopped, or stopped infrequently, at that station and therefore selects the wrong braking point.
The train driver is looking out for car stop markers, but the station does not have them.

3.5 Human Error Analysis

Human error can be defined as inappropriate or undesirable behaviour which has the potential to reduce effectiveness, safety or system performance. Human error analysis provides a range of methods to investigate those factors that can affect an individual’s performance.

This stage of the process prepared a description of the psychological mechanisms underpinning each causal factor. This stage comprised the following activities:

- ❑ Classification into error types.
- ❑ Identification of influencing factors.

<u>Classification into Error Types</u>

This activity involved the classification of causal factors associated with ineffective performance and incident data. The classification process adapted a situation awareness error taxonomy used by Mica Endsley. This taxonomy, reproduced at Table 6, reflects the components of situation awareness described in the route knowledge model – Perception, Comprehension, Projection – and is provided here to illustrate the role of the route knowledge model in examining performance issues.

Table 6 – Error Taxonomy (adapted from that developed by Mica Endsley for use in several situation awareness studies)

High Level Error Type	Error Type	Description
Perception - failure to correctly perceive information	Data not available	Data may not be available to the person, due to a failure of the system design to present it or a failure in the communication process.
	Data hard to discriminate or detect	The data is available, but is difficult to detect or perceive, e.g. inadequate light, obstructions blocking view.
	Failure to monitor or observe data	The information is directly available but for various reasons is not observed or included in the scan pattern. This can be due to several factors, simple omissions, external distractions or high task workload.
	Misperception of data	The information is attended to, but is misperceived, often due to the influence of prior expectations (for example, the signal is 'always' green, and is misread on the occasion when it is not).
	Memory loss	Person may initially perceive some piece of information but then forgets about it.
Comprehension - failure to correctly integrate or comprehend information	Lack of or poor mental model	Whilst information has been perceived, its significance or meaning is not comprehended due to the absence of a good mental model for combining information in association with pertinent goals. This frequently occurs in automated systems, in which the operator is insufficiently 'in-the-loop' to comprehend information perceived.
	Use of incorrect mental model	The incorrect mental model, probably from a similar system, may be used to interpret information, resulting in an incorrect understanding or diagnosis of the situation in areas where the systems are different. A common problem is where people adopt a mental model, then interpret all perceived cues into that model, leading to an incorrect interpretation of the situation (for example, the driver might think that they are further down the track than they are, and 'fit' position-notifying cues into this model.

High Level Error Type	**Error Type**	**Description**
	Over-reliance on default values	The operator over-relies on default values in mental model. These defaults can be thought of as general expectations about how parts of the system function, in the absence of real-time information. In other cases, reliance on habitual expectations about the behaviour of the system may preclude comprehension of current data, even when it is available.
Projection - failure to project future actions or state of the system	Lack of or poor mental model	In this case, even though an operator has adequately comprehended the situation, they may still be unable to correctly project (predict) what this means for the future due to them having a poor or incomplete mental model of the situation.
	Over-projection of current trends	The operator assumes too much about the future situation, based on current trends. This may result in selection of inappropriate decisions or actions (although the decision/action may be entirely appropriate for the operator's picture of the situation).

If causal factors are the *real-world* reasons why problems arise, error types give an indication, from a situation awareness perspective, of the psychological processes that might give rise to the problem. Causal factors were collated and assigned one or more error types. An example of the results of this classification of error types is provided in Table 7.

Table 7 – Classification of error types relating to two causal factors associated with the ineffective performance '*stops short of appropriate stop point*' (refer to Table 5 for identification of Causal Factors)

Causal Factor	**Failure to correctly perceive information**	**Failure to correctly integrate or comprehend information**	**Failure to project future actions or state of the system**
The train driver is distracted by passengers on the platform.	Failure to monitor or observe data		
The train driver is looking out for car stop markers, but the station does not have them		Lack of or poor mental model	Lack of or poor mental model

Principal results of this process are presented at 3.6 - Section Summary, to illustrate the relative importance of particular types of error in reducing driver performance, and to highlight some of the differences between information generated during discussion with industry specialists and that generated from analysis of rail incident data.

Identification of Influencing Factors

The route knowledge model predicted that a range of individual and external influencing factors might impact situation awareness or its component parts. Causal factors identified previously were assessed, and associated influencing factors identified from those provided by the model.

Principal results of this process are presented at 3.6 - Section Summary, to give an indication of the relative priority of the model's influencing factors in affecting driver performance.

3.6 Section Summary

Observations relating to the consequence analysis:

- Different ineffective performance can result in the same observable consequence. For example, thirty-four examples of ineffective performance, derived from all four Decisions, were shown to have the potential to result in a SPAD.
- Consequences associated with ineffective performance can exacerbate route knowledge related performance issues. For example, overrunning a station may lead to a driver being required to perform an infrequent, wrong direction move to return to the correct stopping point.
- Consequences associated with ineffective performance can have route knowledge related impacts on other drivers. For example, delays caused by one driver's inadequate performance may result in the driver of the following train experiencing more cautionary signal aspects than usual.
- Consequences associated with ineffective performance range significantly in their severity, from minor delays to derailments and collisions.

Observations relating to the identification of causal factors

- All examples of ineffective performance were shown to have causal factors associated with route knowledge.
- The causal factor most commonly cited by industry specialists was 'the train driver tried to reduce speed, but didn't allow for the effects of weather or gradients on braking'.
- Some causal factors were shown to result in different ineffective performance. For example, the train driver being distracted by people on the platform was cited as one explanation for the following examples of ineffective performance:
    - stops short of appropriate stop markers
    - selects inappropriate platform markers for train length/type
    - stops beyond appropriate platform markers
    - fails to stop at appropriate point to view platform monitors
    - fails to respond to signal aspects along platform.

Observations relating to the human error analysis

- From the HE analysis and discussion with industry experts it can be concluded that incidents were not caused by the necessary information needed to perform the task (in the external environment, through cab interfaces or by communication from others) being unavailable to the driver.

- The most frequently identified causal factor found in the incident data related to a *perception* error relating to a failure to monitor or observe data – not looking in the right place, for the right information, at the right time. Conversely, the two causal factors most frequently identified by industry specialists related to two *comprehension* and *projection* errors relating to a poor mental model - information stored in long term memory about a system, equipment or environment that is used to interpret and contextualise new information. Evidence from real-world data identified that this poor mental model usually resulted from a train driver's:

  - lack of knowledge resulting from not having previously experienced the situation, such as driving in unusual climatic conditions
  - lack of knowledge associated with skill fade, not having experienced the situation for some time, such as driving a diversionary route
  - expectancy based on previous experience, such as expecting a signal to clear.

  Whilst the study was not able to investigate reasons behind this observation, the situation awareness based approach to determining route knowledge training requirements addresses both perception and comprehension related performance issues.

- Another set of errors, identified by industry specialists and to a lesser extent from incident data, related to misperception of information. This occurs when a driver looks for information, such as a signal aspect, in the right place and at the right time, but fails to correctly read the data. This can happen when drivers have prior expectations of the state of the situation, and fail to notice when the situation differs from these expectations. This effect can be mitigated by consciously checking and confirming their expectations, and learning not to over-rely on acquired experience.

- More than twenty influencing factors were initially identified as potentially affecting train driver performance. Several of these, including physical health, aptitude and personality, were not confirmed to have any observed effect during the analysis of incident data or discussion with industry specialists. The most likely explanation for this is that controls already in place (selection, monitoring) are effective in mitigating negative effects. It is worth noting, however, that several operators reported that existing psychometric selection tests were prone to being 'fooled' by some potential recruits, and that work was underway to revise selection processes.

- The following influencing factors were identified as being most likely to affect situation awareness, decision making and driver performance:

  - <u>External Cues</u>. These include any environmental features, such as lineside infrastructure (including signals and signage), landmarks, people and animals. Other identified effects related to the potential confusion and misinformation generated by poorly positioned signals, signage and lineside clutter. Also commonly identified were distractions resulting either from unexpected events (such as animals, vandalism) or predictable events (including track-workers, customers on platforms). These issues can be mitigated through improved situation awareness and training in how to avoid distractions and appropriately focus attention.
  - <u>Recall of Knowledge</u>. This refers to working memory, long term memory and the process of retrieval of information. Related effects were frequently identified by industry specialists and to a lesser extent from incident data. These related to forgetting or failing to recall important information (stopping stations, previous signal aspects, location of information, speed restrictions). It suggests that current regimes may not be adequately addressing issues relating to knowledge and skill decay. These issues can be mitigated through improved situation awareness.
  - <u>Mental Model.</u> This term was described above as information stored in long term memory about a system. Mental models develop through training and experience, and they provide a way to interpret and respond to information and

situations. People use many different models in response to different situations. If a driver's mental model is flawed, or if they use an incorrect model, this can result in various and wide-ranging problems. Perhaps for this reason, it was the influencing factor most often identified during discussion with industry specialists, and was commonly identified from incident data. A typical and common example of error relating to a poor mental model is the case in which a driver believes they are further down the track than they are, and then fits landmarks and other information into this model until something significantly 'out of place' (such as a bridge, junction, station or signal) triggers the realisation of the mistake. This could be seconds, or possibly minutes later, during which time various errors could occur. Some of the problems associated with poor mental models can be mitigated by training in attention distribution and self-checking skills, as well as training to develop the appropriate mental models.

- In some cases, influencing factors were identified to have both a positive and negative potential impact on performance. Taking the example of driver experience, whilst inexperienced drivers may drive more reactively (by failing to predict and plan for future events), experienced drivers may *over*-project current trends, potentially resulting in expectancy-related errors.

The results of this assessment were used to focus training and assessment investigation in later phases of the study.

4 Training and Assessment

4.1 Introduction

This phase of the study (Ref 2) focused on issues relating to route knowledge training and assessment. A variety of activities were conducted, grouped in the following stages:

- **Review of current route knowledge training and assessment** – to identify current good practice, and related issues identified by railway industry stakeholders.
- **Development of route knowledge and situation awareness training objectives** – presented together with their supporting requirements in terms of knowledge, skills and attitudes.
- **Review of training and assessment media solutions** – to identify those that may be effective in addressing the varied route knowledge and situation awareness requirements.
- **Identification of improvement strategies** – which might help to address some of the issues identified.

The section concludes by providing a summary of the findings and recommendations of this stage of the study, designed to identify opportunities for sharing good practice, improving standards and directing further investigation.

Because of the wide variation in operators' existing training and assessment strategies, it is worth commenting on what might be drawn from this section. Several operators are already addressing many of the issues and requirements presented in this section of the report, and will perhaps find little that is new or surprising. Others will perhaps regard a number of the results as inappropriate or irrelevant to their needs. It is hoped that many will identify opportunities to improve, refine or standardise their current practices.

The report (Ref 4) provides a possible framework for the closer integration of currently disparate, and in some cases omitted, elements of route knowledge and situation awareness training. It supports a more objective approach to the assessment of route competence. It provides detailed training and assessment content, and descriptions of possible solutions. The report does, however, require operators to consider the implications of the report from their particular perspective. Operators have very different needs, priorities, operational and logistical concerns. The study considered issues from a national level; because of this, its focus is on trends, key differences and general requirements. Results of this work need to be tailored to meet operators' specific requirements and circumstances.

4.2 Current Route Knowledge Training and Assessment

This stage of the study reviewed operators' current route knowledge training and assessment in the following areas:

- training and assessment media and methods
- route maps
- route risk assessment
- issues associated with route knowledge training and assessment.

Training and Assessment Media and Methods

Table 8 provides a summary of the results of a survey of 18 operators (11 passenger, 2 freight, 5 infrastructure maintenance contractors (IMC)) investigating the use of training media and methods in three phases of driver training.

Table 8 –Training Media and Methods

Type of Media	Percentage of Operators using media		
	During initial training	After qualification for new routes	For refresher training
Sectional appendices	100%	100%	93%
Route maps	100%	100%	100%
DVD or video	94%	81%	80%
Interactive DVD or video	33%	51%	40%
CBT	11%	7%	0%
Driving simulators	13%	16%	17%
In-service trains	100%	100%	100%
Route learning train	19%	33%	33%

The study team made the following observations during this activity:

- A minority (<20%) of train operators use high technology based media (CBT and simulators). These were typically those operators with large numbers of drivers.
- The degree to which route learning media are used either with an instructor or for self-study varies according to type of training. In general, refresher training tends to rely more on the driver undertaking self-study.
- The practice of route signing during initial training varies by operator. Some operators have trainees learn a relevant route during practical handling. Others do not require trainees to sign routes, but do conduct training over routes the trainee will drive over on completion of training.
- All train operators use in-service trains for route knowledge training. The way in which these are used varies by operator and phase of training. Some operators provide instructors or mentors to provide in-cab training. Others provide trainees with cab passes that allow them to accompany an experienced driver, providing exposure to the route, but no formal training.
- During route knowledge training, some train operators may use in-service trains that are different to those which the driver will go on to use. Freight and IMC drivers in particular may need to do this, because access to a particular route may be otherwise unavailable. One Intercity operator reported that their trainees needed to travel on slower, stopping services so that they could develop awareness of signals showing cautionary and stop aspects.
- The majority (>80%) of operators monitor drivers' route knowledge training requirements within a formal competence management programme. This typically includes a route risk assessment to determine refresher training periodicity and details of the frequency at which a driver must drive over the route to remain current. Drivers are also responsible for monitoring their own route knowledge and

indicating if they require training. Operators reported encouraging drivers to inform their management of any issues associated with their route knowledge.

- The assessment of route knowledge by train operators for both new and experienced drivers is primarily conducted using in-service trains. This may be supplemented with a written or verbal examination. During the practical assessment, instructors typically use their judgement of the driver's general route competence, based on their performance whilst driving over the route and use of specific questions during and immediately after driving.
- A number of operators reported encouraging drivers to provide a running commentary during assessment of route knowledge. It was identified that this technique is more often used during refresher assessments than during initial route knowledge assessments. Train operators indicated that running commentaries were useful, but that not all drivers were comfortable with this form of assessment.
- Operators report basing calculation of the duration of route knowledge training either on their own in-house route risk assessments or on union norms.

Route Maps

The study did not include undertaking a detailed review of route maps, however, the following suggestions are made to improve the effectiveness of route maps used for training purposes:

- The intended audience and purpose of the map should be considered during its development and clearly stated. For example, whether the map is intended for a driver learning a route for the first time or an experienced driver refreshing the route.
- The scale of the map should be stated (or if no scale is used, this should be stated).
- A key for all symbols used should be included.
- The publication date of the map and any past/future review dates should be stated.
- Routes should be divided into parts with distinct character (such as the nodal point process used by some train operators, in which the route is divided by using locations of significant features such as major junctions, large stations, yards etc.).
- Route Information provided should be chosen to support informed decision making (for example, gradients should be included to inform decisions about braking). Information which does not aid decision making should be considered for removal.
- Inclusion of extensive information on a single map reduces its suitability for training purposes. If the map is to be used for multiple purposes, a layering format should be considered with different levels of detail available on each layer (for example, layer 1 might show signals and stations, layer 2 line speeds and gradients, layer 3 principal route risks).

Route Risk Assessment

As discussed in Section 2 of this report and illustrated in Figure 2, several external factors have the potential to influence a train driver's situation awareness. To ensure that an holistic, or *systems*, approach is taken to route risk assessment, it is important to take into account the potential influence of all these factors during route risk assessment.

A review and comparison of the route risk assessments used by five train operators was conducted. The summarised observations from this review are presented below:

- Some train operators do adopt a systems approach to route risk assessments, including such factors as likely frequency of operation over a route, risks relating to particular times of day and climatic effects.

- Train operators base the content of their risk assessments closely on GO/RC 3551, but there are differences in the details considered.
- None of the route risk assessments reviewed identified risks additional to those described in GO/RC 3551 and the Red Alert SPAD Newsletter.
- It was not clear from the provided route risk assessments *why* specific risks were included or excluded.
- Operators use different algorithms to calculate the level of risk associated with a route, and to determine the resulting training 'allowance'.

The following suggestions are provided to improve the effectiveness of route risk assessment for *route knowledge training* purposes:

- Route risk assessment consistency could be improved by introducing a common format for risk assessment, incorporating a standardised, systems-based set of risks (drawing on those identified in GO/RC 3551). Those responsible for assessing route risks would then be required to identify (and justify) specific risks as 'not applicable' for their operations or for specific routes.
- The development of a standardised route risk assessment should take account of the additional route risks which have been identified by the industry since the publication of GO/RC 3551 in October 2002. For example, the Red Alert SPAD Newsletter Issue 21, July 2004 provides a comprehensive list. Further work is currently being undertaken jointly by Network Rail and Train Operators in Scotland to identify core risk.

<u>Issues associated with Route Knowledge Training and Assessment</u>

Broad consultation with industry and analysis of incident data identified 17 principal issues relating to route knowledge training and assessment. These are summarised in Table 9.

Table 9 – Summary of Issues relating to route knowledge training and assessment

Category	**Industry issue with route knowledge training and assessment**	
	Ref	**Description**
Assessment	01	Route knowledge competence is hard to define and quantify.
	02	There may be a tendency to assume route knowledge of experienced drivers and not formally measure it.
	03	Companies use a line based risk assessment to define the questions that they will use to measure competency, but the risk assessment content/approach is not standardised across the industry.
Training Course	04	Few companies have dedicated resources for route knowledge training/learning (e.g. a dedicated route learning instructor).
	05	Operators provide extensive information about the route, and it is not clear if all this information is required.
	06	There is a need to consider efficient ways of

Category	Industry issue with route knowledge training and assessment	
	Ref	Description
		maintaining and updating route knowledge training material to reflect the continuous changes in the railway infrastructure.
	07	Companies may not have set braking points/areas on their route maps, but will rely on the instructors/mentors to pass this information down. This may mean that there are inconsistencies in what is taught.
	08	Weather and time of day are important considerations within route knowledge training and assessment.
	09	Route knowledge training and assessment should include common reasons for failing to observe data, such as failing to check, external distractions or high task workload.
	10	Cues taught for braking are only significant in the context of the traction that is being driven.
Type of Operator	11	There is a need to take into consideration the differences between service types and performance requirements e.g. Freight train drivers do not travel over routes with great regularity; their route knowledge is extensive and relatively infrequently used compared to passenger train drivers.
Instructor	12	Route knowledge instructor competence is defined by experience. Instructors are not provided with formal training and this may result in inconsistent route knowledge training.
Media	13	Training videos are generally only produced in bright daylight conditions.
	14	It is difficult to ensure that train drivers retain accurate route knowledge, especially for routes travelled infrequently, and when there are disruptions on the network.
Retention of Route Knowledge	15	Drivers have a lot of information to recall. How can operators optimise retention of this information?
	16	Driver expectancy may be connected to error when driving e.g. a driver expects the signal to clear by the time they reach it, based on previous experience.
Signallers	17	Signallers and train drivers communicate route information using different terminology and reference points.

These issues were used to inform subsequent study activities. Most have been specifically addressed, in whole or part, by the study.

4.3 Route Knowledge and Situation Awareness Training

As discussed previously, effective driving over a route involves the integration of route knowledge with rules and traction knowledge. This is then incorporated with information extracted from the environment to develop situation awareness. This in turn informs planning and decision making to enable demonstration of route competence.

This stage of the study started with the identification of training objectives to support the development and maintenance of situation awareness. This focus was appropriate because demonstration of situation awareness requires knowledge, skills and behaviours in the following areas:

- Knowledge relating to the general principles of route knowledge, together with those elements of the underpinning rules, traction and technical knowledge that needs to be in place for route knowledge to be effectively trained.
- Route knowledge necessary to drive over a particular route and to support the development of situation awareness.
- Mental skills necessary to permit the development and maintenance of situation awareness and the application of route knowledge.
- Behaviours that drivers need to demonstrate to ensure maintenance of good situation awareness, and good performance generally.

Table 10 lists the training objectives identified by this process to support the driver in developing and maintaining situation awareness,.

Table 10 – List of Training Objectives

Ref	Objective	Description
T01	**Uses cues to inform situation awareness**	
T01.01	Identifies cues associated with decision points	Identifies cues to prompt decisions.
T01.02	Distributes attention	Attends to various in-cab and external sources of information
T01.02.01	Uses scanning techniques	Systematically scans the environment and cab interfaces for information
T01.02.02	Controls own attention levels	Is aware of the impact of work overload and underload on attention, and regularly checks own attention levels.
T01.03	Uses cues associated with decision points	Ensures cues are meaningful and associated with decision points
T01.03.01	Uses cues taking into account time of day	Adapts cues to the time of day
T01.03.02	Uses cues taking into account weather conditions	Adapts braking cues and situational cues according to weather
T01.03.03	Uses cues taking into account the characteristics of the train being driven	Knowledge of train performance and handling are used to inform cue selection
T01.03.04	Uses cues taking into account associated risks	Cues are informed by the specific risks along a route
T02	**Uses information held in memory to inform situation awareness**	

Ref	Objective	Description
T02.01	Uses strategies to recall information	Use of environmental or mental cues to recall information
T02.02	Obtains and integrates new information	Assimilates new information with existing knowledge
T02.03	Identifies gaps in existing knowledge	Maintains awareness of information gaps and take action to address and/or mitigate them
T03	**Manages workload to maintain situation awareness**	
T03.01	Maintains situation awareness in high workload situations	Orders and prioritises work to manage workload. Distributes attention appropriately to maintain situation awareness
T03.02	Maintains situation awareness in low workload situations	Employs techniques and strategies to maintain alertness and attention levels in low workload.
T04	**Communicates situation awareness**	
T04.01	Conveys situation awareness verbally	Able to communicate location and understanding of the situation.
T04.02	Integrates information from other people to inform situation awareness	Attends to information communicated, and is able to assimilate this with existing knowledge and information

Table 11 presents a summarised list of knowledge statements, derived from the training objectives presented in Table 10. The complete list of knowledge statements is presented at Annex A.

Knowledge statements in the category ‘Kn1..’ include generic knowledge that could form part of a route learning principles course. This category also includes underpinning knowledge that will typically be included in driver training outside route knowledge training (e.g. knowledge of signalling systems). Whilst this is not ‘route knowledge’, it is required to support development of route-specific knowledge, so is listed here. With the exception of Kn1.19 and Kn1.21, content in this category is primarily applicable, in terms of training and assessing route knowledge and situation awareness, to new drivers, or those joining from other operators.

Kn1.19 and Kn1.21 differ from the remainder of Kn1 in that they address the principles which underpin effective situation awareness and decision making. This knowledge is independent of operator type, driver or route, but is nonetheless essential for the effective application of traditional route knowledge.

Knowledge statements in the category ‘Kn2..’ represent a comprehensive set of knowledge which can be made specific to any route. This information is provided at a level believed to be suitable for customisation by operators to address their particular needs. Those knowledge statements that may present particular differences in detail or priority depending on the operational circumstances are commented upon in the final column.

It is *not* suggested that operators should train all of the knowledge items listed within Table 11 for all routes. Rather, operators should base training requirements on a comprehensive route risk assessment and consideration of their drivers’ individual needs. Once this has been done, it is likely that the required knowledge training can be developed from the content presented in Table 11 and Annex A.

Table 11 – High level Knowledge list (Refer to Annex A for detailed list)

Reference	Description
Kn1	**Principles of Route Knowledge and Underpinning Knowledge**
Kn1.1	Knowledge of train protection systems
Kn1.2	Knowledge of running lines
Kn1.3	Knowledge of signalling systems
Kn1.4	Knowledge of junctions
Kn1.5	Knowledge of train radio systems
Kn1.6	Knowledge of gradients
Kn1.7	Knowledge of lineside signage
Kn1.8	Knowledge of points
Kn1.9	Knowledge of signal boxes
Kn1.10	Knowledge of bridges
Kn1.11	Knowledge of tunnels
Kn1.12	Knowledge of level crossings
Kn1.13	Knowledge of stations
Kn1.14	Knowledge of depots
Kn1.15	Knowledge of sidings
Kn1.16	Knowledge of power supplies
Kn1.17	Knowledge of authorised walking routes
Kn1.18	Situation awareness knowledge required in an emergency
Kn1.19	Principles of an appropriate cue to use over a route
Kn1.20	Knowledge of preparation required before commencing journey
Kn1.21	Knowledge of factors that can impact situation awareness
Kn2	**Route specific knowledge**
Kn2.1	Knowledge of train protection systems
Kn2.2	Knowledge of running lines
Kn2.3	Knowledge of signalling systems
Kn2.4	Knowledge of junctions
Kn2.5	Knowledge of train radio systems
Kn2.6	Knowledge of gradients
Kn2.7	Knowledge of lineside signage
Kn2.8	Knowledge of permissible speeds in relation to train being driven
Kn2.9	Knowledge of points
Kn2.10	Knowledge of signal boxes
Kn2.11	Knowledge of bridges
Kn2.12	Knowledge of tunnels
Kn2.13	Knowledge of level crossings
Kn2.14	Knowledge of stations
Kn2.15	Knowledge of depots
Kn2.16	Knowledge of sidings
Kn2.17	Knowledge of power supplies
Kn2.18	Knowledge of authorised walking routes

Reference	Description
Kn2.19	Knowledge of timetable
Kn2.20	Knowledge of cues available to inform situation awareness on a route
Kn2.21	Situation awareness knowledge required in an emergency

Skills associated with training objectives were allocated to categories and sub-categories based on components in the Route Knowledge Model (refer Figure 1). This enabled the study team to identify a comprehensive list of skills associated with each aspect of situation awareness. No skills unique to passenger, freight or IMC drivers were identified; it is suggested that these skills apply to all service types.

The skills listed in Table 12 are required to enable the *application* of the knowledge listed in Table 11.

The error analysis reported in Section 3 identified that it is not usually the recall of static knowledge that causes errors when driving a route. Errors more typically relate to ***failure to maintain situation awareness when driving****. If route knowledge training and assessment specifically addressed the skills listed in Table 12, a reduction in observable driver error could be expected.*

Table 12 – List of Skills

Ref	Skill	Description
Sk1	**Perception Skills**	
Sk1.1	Attention sharing skills	Distributes attention strategically.
Sk1.2	Information gathering skills	Collects appropriate information available in the environment.
Sk2	**Comprehension skills**	
Sk2.1	Remembering skills	Stores information for future recall.
Sk2.2	Organising skills	Categorises and prioritises information.
Sk2.3	Analysing and integrating skills	Analyses and integrates diverse forms of information.
Sk3	**Projection skills**	
Sk3.2	Contingency planning skills	Plan actions associated with possible future events.
Sk3.3	Self checking skills	Checks own assumptions by seeking information from the external environment.
Sk4	**Decision making skills**	

Ref	Skill	Description
Sk4.1	Communicating skills	Passes information accurately, concisely and unambiguously taking into consideration the needs of the intended audience. Ensures that information received is fully understood.
Sk4.2	Task managing skills	Organises and prioritises tasks based on their criticality.
Sk4.3	Decision making skills	Evaluates a set of circumstances concluding in an objective and logical output.

Principal behaviours associated with achieving the required performance outcomes are identified in Table 13. While these behaviours are associated with good performance in general terms, they will assist the specific goals of gaining and maintaining situation awareness. No behaviours unique to passenger, freight or IMC drivers were identified; it is suggested that these behaviours apply to all service types.

Table 13 – List of Behaviours

Ref	Description
B1	Strives to maintain high standard of performance in all aspects of work.
B2	Shows a commitment to rail safety.
B3	Adapts and responds appropriately to change.
B4	Follows organisational procedures and policies.
B5	Follows instructions from others.
B6	Recognises own strengths and weaknesses in terms of performance.
B7	Balances demands of work life and personal life.

4.4 Training and Assessment Media Solutions

This stage of the study used the information relating to route knowledge and situation awareness training requirements to consider the suitability of a range of training and assessment solutions.

To ensure that this process benefited from current good practice in training analysis and from expertise in train driver training, two principal activities were conducted:

- ❑ Assessment by the study team's training specialists of the capability of media to address route knowledge and situation awareness knowledge, skills and behaviours.
- ❑ Review of training and assessment media by a 'Measure of Training Effectiveness' (MOTE) Panel, comprising training and media specialists drawn from across the rail industry.

Study Team Assessment

This activity involved consultation with training systems providers, simulation developers and industry representatives to identify a range of current or potentially relevant training and assessment media and methods. These are described in Table 14 and Table 15.

Table 14 – Training Media Considered in the Study

Ref	Training Media	Definition
M1	Sectional Appendix	A regional collection of line diagrams in the format produced by Network Rail.
M2	Route Map	A map of the route produced by the operator for use by the trainee.
M3	Static Visual Imagery	Still images (paper, projected or computer-based) together with textual or audio supporting information.
M4	DVD	Film of the route (with in-cab audio) in linear format on DVD. Option (selectable by the user) to provide basic 2D informational overlays on video (e.g. signal number, line speed, level crossings etc.).
M5	Interactive DVD	Film of the route (with in-cab audio), with a menu to permit basic selection of sequences. Option (selectable by the user) to provide basic 2D informational overlays on video (e.g. signal number, line speed, level crossings etc.). Playable on standard DVD player.
M6	Interactive DVD with hardware overlay	Film of the route (with in-cab audio), together with a basic hardware interface (e.g. joystick) enabling control of direction and speed of progress. Option (selectable by the user) to provide basic 2D informational overlays on video (e.g. signal number, line speed, level crossings etc.).
M7	Video-based Part-Task Trainer	A high-speed (improved quality) film of the route (with in-cab audio), together with a basic approximation of a generic cab desk, with power/brake control and horn button. User can control direction and speed of progress. Option (selectable by the user) to provide basic 2D informational overlays on the video (e.g. signal number, line speed, level crossings etc.).
M8	Computer Aided Instruction (CAI)	Instructor-led training using computer technology as a training aid. Can comprise graphics, text, audio, animation and video sequences.
M9	Computer Based Training (CBT)	Essentially the same as CAI, but structured to be controlled and used by the student for training and assessment independent of an instructor.
M10	Geo-typical, Synthetic Environment Part-Task Trainer	A computer-generated representation of a *typical* route, displayed on CRT/plasma/LCD, together with a basic approximation of a generic cab desk, with power/brake control and horn button. User can control direction and speed of progress. Scenarios can be created by instructors to influence signal aspect, time of day and weather. Student performance (e.g. speed, progress, SPADs, braking profile) can be monitored, recorded and reviewed for training purposes.

Ref	Training Media	Definition
M11	Geo-specific, Synthetic Environment Part-Task Trainer	A computer-generated representation of a *specific* route, displayed on CRT/plasma/LCD, together with a basic approximation of a generic cab desk, with power/brake control and horn button. User can control direction and speed of progress. Scenarios can be created by instructors to influence signal aspect, time of day and weather. Student performance (e.g. speed, progress, SPADs, braking profile) can be monitored, recorded and reviewed for training purposes.
M12	Simulator (Geo -typical)	A computer-generated representation of a typical route, displayed using a single-channel projector and screen, together with a good approximation of a generic cab desk, with power/brake control, horn button, radio and other essential components. User can control direction and speed of progress. Scenarios can be created by instructors to influence signal aspect, time of day and weather. Student performance (e.g. speed, progress, SPADs, braking profile) can be monitored, recorded and reviewed for training purposes.
M13	Simulator (Geo -specific)	A computer-generated representation of a specific route, displayed using a single-channel projector and screen, together with a good approximation of a generic cab desk, with power/brake control, horn button, radio and other essential components. User can control direction and speed of progress. Scenarios can be created by instructors to influence signal aspect, time of day and weather. Student performance (e.g. speed, progress, SPADs, braking profile) can be monitored, recorded and reviewed for training purposes.
M14	In-service Train	A train performing its scheduled operational duties.
M15	Route Learning Train	A train that is dedicated to training.

Table 15 –Assessment Media and Methods Considered in the Study

Ref	Assessment Media	Definition
A1	Trainee Route Maps	The trainee is asked to produce a route of the map. The map is assessed on content.
A2	Trainee Logbooks	The trainee is asked to produce a logbook of the all the routes/journeys made. The logbook is assessed in terms of the number of times the trainee has driven the route, direction travelled, time of day and weather conditions.
A3	Multiple choice written questionnaire	Written test for trainees that includes multiple choice questions of the route, including questions on specific route risks.
A4	Open ended written questionnaire	Written test for trainees which includes open ended questions of the route, including questions on specific route risks.
A5	Oral Interview (predefined questions)	A structured interview conducted by an instructor using a predefined questionnaire. The trainee responds verbally to questions.

Ref	Assessment Media	Definition
A6	Oral Interview (questions determined at time of interview)	An interview conducted with the instructor determining the questions at the time. The trainee responds verbally to questions.
A7	Computer Based Training (CBT) Assessment	The driver ‘drives’ a route and the CBT tool asks questions. The questions type/content can be adjusted depending on trainee type/route etc.
A8	Verbal Protocol (Watching a DVD)	The trainee provides a verbal protocol of the route whilst watching a DVD. The verbal protocol includes what actions should be conducted, any route risks etc.
A9	Verbal Protocol (Driving in train)	The trainee provides a verbal protocol of the route whilst driving an in-service train. The verbal protocol includes what actions should be conducted, any route risks etc.
A10	Verbal Protocol (Conducting the train)	The trainee provides a verbal protocol of the route whilst an instructor is driving an in-service train. The verbal protocol includes what actions should be conducted, any route risks etc.
A11	Instructor Judgement (observation in simulator)	Observation of a trainee’s performance whilst driving a route in a simulator. The instructor notes any observations and assesses the trainee using their own judgement.
A12	Instructor Judgement (observation in train)	Observation of a trainee’s performance whilst driving a route in a train. The instructor notes any observations and assesses the trainee using their own judgement.
A13	Instructor pre-defined Questions (observation in simulator)	Observation of a trainee’s performance whilst driving a route in a simulator. The instructor notes any observations and asks questions from a pre-defined questionnaire/ competency assessment.
A14	Instructor pre-defined Questions (observation in train)	Observation of a trainee’s performance whilst driving a route in a train. The instructor notes any observations and asks questions from a pre-defined questionnaire/ competency assessment.
A15	Simulator data	This is the download of a trainee’s data from a specific session within a simulator. This data will typically include information about the driver’s speed, braking pattern etc. The instructor assesses the data against an expected performance profile.
A16	Use of 'black box' data	This is the download of a driver's data from a specific route. This data will typically include information about the driver’s speed, braking pattern etc. The instructor assesses the data against an expected performance profile.

These media and methods were evaluated by the study team's training specialists to determine their capabilities to address the lowest level knowledge, skills and behaviours identified in Tables 6-8 and Annex A. Each of these assessments resulted in a 'Yes' (effective solution) or 'No' (ineffective solution) result. Results of this assessment were then compiled to give a summary rating of the capability of media and methods in Knowledge and Skill areas (behaviour assessment were not summarised). This rating is described in Table 16.

Table 16 – Summary Capability Rating Levels

Rating	Definition
0	Ineffective - Not able to train/assess any of the knowledge, skills or behaviours being assessed. ('No' responses for all knowledge, skills or behaviours).
1	Partial – Able to train/assess only a subset of the knowledge, skills or behaviours being assesses. ('Yes' and some 'No' responses).
2	Effective – can train/assess the full set of either knowledge, skills or behaviours being assessed. ('Yes' responses for all the knowledge, skills or behaviours).

The detailed results of this assessment are presented in Ref 2.

<u>MOTE Panel Evaluation</u>

A MOTE panel was used to ensure that consideration of the effectiveness of training and assessment media benefited from experience within the rail industry. The MOTE Panel comprised driver training and media specialists from passenger, freight and IMC operators. Members of the panel considered, individually and collectively, the capabilities of media and methods to address the training requirements. The group exercise was facilitated by a member of the study team.

The detailed results of this assessment are presented in Ref 2. This report, in Table 17 (training methods and media) and Table 18 (assessment methods and media) provides a summary of the assessment of the effectiveness (effect %) of each medium and its relative cost.

Table 17 – Summarised results of MOTE Panel evaluation of training media and methods, ordered by Effectiveness and Cost

Media	M15	M5	M14	M13	M4	M8	M6	M7	M11	M9	M3	M2	M12	M10	M1
	Route learning train	Interactive DVD	In-service train	Simulator (Geospecific)	DVD	Computer aided Instruction (CAI)	Interactive DVD	Video based PTT	Geospecific synthetic environment PTT	Computer Based training	Static Visual Imagery	Route Map	Simulator (geo-typical)	Geo-typical Synthetic environment PTT	Sectional Appendix
Effect %	78	71	70	70	68	68	67	64	64	61	59	58	46	43	36
Cost	£££	££	£	££££	££	£££	£££	£££	££££	£££	£	£	££££	££££	£

Table 18 – Summarised results of MOTE Panel evaluation of assessment media and methods, ordered by Effectiveness and Cost

Media	A5	A6	A9	A10	A12	A14	A16	A8	A7	A11	A13	A15	A4	A3	A2	A1
	Oral Interview (predefined questions)	Oral Interview (questions determined at time of interview)	Verbal Protocol (when driving the train)	Verbal Protocol (when conducting the train)	Instructor judgement (observing in train)	Instructor pre-defined questions (observation in a train)	Use of 'black box' data	Verbal protocol (watching a DVD)	Computer Based Training Assess't	Instructor judgement (observing in simulator)	Instructor pre-defined questions (observing in a simulator)	Simulator data	Open ended written questionn-aire	Multiple choice written questionn-aire	Trainee logbooks	Trainee route maps
Effect %	56	56	56	56	56	56	56	56	56	56	56	56	49	45	44	41
Cost	£	£	£	£	£	£	£	££	£££	££££	££££	££££	£	£	£	£

4.5 Section Summary

Training Media and Methods

The MOTE Panel evaluation of media for training purposes (summarised in Table 17) shows a good spread of assessed effectiveness. The medium assessed to be most effective (78%) was M15 – Route Learning Train. This was assessed to be acceptable in all categories except regarding its suitability for sharing between train operators. It had the following, relatively minor, shortcomings:

- its ability to train to a consistent standard (because it cannot control the conditions)
- its ability to train under varying conditions, such as times of day weather conditions (because it cannot select the required conditions)
- training route risks (because these cannot be controlled or injected in a planned manner)
- for training the principles of route learning (not a particularly effective location for core knowledge training)
- for freight or IMC drivers (who have different needs and constraints on access to routes).

The assessment of the same medium against knowledge, skills and behaviour requirements found that a route learning train would only enable the partial training of situation awareness knowledge, and skills. The ability to impart knowledge of risks along a specific route would require the presence of an appropriately skilled instructor on the route learning train.

The Interactive DVD (M5) option was considered to be an effective (71%) training solution. An identified shortcoming was its suitability for training dynamic/real-time situation awareness and training for driving at different times of day or in different weather conditions.

The in-service train (M14) was regarded to be an effective (70%) training medium. A noted shortcoming was its suitability for sharing between train operators. For similar reasons to the route learning train, training risks along a specific route would require the presence of an instructor.

The Geo-specific Simulator (M13), did not generate the same degree of confidence in its overall abilities as the leading media. It was, however, assessed as broadly acceptable in all assessment categories, the only medium to do so. These twin factors resulted in an assessment (70%) equivalent to the in-service train

The assessment of the Geo-specific Simulator against knowledge, skills and behaviour requirements indicated that a geo-specific simulator could be used to train the situation awareness knowledge, skills and behaviours. The failure of this medium to score more highly warrants some comment. Military aviation training relies to an increasingly significant extent on high fidelity simulation. Use of the real equipment is typically used only to demonstrate competence and develop advanced tactical skills under real conditions, having acquired operational skills in the simulator. Civil aviation goes even further, with nearly all training done in a simulator. There are many reasons why a simulator may not be suitable for route knowledge training (maintaining an accurate database of line-side features, cost, low effective throughput, high staff ratio, etc.) but it is extremely unlikely that a modern simulator would be unable to address any significant element of driver situation awareness. It would additionally provide control of weather, time of day, events on the line and immediate review of actions.

That said, results of the MOTE Panel evaluation suggest that the training benefit to be gained from high technology based solutions is likely to be outweighed by the high costs.

*The decision to procure a high fidelity simulator **specifically** for route learning is difficult to justify. Operators who already have access to geo-specific simulation facilities, with sufficient spare capacity, may find this an effective option.*

More generally, the analysis of the training media indicates that there are various combinations of media that could be used to train the information within the drivers' memory. Route maps, DVDs and videos, and lower fidelity interactive media are all well suited to this purpose. The results of the MOTE panel and the study team's assessment found that more specialised media/methods are required to effectively train real-time dynamic situation awareness. Route learning trains, in-service trains and route-specific simulators would all support this requirement.

This study has identified that all operators use media appropriate to address requirements, but that their effectiveness is dependent on it being used appropriately. For example, the results of the MOTE panel indicate that train operators should use in-service or route knowledge trains to train situation awareness, but to ensure that route risks and individual factors that might impact on situation awareness are being trained, it is important that an appropriately-skilled instructor is present.

Cab rides on in-service trains will not necessarily address the training of route risks. Train operators adopting this approach should ensure either that the driver learning the route is accompanied by an instructor/mentor, or that additional information on route risks is available.

The analysis identified that various combinations of media could be used to train situation awareness effectively. This view is supported by current research into situation awareness training.

For example, one operator uses a route map to train self-checking skills, to reduce the risk of drivers relying on assumptions and expectations. Although the training uses a route map, the same effect could be achieved with other media including video or static imagery. It is not the media that is the crucial factor in this training, but the focus and content of the training itself, i.e. on reducing error due to driver expectations.

Assessment Media and Methods

The MOTE Panel evaluation of media for assessment purposes (summarised in Table 18) provided conflicting results. The MOTE panel effectiveness assessments indicate that *none* of the assessment media and methods could be used to effectively assess:

- stopping at signal and other locations not previously stopped at
- dynamic/real-time situation awareness

- performance under all seasonal and weather conditions e.g. rain, fog, sunshine, snow, leaf-fall, ice
- performance at different times of day e.g. daylight, dusk, dark.

Conversely, subsequent discussion regarding the strengths and weaknesses of the assessment media identified that eight of the media and methods could potentially be used to assess real-time dynamic situation awareness (possibly the most challenging aspect of the required assessment), namely:

- verbal protocol (whilst driving or conducting train)
- instructor judgment (observing in a train or simulator)
- instructor using pre-defined questions (observing in a train or simulator)
- simulator data
- 'black box' download data.

The assessment of media and methods against knowledge, skills and behaviour requirements identified several solutions that could be used to assess knowledge (both underpinning and route specific knowledge). These are all based on inclusion of written and oral tests, which are well understood across the industry.

In terms of assessing situation awareness, instructor judgement (observing drivers in a train or simulator) was found to be of limited benefit, especially in assessing drivers' understanding of route risks. Simulator and black box data has the potential to provide very specific data for assessment purposes, but only for a limited set of the knowledge, skills and behaviours identified.

The recommended regime for assessment of situation awareness is:

- verbal protocol (whilst driver is driving a train)
- verbal protocol (whilst driver is conducting a train)
- instructors' use of pre-defined questions to assess real-time situation awareness (whilst observing the driver in a simulator or train).

The assessment of media and methods indicates that operators typically *are* using media which is appropriate to address situation awareness assessment requirements, if they are effectively used.

It is important for train operators to consider the *objectivity* and *consistency* of the assessment process used. There is some cause for concern regarding the reliance some train operators place on using instructor's subjective judgement whilst observing driving as an assessment method.

Basing assessment on unstructured observation increases the potential for variation between instructors and increases reliance on consistent, high standards of instructor and assessor competence beyond that which might be currently expected.

Where practicable, trainee drivers should be assessed under those conditions shown by their route risk assessment to present a safety risk, appropriate to the nature of their drivers' task. For example, if route risk assessments identify particular risks at night, during peak times, in poor visibility, these conditions should feature in assessments. Where assessment under such conditions is not possible, this should be recorded in the competence management system, mitigated by, for example, group discussion exercises, and appropriate assessment performed when conditions permit.

General Observations

The analyses conducted during this phase of the study identified that accurate replication of internal and external cues available to the driver is important. These cues should include rail infrastructure and external cues used by drivers to inform braking and location. The operators in the MOTE Panel observed that they would be reluctant to identify specific braking cues for drivers to use. This was because drivers are trained in specific techniques associated with train braking and defensive driving, and a key skill of train driving is that braking points are often affected by restricted signals aspects, temporary and emergency speed restrictions, and weather / adverse rail head conditions. Identification by drivers of braking cues (i.e. environmental features which prompt a response by the driver) are, however, essential to the maintenance of situation awareness. Guidance should be provided to trainee drivers on the *characteristics* of effectives cues. *If* cues are identified by instructors and mentors during initial driver training, operators should take steps to ensure that these cues are appropriate.

Media used to train or assess situation awareness should be able to replicate braking cues with a high degree of fidelity. In-service or route knowledge trains meet this requirement.

The analysis of situation awareness assessment media and methods suggests that there is a pressing need to develop training and assessment regimes to ensure that situation awareness competence is measured appropriately, objectively and consistently. In general, basing assessment on judgement and observation will not facilitate objective and consistent assessment. A detailed set of training and assessment objectives, including those addressing situation awareness training, is provided at Section 4.3 of this report, with supporting lists of knowledge (refer Annex A, with summarised list at Table 11), skills (refer Table 12) and behaviours (refer Table 13). Guidance on the selection and use of training and assessment media is provided at Section 4.4 These should be suitable for tailoring by operators to meet their particular needs.

Verbal commentary, including asking the driver to identify anticipated hazards, can improve assessment. The verbal commentary in itself cannot provide objective and consistent assessment. Train operators need to develop key performance indicators, assessment criteria and probing questions against which a driver's commentary can be assessed.

The study did not identify major problems with the content of training relating to identification of route features. Drivers are provided with adequate (and in some cases, perhaps excessive) information about route features, but this information in itself is not sufficient to develop an effective mental model or build situation awareness.

Analysis of real incident data identified the *perception* error 'failure to monitor or observe data' as the most common causal factor in incidents. Incorrect understanding of the aspect of signals, either by not looking at the signal, or incorrectly perceiving its aspect, is recognised as a significant cause of driver error. This perception error is not typically regarded by industry as a route knowledge issue, but rather a feature of general driver competence. However classified, this type of risk can be effectively mitigated by improving drivers' situation awareness.

Whilst the focus of this study is on driver training and assessment needs, it should be noted that driver instructor and assessor skills need to be reviewed and developed to ensure that they are able to consistently meet requirements for route knowledge and situation awareness training and assessment.

5 Preparing for the Future

5.1 A Change for the Better?

Recent technological advances in the rail industry have the potential to affect both the nature of the train driving task and the task environment (i.e. where and how information is presented to the driver). For example, whereas drivers currently gather information about permitted line speed from lineside signage, under the developing European Rail Traffic Management System (ERTMS) they could (in Level 2D) be given this information on in-cab displays. This phase of the study (Ref 3) examined the impact of a range of new technologies on one key aspect of driver performance, route knowledge.

The introduction of well-considered technology is likely to significantly improve and safety and performance standards. For example:

> *Safety analysis work by the ERTMS programme team has indicated that TPWS will avoid 80% of the risks associated with ATP preventable accidents.*

In the future, new technology has the potential to further reduce the consequences of driver errors. For example, continuous speed supervision[3] (such as that expected in ERTMS) has the potential to mitigate the effects of the following indicators of ineffective driving performance:

- Failure to stop at a red signal (SPAD).
- Moving off before signal aspect clears (SASSPAD).
- Exceeding the speed limit in relation to permanent speed restrictions.
- Travelling below the speed limit in relation to permanent speed restrictions.
- Failure to control speed in relation to signal aspects.
- Failure to control speed in relation to vehicle or traction speed limits.

Whilst there are clear safety and efficiency benefits associated with advanced technology, studies have noted some negative issues relating to operator interaction with advanced systems.

For example, studies have found that operators may have difficultly understanding *how* complex, automated systems work, even after training. This effect has been reported in the aviation, petrochemical refining, and air traffic control industries. Other observed effects of advanced technology on human performance include:

- Failure to properly monitor the automated system.
- Failure to acquire manual skills replaced or supported by the system.
- Loss of proficiency in manual skills.
- Reduced job satisfaction.

This phase of the study used knowledge developed in other industries to provide a preliminary examination of the risks presented by new rail technologies to driver situation awareness. It then identified appropriate mitigation strategies to limit the effects of identified potential risks.

[3] Where communication of data between the infrastructure system and the train's onboard systems is continuous.

Because the majority of the systems under discussion in this study are in the preliminary design stages, a full analysis of risk, including identification of risk likelihood and consequence, was not appropriate. This study provides a basis from which further detailed analysis of the risks of technology to driver situation awareness could be conducted in the future.

5.2 Method

As discussed in Section 2 of this report, the study adopted a situation awareness based perspective of route knowledge. This approach ensured that consideration was given both to the information that drivers need to remember about a route (traditional ‘route knowledge’), and how they integrate this knowledge with other information to form a ‘picture’ of their current situation. This phase of the study focused on the potential effects of technology on situation awareness.

This phase of the study was conducted in three stages, identified below:

- Stage 1 – An analysis of potential and planned changes to train operations.
- Stage 2 – An analysis of the impact of advanced technology on operator situation awareness in other industries.
- Stage 3 – An analysis of the impact of identified technologies on driver situation awareness and identification of mitigation strategies.

The results of each of these phases are presented below.

5.3 Stage 1 Results – Analysis of planned changes to train operations

Following investigation and preliminary assessment, the following technologies were identified for further study within this phase of the study:

- Global System for Mobile Communications – Railways (GSM-R)
- Tilting Trains
- ERTMS[4]
- Automatic Train Operation (ATO).

5.4 Stage 2 Results – Analysis of the impact of technology on situation awareness in other industries

Twenty five studies and one website from a range of industries (petrochemical, aviation, air traffic control, space transport, and road transport) were reviewed to evaluate the impact of advanced technology on situation awareness. From the 181 risks generated, 18 collated ‘key’ risks to situation awareness were identified; these are presented in Table 19.

[4] It should be noted that ERTMS Level 2D only was considered in this study as it has been selected for an ‘early deployment’ scheme for ERTMS on the Cambrian Line in Mid-Wales. Other levels of ERTMS and transitions between levels were not considered.

Table 19 – Key Risks to Operator Situation Awareness

Risk	Risk Description
1	Automation/high technology that requires operators to access, monitor, integrate and project system based information can increase workload, particularly cognitive workload.
2	Operators trained in automated systems may not acquire the motor and cognitive skills required to operate the system manually.
3	When a system is automated, operators may lose the motor and cognitive skills required to operate the system manually.
4	Automation/high technology may induce operator fatigue.
5	Automation/high technology can lead to operator boredom and complacency.
6	Automation/high technology that changes the operators' job from actively completing a task to monitoring systems can affect their job satisfaction.
7	Automation/high technology that is unreliable and shows obvious errors can lead to operators distrusting the system.
8	The amount of experience an operator has with a high technology system can affect the degree to which they rely on it. Generally, experienced operators are more likely to rely on the system. However, novices can also be 'automation keen' and spend too much time monitoring the technology.
9	Issues with either design of high technology/automated systems or training related to them can result in the operator having a poor understanding, or 'mental model', of either the system purpose or the system functionality.
10	If automation/high technology requires operators to monitor a display for long periods of time, errors in detecting information can result. This is particularly true if the information to be detected is presented infrequently.
11	If technology is unreliable (e.g. only detects and displays 5/10 events) operators will have to devote attention to gathering missed information from other sources (e.g. through outside observation) rather than attending to other tasks.
12	The attentional demands of the technology can lead to distraction from the operators' primary task.
13	Technology that places the operator in a monitoring role can induce reduced vigilance, both to the system being monitored and to other cues available outside the system.
14	Operator overconfidence in automation/high technology can result in reduced vigilance and monitoring.
15	Automation/high technology can reduce operator situation awareness due to poor system design (poor feedback, complex modes of operation, and mode changes without notification).
16	Automation/high technology can affect operator situation awareness as they may become complacent and fail to sufficiently monitor the automation or other cues.
17	Automation/high technology can result in operators spending more time on decision making, as they may find it more difficult to understand a situation, particularly when passively monitoring the automated system.
18	Highly automated systems can require the operator to plan further ahead than manual tasks. If automated displays do not support planning, operators can have difficulty anticipating and preparing for situations.

The key risks identified during this analysis indicated that advanced technology impacts on operator situation awareness through a range of psychological mechanisms (attention, workload, attitude etc). Generally speaking, however, technology appears to present a risk to situation awareness in two main ways:

1) Complex, multi-mode[5] systems that demand significant operator involvement

Effect – These can increase operator workload by requiring them to hold detailed system knowledge in memory and to track and understand the actions of the system in real-time. These issues are compounded if the operator is not fully 'in the loop' as they may not always understand the system logic.

Psychological Mechanism – Systems with these characteristics appear to be linked to high workload, fatigue, and poor mental models (system knowledge in memory). Consequently, operator situation awareness can be reduced, which affects their decision making ability.

Resulting Error Types – Operator errors that could result from systems of this type include:

- failure to perceive information, due to high workload
- failure to comprehend information presented by the system, due a poor understanding of the system
- failure to anticipate, plan and prepare for future events related to the system, resulting from workload, fatigue or a poor understanding of the system.

2) Highly automated and reliable systems

Effect – In these systems, operators are required to monitor the system to detect very infrequent events (such as system failures). This appears to induce a high degree of trust by the operator in the system.

Psychological Mechanism – Systems with these characteristics can result in reduced operator attention (observable as reduced monitoring and checking) both to the system and the surrounding environment. Systems with these characteristics appear to impact significantly on operator attitude (over-trust and complacency), attention and boredom.

Resulting Error Types – The Route Knowledge Model presented in Section 2 shows that all the factors identified above have the potential to affect situation awareness. The key operator error that could result from systems of this type is failure to perceive information due to reduced vigilance and monitoring of the system. Comprehension and projection errors could also result if knowledge related to the system fades due to long term inattention or reduced interaction with the system.

5.5 Stage 3 Results – Analysis of the impact of technology on driver situation awareness and identification of mitigation strategies

This section presents an overview of the key risks to driver situation awareness associated with each technology. Comments by industry experts and statements taken from studies of the technologies are presented to highlight major issues. In addition, each key risk is listed, together with comment and suggested strategies to mitigate the risk.

[5] This refers to systems that have a range of states that influence opportunities for interaction with the operator. For example, if a video player is in record mode, instructions by the operator to change the channel might be ignored to preserve the integrity of video recording.

GSM-R

Individual comments made by industry specialists or gathered from studies of GSM-R included:

- Comment:
  - When a driver presses the GSM-R emergency button, all trains in that particular geographical area will receive a 'stop' message. In built up areas, trains may be stopped on lines unaffected by the emergency. This may dissuade drivers from using the button in certain areas.
- Studies:
  - Studies investigating car driving behaviour have shown that telephone use diverts attention away from the primary task of driving. In experiments, participants have been found to spend less lime looking at the view ahead and more time looking at, searching for, and manipulating the phone device. Such drivers have significantly poorer situation awareness. These results are believed to be likely to transfer directly to the train driving situation.

These comments and other data were used to conduct an analysis of risks to situation awareness. The risks posed by GSM-R were shown to be relatively few, and related to two main issues:

- The reliability of the information presented by the GSM-R system.
- The potential for the GSM-R system to distract the driver from other tasks.

The main suggested strategies identified for mitigating these issues were:

- Designing the system to mitigate identified risks.
- Design of operating procedures to ensure correct operation by drivers.
- Training in attention management and environmental scanning.

Brief explanations of the training-related mitigation strategies identified above, together with others selected to mitigate risks posed by Tilting Trains, ERTMS and ATO, are presented in Table 20.

Table 20 – Description of training-related mitigation strategies

Training Related Mitigation Strategy	Description
Attention management training	One of the principal ways in which operators build situation awareness is by gathering appropriate and timely information from the environment. This skill can be enhanced through training in attention management, which can involve attentional control, time-sharing, and attention monitoring training. Training in attentional control assists operators in dividing their attention, based on task priorities (rather than having their attention drawn by objects in the environment). Finally, operators can be trained in the knowledge and skills required to monitor their own attention levels and to recognise symptoms of low attention to task.
Environmental scanning training	Scanning is a sequence of monitoring tasks conducted in a specific and consistent order. Training operators to scan their environment ensures that appropriate information is gathered from the environment. Scanning training typically includes guided training, where operators are taught where to look and in what sequence.

Training Related Mitigation Strategy	Description
	Training might also include knowledge of factors that could influence scanning patterns. Appropriate scanning forms part of attention management. Examples of scan patterns from the aviation industry include generalised scan patterns for detecting unexpected hazards and specific scan patterns for tasks such as landing an aircraft using instruments.
Training in self-checking skills	Self-checking involves checking one's own assumptions about the state of the environment against information presented in the environment. Training involves teaching operators to actively seek out information that provides a check on the validity of their own assumptions. This is effective in dealing with false expectations and incorrect mental models.
Workload management training	Workload management training provides operators with knowledge about the effects of high and low workload on situation awareness. It also trains skills in coping with high and low workload scenarios.
Fatigue management training	Fatigue management training typically provides operators with information on a wide range of fatigue-related issues including the impact of fatigue on performance, causes of fatigue and fatigue management strategies (e.g. cab temperature, diet, dehydration etc).
Task management	Task management training provides operators with skills and knowledge to be able to prioritise and order tasks efficiently. Operators can be trained in strategies to manage tasks, such as using procedural task management whereby tasks are completed based on priority (rather than event/interruption driven task management strategies whereby each interruption is dealt with as it comes up). Good task management enables operators to actively manage their task and information flow to avoid becoming overloaded.

It should be noted that there is no evidence that GSM-R represents a significantly *greater* risk in terms of driver distraction than current radio systems. In addition, there is little evidence to indicate that the system poses a high risk to driver situation awareness. However, issues related to system reliability should be reduced where practicable, due to the potential impact of an unreliable system on driver trust and behaviour.

<u>Tilting Trains</u>

Individual comments made by industry specialists or gathered from studies of Tilting Trains included:

- ❑ Comments:
  - ➢ The tilting trains system has no impact upon the driver task under normal circumstances. The driver is still responsible for braking, accelerating, and communicating with signallers.
  - ➢ The driver is still required to make key decisions regarding train control.
  - ➢ The driver still uses in-cab and out-of-cab cues with the tilting trains system. The driver looks in essentially similar places to gain information to make decisions (e.g. out of cab at speed signs to gather speed information).
  - ➢ Drivers will be expected to know Enhanced Permissible Speeds (EPS) and non-EPS speeds.

  - Because of speed increases, more emphasis is placed on knowing shorter sections in training.
  - The system itself is not considered to be demanding. However, the line speed allowed by the tilting function does mean that drivers must see and react to information more quickly.
  - Drivers are taught to anticipate where they might get a cautionary signal to allow them to prime themselves to respond more quickly should one arise.
  - In terms of train operations, the speed of new trains has permitted alterations to the timetable to include more scheduled services. One result of this has been more potential disruption to the line (e.g. a small delay at a station can result in other drivers getting red signals).
- Studies:
  - Inexperienced train drivers may experience perceptual overloading due to multiple signs for tilting trains.

These comments and other data were used to conduct an analysis of risks to situation awareness. Risks presented by Tilting Trains to driver situation awareness were shown to be relatively few. The following issues were identified:

- The impact of increased line speeds on driver visual workload (caused by the same information being presented over a shorter period of time).
- The impact of increased lineside clutter on driver visual workload (caused by the introduction of additional speed signs for tilting trains).
- The effects of timetabling more services on a line (delays are more likely to impact on subsequent services, possibly resulting in increased driver workload).

The main strategies identified for mitigating these issues (refer description of training interventions in Table 20) were:

- workload management training
- fatigue management training
- programmes to monitor driver fatigue
- training in self-checking skills.

The analysis of the risks posed to driver situation awareness by tilting trains identified relatively few risks. While the drivers need to remember some extra information related to the system (e.g. EPS and Non EPS speeds) no comments indicated that this was likely to be a significant burden on drivers.

Self checking skills are particularly important if drivers are being trained (as was reported to the study team) to ‘anticipate’ signal aspects. This may reduce risks relating to expectancy, by teaching drivers to treat any anticipation as a ‘hypothesis’ which must be checked at the earliest opportunity against environmental evidence.

<u>ERTMS</u>

Individual comments made by industry specialists or gathered from studies of ERTMS included:

- Comments:
  - ERTMS may have some impact on drivers’ capacity to make decisions. Because it supervises speed (providing a warning, then intervening if required), there is some risk that drivers will wait until they hear the warning before modifying their speed. Depending on how reliable the system is, this may or may not be a problem.

- The time spent looking in cab will depend to a large extent on how ERTMS is implemented. If the planning area is provided, drivers may become used to reading off the cab display. This becomes a risk if, under abnormal circumstances, they have to transfer to on-sight driving as they may be unused to driving without the screen. Furthermore, the extent to which new drivers are trained to drive 'off the screen' needs to be standardised so that driving behaviour is consistent.
- The risk of driver boredom depends upon how the system is implemented. If the driver is allowed to rely on the system to control speed then there is a risk of driver inattention and boredom. However, if drivers are told they should drive in a way where they do not activate the speed warning they are likely to be more alert.
- Driver training currently emphasises driver skill. There is a possibility of deskilling under ERTMS which may consequently present a risk to job satisfaction.
- A requirement for drivers to have route knowledge still exists under ERTMS. There should be no need for the level of detail currently trained. There could also be a need for less frequent refresher training.

- Studies:
  - Unless the Driver Machine Interface (DMI) instructs drivers where and when to increase vigilance, drivers will need to maintain route knowledge to provide this information.
  - Drivers should be trained to be aware of the information they need to collect and confirm, before making a decision. In this way they can ensure that they have sufficient information upon which to base a decision and improve reliability of decision making.
  - It may be harder to recover from failures under ERTMS, as there will be fewer backups in place and potentially less information to help manage the process. Staff will lose practical experience as systems and processes become automated and consequently they will be less able to respond correctly when the system or process fails.

These comments and other data were used to conduct an analysis of risks to situation awareness. This analysis identified that ERTMS could potentially have a significant impact on driver situation awareness, under both normal and abnormal operating conditions. The following issues were identified:

- The impact of the DMI on visual workload.
- The demands of the system distracting the operator from their primary task.
- The system performance resulting in drivers losing the skills necessary to drive the train in areas or at times when the system is not available.
- The removal of driver responsibility for speed choice resulting in complacency and boredom.
- The enforcement of upper speed limits by the system resulting in the driver becoming over-reliant on the system[6].
- The increase in visual perception tasks and/or the decrease in workload impacting on driver fatigue.

[6] Reliance on the system-controlled upper speed limit may not be inappropriate if the system is reliable. The ERTMS simulator trials in Madrid showed that European drivers place greater reliance on the system controlled upper speed limit than UK drivers.

The main strategies identified for mitigating these issues (refer description of training interventions in Table 20) were:

- Attention monitoring and management skills training.
- Workload management training.
- Fatigue management training.
- Self-checking training.
- Training and assessment to ensure drivers retain any required manual skills (including route knowledge).
- Ensuring that train drivers have a good understanding (mental model) of systems responses under abnormal circumstances.
- Maintaining a professional driving culture and ethos.
- Designing a system that accounts for driver attentional capabilities.
- Designing systems/procedures so that drivers are involved in speed change decisions.
- Developing procedures for abnormal circumstances which take into account driver attentional capabilities and skill fade issues associated with route knowledge.
- Programmes to monitor fatigue.
- Monitoring driver performance (e.g. download and analysis of train data).
- Consideration of alterations to shift pattern or lengths, if fatigue is found to be an issue.
- Selection of drivers with an aptitude for maintaining attention under low workload conditions.
- Reconsideration of driver recruitment, selection and retention practices.
- Ensuring that train drivers are valued by management.

The results of this analysis indicated that the way drivers gain and maintain situation awareness may be considerably different under ERTMS. The requirement for situation awareness, however, will remain. Subject to the real-time information provided by the DMI being able to advise drivers where and when to increase vigilance, drivers may be able to operate the system safely with less route knowledge held in memory.

Route knowledge requirements are unlikely to be removed entirely, as the following example illustrates:

There are instances under ERTMS where drivers will be required to select and maintain appropriate speed. For example, drivers will only be provided with a braking curve on approach to a stopping station if the stop coincides with an End-Of-Authority (EOA). Otherwise, the driver will need to select a braking point and control speed whilst ignoring speed advisory information.

The successful use of real-time information provided by the DMI depends upon the driver having the skills to gather appropriate information in a timely fashion to make decisions. Studies and industry expert comments indicate that:

- drivers should be trained to know what information they should gather from the environment

- ❑ the use of the DMI and/or out of cab cues should be standardised to ensure that all drivers use the DMI consistently.

Current conceptions of ERTMS suggest that drivers would be required to drive without the full supervision of the ERTMS system (i.e. in driver supervised mode) under some circumstances. While this study did not specifically examine issues related to driver supervised mode, the results do provide some support to the view that if drivers are trained in the baseline skills required to gain and maintain situation awareness (e.g. scanning, attention management) they should be able to drive a route safely given that they will be travelling at relatively low speeds and would be driving in this mode for relatively short distances.

A separate study has found that drivers were content with switching between sections of routes protected by ATP those that were not because it kept them alert. It seems likely that with appropriate training, drivers should be able to transition safely between different levels of ERTMS. One key issue may be ensuring that drivers have a distinct set of behaviours associated with each mode (e.g. scanning patterns for ERTMS Level 2D equipped routes and other patterns for ERTMS Level 0 routes). In addition, a set of procedures to assist drivers in 'gearing up' for the mode change should be trained.

<u>Automatic Train Operation (ATO)</u>

Individual comments made by industry specialists or gathered from studies of ATO included:

- ❑ Comments:
  - ➢ The drivers' role becomes more like a guard, with the knowledge of how to control the train in an emergency. Drivers are inevitably more removed from the role of driving under ATO systems.
  - ➢ Drivers typically have less to do under automatic systems than on standard underground or mainline trains. Because some current ATO systems don't function with 100% reliability (in terms of pulling into stations accurately) driver workload is maintained. There are concerns, however, that as the systems become more accurate, boredom and inattention may become an issue.
- ❑ Studies
  - ➢ ATO makes fewer competing activity demands on the train operator than other means of operation (e.g. coded manual) and may support better task performance in some task areas (e.g. watching platform/train interface on entering and leaving station).
  - ➢ Train operators also suggested that ATO took pressure off them in terms of having to meet the platform approach speeds, deceleration, and stopping within an ever-tightening train service.
  - ➢ Under ATO the control element of the driving task is removed. All cognitive resources are allocated to scanning and monitoring tasks. This removes an active task (controlling train speed) and reduces the driving task to one of vigilance only.
  - ➢ In terms of driving between stations, discussions with train operators suggest that ATO does have an impact on alertness. Drivers often reported being bored.

- ➢ The train operators' skills level in driving in coded manual means that little 'attention' is given to the task of actually controlling the speed of the train. As such, this task does not act as a stimulus to combat the effects of boredom.

These comments and other data were used to conduct an analysis of risks to situation awareness. This analysis identified that ATO could potentially have a significant impact on driver situation awareness. The main issues identified were:

- ❑ The system performance resulting in drivers losing the skills necessary to drive the train in areas or at times when the system is not available.
- ❑ Low workload might result in boredom, complacency and fatigue.
- ❑ Limited driver role may result in reduced job satisfaction.
- ❑ Limited system reliability might impact upon driver trust.

The main strategies identified for mitigating these issues (refer description of training interventions in Table 20) were:

- ❑ Training drivers to operate the system manually where required (including route knowledge training).
- ❑ Workload management training.
- ❑ Attention monitoring and management training.
- ❑ Professional driving training.
- ❑ Training in recognition and response to system unreliability.
- ❑ Designing procedures for abnormal circumstances that don't rely on the drivers' manual skills.
- ❑ Designing the task to increase its complexity.
- ❑ Designing the task so that the driver is 'in the loop'.
- ❑ Designing the system to increase its reliability.
- ❑ Providing decision support technology.
- ❑ Selecting drivers with an aptitude for maintaining attention under low workload conditions.
- ❑ Ensuring drivers and the driving task is valued by management.

Analyses suggest that ATO could have a significant effect on a driver's ability to gain and maintain situation awareness were it introduced on mainline trains. The key issues identified related to loss of manual skills, boredom, and fatigue. Issues related to job satisfaction were also noted. Training drivers to manage their attention levels and workload, and most importantly, training them to recognise when their level of vigilance might be reduced, could mitigate some of the risks associated with introducing this technology.

5.6 Section Summary

Across the technologies reviewed, a range of situation awareness risks were identified. These included risks related to:

- ❑ over-reliance on the technology
- ❑ mistrust in the technology due to poor system reliability
- ❑ conflicting attentional demands of the technology
- ❑ increased visual workload (caused by, for example, line speed, visual clutter at the lineside, system/line variability, and interface design)

- a failure to develop and maintain the knowledge and skills required to ensure appropriate situation awareness when required to operate the train manually
- complacency and boredom
- fatigue
- reduced job satisfaction.

It should be noted that more risks were identified for ERTMS and ATO than for GSM-R and Tilting Trains. This may be due in part to the greater impact of ERTMS and ATO upon the capacity of the driver to make decisions and on their role within the system.

A range of strategies were identified to mitigate the risks listed above. The most commonly identified strategies were systems/procedure design and driver training. The training-related strategies, listed below, are described in Table 20:

- Attention monitoring and management training.
- Workload management training.
- Fatigue management training.
- Maintaining a professional driving culture and ethos.
- Training in systems checks and procedures associated with system unreliability.
- Training in the knowledge and skills required to ensure appropriate situation awareness to operate the train manually, if required to do so.

Three of the four technologies reviewed showed risks relating to driver attention and distraction from their primary task. For example, the system might distract drivers when approaching a complex station by using a buzzer or other sound to direct their attention to information as it appears on the display, impacting on their ability to monitor outside the cab for hazards. Another example relates to system reliability. If the system is (or is believed to be) unreliable drivers may need to gather data from other sources to confirm information provided by the system. The potential for the system to inappropriately distract the driver should be assessed and mitigated.

Analyses of two technologies (ERTMS and ATO) indicated that there was concern among industry experts regarding drivers acquiring and maintaining the skills needed to operate the train manually in perturbed operations. In particular, concern was expressed about how drivers would develop and maintain route knowledge when external cues were not often used. If there is any need for manual operation (in either normal or abnormal circumstances), strategies should be implemented to ensure that drivers develop and maintain these skills. Furthermore, because cognitive skills (e.g. route knowledge) are particularly prone to skill fade, these aspects of driving should receive particular attention.

London Underground Central Line drivers operate in a manual mode on Sundays, to allow practice in driving skills not exercised under normal circumstances.

During analysis of comments by industry experts, it was noted that the potential risks to situation awareness described were similar to those identified in studies of other industries. No risks were identified during discussion with industry experts which had not already been defined through analysis of other industries. This suggests that whilst the rail industry has its own unique issues, it can benefit from knowledge gained in other industries to effectively manage the risks associated with implementing new technology.

Finally, the following caveat should be noted about information presented in this section:

The methodological approach taken by this study was to conduct a general review of the effects of technology on route situation awareness within a human factors framework. This provides a basis for reviewing the potential impact of any new technology on the operator. However, a detailed analysis of the likelihood and consequences of the risks identified was not possible due to the immaturity of some of the technologies and the scope of the study. Further research into the risks identified should be conducted so that appropriate interventions can be developed (e.g. investigation into effective and efficient means to maintain skills unique to abnormal operations, and analysis of effective attention and workload management strategies for specific technologies).

6 Conclusions

6.1 Introduction

Earlier sections in this report present and contextualise relevant observations. This section presents the principal conclusions collated from earlier sections of this report.

6.2 Principal Conclusions from Section 3 – Performance Analysis

1) Based on incidents analysed and discussion with industry specialists, information available to the driver, presented by the external environment, through cab interfaces or by communication from others, is likely to be sufficient to inform route knowledge and situation awareness.

2) Analysis of incident data suggests that perception errors – primarily not looking in the right place, for the right information, at the right time – are the most likely cause of driver error. Industry specialists, however, identified comprehension errors – primarily misinterpreting data or failing to recall information – as the most likely cause of error. The study did not examine reasons for this difference, although the identified training and assessment solution addresses both perception and comprehension issues.

3) Misreading data, such as signals, was identified by industry specialists and incident data as a fairly likely cause of error. This can happen when drivers have prior expectations of the state of the situation, perhaps based on an inappropriate mental model, and fail to notice when the situation differs from these expectations. The study identified training and assessment solutions to address issues relating to expectancy and mental models.

6.3 Principal Conclusions from Section 4 – Training and Assessment

Training and assessment content

4) The study did not identify major problems with the content of training relating to route features. These observations support the conclusion that drivers are provided with adequate (and in some cases, perhaps excessive or unnecessary) information about route features, but that this information in itself is not sufficient to develop competence.

5) This study identified a detailed set of route knowledge and situation awareness Training Objectives (refer Table 11) and supporting lists of knowledge (refer Annex A, with summarised list at Table 11), skills (refer Table 12) and behaviours (refer Table 13). These could be tailored by operators to meet their particular operational requirements, and used to augment or refine current training, assessment and selection processes.

6) Whilst assessment of route knowledge requirements showed relatively few differences between operator types, the effects of these differences is quite significant on the level and emphasis of route specific knowledge required. For example, whilst knowledge of gradients is specified as a requirement, freight train drivers may need a more detailed understanding of gradients to allow them to consider the effects of weight on train braking and stopping distances. Similarly, whilst knowledge of stations and risks associated with specific stations along a route is identified, drivers working without a guard may need enhanced training to be particularly vigilant when leaving stations, due to the conflicting attentional demands of passengers on the platform, door closing, dispatchers and signals.

7) Many operators observed that they would be reluctant to identify specific braking cues for drivers to use. Instructors and driver mentors are, however, commonly providing this information to trainee drivers. Identification by drivers of appropriate braking cues and areas are essential to the maintenance of situation awareness.

Route risk assessment

8) The content of existing route risk assessments is based primarily on the risks listed in GO/RC 3551. Route risk assessment processes are not, however, consistently conducted or reported across the industry.

9) Data obtained during the route risk assessment process is not consistently or explicitly used to inform route knowledge training duration and content, or assessment content.

10) The relative importance of risks associated with specific routes may vary significantly between operators. For example, IMC drivers may drive a route only in the dark, so risks associated with sunlight affecting signals may not be relevant.

Training Media and Methods

11) Guidance on the selection and use of training and assessment media is provided at Section 4.4 Together with the detailed information provided on training and assessment requirements, these should be suitable for tailoring by operators to meet their particular needs - the variability between operators limits the detailed guidance that can be provided in this report.

12) The types of media used by train operators to train route knowledge and situation awareness are broadly appropriate, if used appropriately. The training benefit to be gained from high fidelity solutions such as simulators is likely to be outweighed by their cost, if procured specifically for route knowledge and situation awareness training.

13) Train operators do not typically provide information regarding the intended target audience or specific purpose of route maps, nor do they typically tailor route maps for different purposes.

Assessment

14) Evidence gained during the study suggests that there may be some uncertainty within the rail industry regarding what media are appropriate for assessment of route knowledge.

15) All train operators interviewed reported using observation of the driver driving a train as part of the assessment process. Typically, this observation relies on the instructor's judgement of the driver's competence. This introduces the likelihood of inconsistency in assessment standards.

16) Assessment of train driver route knowledge and situation awareness may require instructors and assessors to be provided with additional skills, to enable them to assess drivers' situation awareness during a cab ride.

6.4 Principal Conclusions from Section 5 – Preparing for the Future

17) Across the technologies reviewed, a range of situation awareness risks were identified. These included risks related to:
   - over-reliance on the technology
   - mistrust in the technology due to poor system reliability
   - conflicting attentional demands of the technology
   - increased visual workload (caused by, for example, line speed, visual clutter at the lineside, system/line variability, and interface design)
   - a failure to develop and maintain the knowledge and skills required to ensure appropriate situation awareness when required to operate the train manually
   - complacency and boredom

- fatigue
- reduced job satisfaction.

18) More risks were identified for ERTMS and ATO than for GSM-R and Tilting Trains. This may be due in part to the greater impact of ERTMS and ATO upon the capacity of the driver to make decisions and on their role within the system.

19) Three of the four technologies reviewed showed risks relating to driver attention and distraction from their primary task. For example, the system might distract drivers when approaching a complex station by using a buzzer or other sound to direct their attention to information as it appears on the display, impacting on their ability to monitor outside the cab for hazards. Another example relates to system reliability. If the system is (or is believed to be) unreliable drivers may need to gather data from other sources to confirm information provided by the system.

20) Analyses of two technologies (ERTMS and ATO) indicated that there was concern among industry experts regarding drivers acquiring and maintaining the skills needed to operate the train manually. In particular, concern was expressed about how drivers would develop and maintain route knowledge when external cues were not often used.

21) During analysis of comments by industry experts, it was noted that the potential risks to situation awareness described were similar to those identified in studies of other industries. No risks were identified during discussion with industry experts which had not already been defined through analysis of other industries. This suggests that whilst the rail industry has its own unique issues, it can benefit from knowledge gained in other industries to effectively manage risks associated with implementing new technology.

7 Recommendations

1) Route knowledge and situation awareness training should be reviewed and updated as required to reflect the results of this study and the particular needs of the operator. (Conclusions 2, 3, 5, 6, 10, 11)

2) Novice drivers should be provided with information on the characteristics of good cues, to enable them to identify appropriate, route-specific cues when learning routes. Whilst this study is not recommending that driver instructors or mentor drivers *should* advise on specific braking points for novice drivers, those operators whose training staff *do* provide this information should take steps to ensure that they identify appropriate, consistent cues. (Conclusion 7)

3) There is a need to develop an objective and formal route situation awareness assessment approach within driver assessment. The recommended regime for assessment of situation awareness is:
   - verbal protocol (whilst driving a train)
   - verbal protocol (whilst conducting a train)
   - instructors' use of pre-defined questions to assess real-time situation awareness (whilst observing the driver in a simulator or train). (Conclusion 14, 15)

4) Route risk assessment processes should be made consistent, based on a systems approach to ensure consideration is given to all factors which might affect performance and safety of the operator over the route. Results of this process should be used explicitly to inform development of route maps. Route risk assessments should include identification of principal time of day, time of year and climatic safety risks affecting a route. These should inform the route knowledge assessment process. (Conclusions 8, 9, 10)

5) The following usability features should be incorporated into route maps:
   - The intended audience and purpose of the map should be stated.
   - The scale of the map should be stated (or if the map is not to scale, this should be stated).
   - A key for all symbols used should be included.
   - The publication date of the map and any past/future review dates should be stated.
   - Routes should be divided into parts with distinct character (such as the nodal point process used by some train operators, in which the route is divided by using locations of significant features such as major junctions, large stations, yards etc.).
   - Route Information provided should be chosen to support informed decision making (for example, gradients should be included to inform decisions about braking). Information which does not aid decision making should be considered for removal.
   - Inclusion of extensive information on a single map reduces its suitability for training purposes. If the map is to be used for multiple purposes, a layering format should be considered with different levels of detail available on each layer (for example, layer 1 might show signals and stations, layer 2 line speeds and gradients, layer 3 principal route risks). (Conclusion 13)

6) Driver instructor and assessor skills should be reviewed and developed to ensure that they are able to consistently meet requirements for route knowledge and situation awareness training and assessment. (Conclusion 16)

7) Further work is likely to be required to quantify the risks to driver route knowledge and situation awareness from new technologies as their capabilities and operational characteristics become better defined. Considered use of studies conducted in other industries may be of benefit in this activity. (Conclusions 17, 18, 19, 20, 21)

8 References

1. Deighton, C. (18 June 2004) *Route Knowledge Study Work Package 1*. Reference PR04001-D1.

2. Livingstone, H., Gipson, T. & Luther, R. (26 June 2005) *Work package 2 Report on analysis of route knowledge training and assessment*. Reference PR00401-D4.

3. Luther, R. (22 April 2005) *Work Package 3 Report on the impact of change on route knowledge*. Reference PR00401-D3.

4. Gipson, T. (22 November 2004) *Work Package 4 Report on the relationships between route knowledge and performance*. Reference PR00401-D2.

5. Human Factors Research Catalogue CD Rom 2005 Available from: http://www.rssb.co.uk/hfcd.asp

ANNEXES

Section **Page**

Annex A Detailed Knowledge List (expanded from Table 6)

Reference	Description	Comments
Kn1	**Principles of Route Knowledge and Underpinning Knowledge**	
Kn1.1	Knowledge of train protection systems	
Kn1.1.1	Types and format of train protection systems	-
Kn1.1.2	Working arrangements associated with train protection systems	-
Kn1.1.3	Issue associated with the commencement and termination of train protection systems	-
Kn1.1.4	Information provided by train protection systems	-
Kn1.1.5	Format/recognition of in-cab train protection systems display data	-
Kn1.1.6	Typical risks associated with train protections systems	-
Kn1.2	Knowledge of running lines	
Kn1.2.1	Types of signalling associated with running lines	-
Kn1.2.2	How to identify the signals associated with running lines	-
Kn1.2.3	Impact of limited clearance arrangements on running lines	-
Kn1.3	Knowledge of signalling systems	
Kn1.3.1	Types of signals	-
Kn1.3.2	Information provided by signals	-
Kn1.3.3	Typical risks associated with signalling systems	-
Kn1.3.4	Format and meaning of Banner repeaters	-
Kn1.3.5	Format and meaning of Stop boards	-
Kn1.4	Knowledge of junctions	
Kn1.4.1	Types of junctions	-
Kn1.4.2	Operational procedures associated with types of junctions	-
Kn1.4.3	Typical risks associated with junctions	-
Kn1.5	Knowledge of train radio systems	
Kn1.5.1	Types of radio systems	-
Kn1.5.2	Operational procedures associated with types of radio systems	-
Kn1.6	Knowledge of gradients	
Kn1.6.1	Operating restrictions associated with gradients and train type/weight/weather conditions	Freight and IMC will be more likely to be affected by weight of train
Kn1.6.2	Typical risks associated with gradients	Freight and IMC will be more likely to be affected by weight of train
Kn1.7	Knowledge of lineside signage	
Kn1.7.1	Format and meaning of Fire zones	-
Kn1.7.2	Format and meaning of Mileage markers.	-
Kn1.7.3	Format and meaning of Temporary/Emergency speed signs	-
Kn1.7.4	Format and meaning of Speed boards	-
Kn1.7.5	Format and meaning of Reflective boards	-
Kn1.7.6	Format and meaning of Warning boards	-
Kn1.7.7	Format and meaning of Whistle signs/stop	-
Kn1.7.8	Format and meaning of Coasting boards	-
Kn1.7.9	Format and meaning of Countdown board/markers	-
Kn1.7.10	Format and meaning of Clearance boards	-
Kn1.7.11	Format and meaning of Low adhesion warning sites	-

Reference	Description	Comments
Kn1.8	Knowledge of points	
Kn1.8.1	Format and function of points	-
Kn1.8.2	Permissible speeds over points	-
Kn1.8.3	Typical risks associated with points	-
Kn1.9	Knowledge of signal boxes	
Kn1.9.1	Operation of signal boxes including any restrictions	-
Kn1.9.2	Communicating methods associated with signal boxes	-
Kn1.9.3	Typical risks associated with signal boxes	-
Kn1.10	Knowledge of bridges	
Kn1.10.1	Operating restrictions associated with bridges	-
Kn1.10.2	Typical risks associated with bridges	-
Kn1.11	Knowledge of tunnels	
Kn1.11.1	Operating restrictions associated with tunnels	-
Kn1.11.2	Typical risks associated with tunnels	-
Kn1.12	Knowledge of level crossings	
Kn1.12.1	Types of level crossings including their method of working	-
Kn1.12.2	Permissible speeds associated with level crossings	-
Kn1.12.3	Knowledge of special working arrangements for degraded situations	-
Kn1.12.4	Typical risks associated with level crossings	-
Kn1.13	Knowledge of stations	
Kn1.13.1	Methods of working associated with stations	-
Kn1.13.2	Train dispatch arrangements during normal and degraded working	-
Kn1.13.3	Typical risks associated with stations	-
Kn1.14	Knowledge of depots	
Kn1.14.1	Methods of working associated with depots	-
Kn1.14.2	Typical risks associated with depots	-
Kn1.15	Knowledge of sidings	
Kn1.15.1	Methods of working associated with sidings	-
Kn1.15.2	Typical risks associated with sidings	-
Kn1.16	Knowledge of power supplies	
Kn1.16.1	Operating methods associated with neutral sections	-
Kn1.16.2	Operating methods associated with wired/unwired sections	-
Kn1.17	Knowledge of authorised walking routes	
Kn1.17.1	How to recognise authorised walking routes	-
Kn1.17.2	Typical risks associated with walking routes	-
Kn1.18	Situation awareness knowledge required in an emergency	
Kn1.18.1	Where not to stop during an emergency	-
Kn1.18.2	Processes to follow in event of an emergency	-
Kn1.19	Principles of an appropriate cue to use over a route	
Kn1.19.1	Principles of effective cues	-
Kn1.19.2	Principles of ineffective cues	-
Kn1.20	Knowledge of preparation required before commencing journey	
Kn1.20.1	Types of information required to be collected prior to a journey (e.g. weather reports, timetable changes, temporary speed restrictions)	-
Kn1.20.2	Format and typical location of types information required prior to a journey	-
Kn1.21	Knowledge of factors that can impact situation awareness	
Kn1.21.1	External factors that can impact situation awareness	
Kn1.21.1.1	Factors associated with external cues and techniques to manage this, e.g. typical risks associated with route features like signals, signs, and bridges	-

Reference	Description	Comments
Kn1.21.1.2	Factors associated with external environment and techniques to manage this, e.g. fog, low adhesion areas etc	-
Kn1.21.1.3	Factors associated with internal environment and techniques to manage this, e.g. cab temperature	-
Kn1.21.1.4	Factors associated with onboard cues and techniques to manage this, e.g. use of AWS warning as distance cue (distances from magnet to signal can vary) or the introduction of new in-cab cues	-
Kn1.21.1.5	Factors associated with other people and techniques to manage this, e.g. information passed by signaller, customer movements on platform	-
Kn1.21.1.6	Factors associated with a train's characteristics and techniques to manage this, e.g. driving trains of different weights and lengths	-
Kn1.21.1.7	Factors associated with workplace organisation and techniques to manage this, e.g. pressures to meet the timetable	-
Kn1.21.2	Individual factors that can impact situation awareness	
Kn1.21.2.1	Factors associated with physical health and techniques to manage this, e.g. illness	-
Kn1.21.2.2	Factors associated with psychological state and techniques to manage this, e.g. fatigue	-
Kn1.21.2.3	Factors associated with stress and techniques to manage this, e.g. how stress reduces a driver's ability to remember previous signal	-
Kn1.21.2.4	Factors associated with attitude and techniques to manage this, e.g. commitment to safe driving	-
Kn1.21.2.5	Factors associated with route experience and techniques to manage this, e.g. drivers with more experience over a route may be more prone to expectancy	-
Kn1.21.2.6	Factors associated with driver experience and techniques to manage this, e.g. drivers with less experience may have less spare cognitive capacity and experience heightened workload because of this	-
Kn1.21.2.7	Factors associated with building a mental model of a route, e.g. information must be built up progressively	-
Kn1.21.2.8	Factors associated with maintaining a mental model of a route, e.g. issues associated with memory and skill fade	-
Kn1.21.2.9	Factors associated with workload and techniques to manage this, e.g. managing high workload situations	-
Kn2	**Route specific knowledge**	
Kn2.1	Knowledge of train protection systems	
Kn2.1.1	Commencement and termination points of train protection systems including AWS, TPWS, ATP	-
Kn2.1.2	Risks associated with train protection systems along the route	-
Kn2.2	Knowledge of running lines	
Kn2.2.1	Names of running lines	-
Kn2.2.2	Directions of running lines (up/down/bi-directional)	-
Kn2.2.3	Risks associated with the running lines	-
Kn2.3	Knowledge of signalling systems	
Kn2.3.1	Location and type of signals	-
Kn2.3.2	Location of bidirectional signals	-
Kn2.3.3	Location of route indicators	-
Kn2.3.4	Location of Banner repeaters	-

Reference	Description	Comments
Kn2.3.5	Location of stop boards	-
Kn2.3.6	Location of signals that are at risk of SPADs	May vary between operators
Kn2.3.7	Risks associated with specific signals along the route (not just those with a record of multi SPADs)	May vary between operators
Kn2.4	Knowledge of junctions	
Kn2.4.1	Name of junctions	-
Kn2.4.2	Location of junctions	-
Kn2.4.3	Permissible speeds over junctions	May vary between operators
Kn2.4.4	Diversionary routes available at junctions	May vary between operators
Kn2.4.5	Permissible routes according to train type and route knowledge of driver	May vary between operators
Kn2.4.6	Risks associated with specific junctions along the route	May vary between operators
Kn2.5	Knowledge of train radio systems	
Kn2.5.1	Commencement and termination points of radio systems	-
Kn2.5.2	Radio channel change locations	-
Kn2.5.3	Radio contacts along route	-
Kn2.5.4	Risks associated with radio contacts along the route	-
Kn2.6	Knowledge of gradients	
Kn2.6.1	Commencement and termination of significant changes in gradient	May vary between operators
Kn2.6.2	Location of steep gradients	May vary between operators
Kn2.6.3	Risks associated with specific gradients along a route	May vary between operators
Kn2.7	Knowledge of lineside signage	
Kn2.7.1	Location of Fire zones	-
Kn2.7.2	Location of Mileage markers	-
Kn2.7.3	Location of Temporary/Emergency speed signs	-
Kn2.7.4	Location of Speed boards	-
Kn2.7.5	Location of Reflective boards	-
Kn2.7.6	Location of Warning boards	-
Kn2.7.7	Location of Whistle signs/stop	-
Kn2.7.8	Location of Coasting boards	-
Kn2.7.9	Location of Countdown board/markers	-
Kn2.7.10	Location of limited clearance boards	-
Kn2.7.11	Location of low adhesion warning sites	-
Kn2.7.12	Risks associated with specific signs along the route	May vary between operators
Kn2.8	Knowledge of permissible speeds in relation to train being driven	
Kn2.8.1	Commencement and termination of permanent speed limits	-
Kn2.8.2	Commencement and termination of temporary speed limits	-
Kn2.8.3	Commencement and termination of emergency speed limits	-
Kn2.9	Knowledge of points	
Kn2.9.1	Location of points along route	-
Kn2.9.2	Permissible speeds over points	-
Kn2.9.3	Risks associated with specific points along a route	May vary between operators
Kn2.10	Knowledge of signal boxes	
Kn2.10.1	Location of signal boxes along route	-

Reference	Description	Comments
Kn2.10.2	Risks associated with specific signal boxes along a route	May vary between operators
Kn2.11	Knowledge of bridges	
Kn2.11.1	Location of bridges along route	-
Kn2.11.2	Identification details of bridges along route	-
Kn2.11.3	Risks associated with specific bridges along a route	May vary between operators
Kn2.12	Knowledge of tunnels	
Kn2.12.1	Location of tunnels along route	-
Kn2.12.2	Identification details of tunnels along route	-
Kn2.12.3	Lengths of tunnels (approximate e.g. long, short)	-
Kn2.12.4	Risks associated with specific tunnels along a route	May vary between operators
Kn2.13	Knowledge of level crossings	
Kn2.13.1	Location of level crossings	-
Kn2.13.2	Types of level crossings along route	-
Kn2.13.3	Identification details of level crossings along route	-
Kn2.13.4	Permissible speeds associated with level crossings	-
Kn2.13.5	Risks associated with specific level crossings along a route	May vary between operators
Kn2.14	Knowledge of stations	
Kn2.14.1	Locations and names of stations along route	-
Kn2.14.2	Platforms layouts and stopping markers	-
Kn2.14.3	Signal locations in relation to station, including risk of SOY and SAS SPAD	-
Kn2.14.4	Local working instructions applicable to a station	-
Kn2.14.5	Risks associated with specific stations along a route	May vary between operators
Kn2.15	Knowledge of depots	
Kn2.15.1	Locations and names of depots along route	-
Kn2.15.2	Local working instructions applicable to a depot	-
Kn2.15.3	Risks associated with specific depots along a route	May vary between operators
Kn2.16	Knowledge of sidings	
Kn2.16.1	Locations and names of sidings along route	-
Kn2.16.2	Local working instructions applicable to a siding	May vary between operators
Kn2.16.3	Risks associated with specific sidings along a route	May vary between operators
Kn2.17	Knowledge of power supplies	
Kn2.17.1	Commencement and termination of neutral sections along route	-
Kn2.17.2	OLE/3rd rail changeover points along route	-
Kn2.17.3	Risks associated with specific power supplies along a route	May vary between operators
Kn2.18	Knowledge of authorised walking routes	
Kn2.18.1	Location of authorised walking routes to which the drivers are required to have access	-
Kn2.18.2	Risks associated with specific authorised routes along a route	-
Kn2.19	Knowledge of timetable	
Kn2.19.1	Train timetable including stations to be stopped at and times of arrivals and departures	Freight/IMC do not need to know arrivals and departures at all stations
Kn2.19.2	Where on route it is possible to make up lost time and	Freight/IMC may

Reference	Description	Comments
	the associated safety implications	have different strategies
Kn2.20	Knowledge of cues available to inform situation awareness on a route	
Kn2.20.1	Cues used for location/distance recognition	-
Kn2.20.1.1	Visual, auditory and kinaesthetic cues used for location/distance recognition	-
Kn2.20.1.2	Risks associated with specific location/distance cues along a route	-
Kn2.20.2	Cues used for speed recognition	-
Kn2.20.2.1	Visual, auditory and kinaesthetic cues used for speed recognition	-
Kn2.20.2.2	Risks associated with specific speed recognition cues along a route	-
Kn2.20.3	Cues used for braking and acceleration	-
Kn2.20.3.1	Visual, auditory and kinaesthetic cues used for braking and acceleration	-
Kn2.20.3.2	Impact of train length/weight on cues used for braking and acceleration	More significant for Freight/IMC
Kn2.20.3.3	Risks associated with specific braking and acceleration cues along a route	May vary between operators
Kn2.21	Situation awareness knowledge required in an emergency	
Kn2.21.1	Specific locations along a route to avoid stopping in an emergency	-
Kn2.21.2	Key track site names in the event of a failure	-
Kn2.21.3	Contact point in an emergency	-

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