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Partners: DNV - Det Norske Veritas
ERRI - European Rail Research Institute
HRA - Human Reliability Associates
HR - Halcrow Rail
SNCF - Société Nationale des Chemins de Fer Français
TAT - TÜV Rheinland Anlagentechnik

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HUSARE

Human Safe Rail in Europe

Managing the Human Factor in Multicultural and Multilingual Rail Environments

*Human Factor Analysis Techniques for Cross-Border Rail Operation*
0. Executive Summary

The EC transport policy proposes that European railways should be revitalised to attain a more important role in freight and passenger transport within the European community, necessitating increased interoperability. Cross-border rail operation generates new human factors problems and associated risks which need to be addressed. As trains pass through national and infrastructure borders, the different technological systems, rules, procedures and cultural characteristics all have profound implications for safe operation.

This report describes the work of the HUSARE project group to develop and test human factor analysis techniques to reduce human related risks in cross-border rail operation. The objective was to provide the European rail industry with a common method for evaluating and improving the management of human factors to contribute towards safe, reliable and efficient interoperability.

Selected human factor analysis techniques were applied to eight test scenarios encompassing hazards related to cross-border rail operation under normal and degraded conditions and in emergency situations. The experience gained from this exercise has led to the development of a practical toolkit of techniques for rail operators. This toolkit includes:

- data collection and comparison techniques and documentation proforma for the rules, procedures, operating practices and technical systems to identify differences between rail infrastructures and the relevant human factor issues.
- human factor analysis techniques to identify possible human errors/failures, potential for error recovery and risk reduction strategies.

The toolkit provides for a structured approach to the management of human factors in cross-border operation (both existing and proposed routes) and may also be applied to the consideration of human factors within a single infrastructure. Furthermore, it may be employed in a stand-alone manner, or may be integrated into formal (traditionally hardware-oriented) risk analyses. The toolkit may also be used to address a range of human factors issues within the rail sector:

- design of human-machine interface, such as in-cab displays and disposition control rooms
- the development of rules and procedures and other documentation
• specification of training requirements

• job design

In the analysis of the test scenarios human factor issues were examined and a number of generic risk reduction measures are suggested. Although these measures may be widely applicable, it is nevertheless essential that they should be individually evaluated within the rail operator’s risk assessment and safety justification process.

It is considered that the objectives of the HUSARE project have been achieved. However the success of the project lies in the application of the toolkit within the rail industry. Progress in this direction is dependent on the recipients of this report, who have responsibility for safety, to promote the use of the HUSARE toolkit within their organisation and to support the dissemination of the HUSARE toolkit and the underlying principles as a European rail standard. These are the necessary prerequisites to achieve implementation at the international level for safe and effective rail operation throughout Europe.
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1. **Project Sponsors**

Project:
HUSARE "**Human Safe Rail in Europe** - Managing the Human Factor in Multicultural and Multilingual Rail Environments".

The HUSARE Project is funded jointly by DG VII, CEC, (Framework IV, Transport RTD Programme) and by the Union Internationale des Chemins de Fer (UIC).

2. **Partners**

The consortium of Partners working on the HUSARE project come from a number of European countries and bring together extensive expertise in the analysis of human factors. The Partners from SNCF and HT are closely connected to rail operators; the remaining partners come from specialist organisations with experience in systems safety and human reliability. A brief description of each of the partners is provided below, along with the names of the contributors to the project.

**TÜV InterTraffic GmbH, ISEB** (a member of the **TÜV Rheinland/Berlin-Brandenburg Group**), Germany is the project co-ordinator.

With its 69 offices in 32 countries the TÜV Rheinland/Berlin-Brandenburg Group can be found nearly all over the world. Its specialised services are available wherever there is a man-machine interaction and where environmental interests are at stake. Roughly 7,000 employees with a special commitment to service form the basis of the TÜV Rheinland/Berlin-Brandenburg Group’s success in business.

The **Institute for Software, Electronics and Railway Technology (ISEB)** an accredited organisation with extensive experience in the safety assessment of Guided Transport systems and operations including new systems such as Transrapid. It recently became a company of its own named TÜV InterTraffic GmbH. More information about ISEB and their services can be found on their internet address [www.iseb.com](http://www.iseb.com). (Rüdiger Wiedenmann).

**Det Norske Veritas (DNV), Norway** is an independent foundation working to safeguard life, property and environment at sea and on land, and was founded as a ship classification society in 1864. Ship classification is still one of their main activities, but
their work has been expanded to also cover other areas including railways. DNV has a total of 5500 employees serving an international office network of 300 exclusive offices in 100 countries. Their head office is at Høvik outside Oslo in Norway.

Risk analyses and safety advisory services to the railway community are carried out in many countries including: Denmark, Finland, Norway, Sweden, Netherlands, UK, Australia and Hong Kong. DNV has been notified as a competent body for EC-verification of conformity of railway components (infrastructure and rolling stock) according to the Council directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail system. More information about DNV and their services in general can be found on their internet address www.dnv.com (Terje Andersen, Michael Lehmann).

TÜV Rheinland Anlagentechnik (TAT), Germany is part of the TÜV Rheinland/Berlin-Brandenburg Group and has extensive experience of safety in technological systems. TAT contributed Human Factors expertise and research experience in the area of human behaviour in complex tasks to the HUSARE project. (Susan Reinartz).

Human Reliability Associates Limited, UK is an international consulting company specialising in improving human performance and minimising human error in industrial sectors such as chemical processing, aviation, road and rail transport, nuclear and conventional power generation, marine transport and space systems. The company has over 18 years of experience in these areas. HRA have built up a balanced team of both engineers and behavioural scientists who are able to address these areas. In addition to their in-house staff, HRA have access to a network of Associates who are able to provide specialist support for specific projects as required.

HRA have achieved an international reputation in the area of the management of the human factor in systems. Their clients include major organisations in the United Kingdom, the European Union, the USA, South America and the Far East. The range of services offered by HRA includes consultancy, contract research, training and specialist software. Their experience in the railway sector has included clients such as Railtrack, British Rail, London Underground Ltd, the Rail and Maritime Transport Union and Docklands Light Railway. Further information about their capabilities and services may be found at their internet address www.humanreliability.com. (Dr. David Embrey, Martin Anderson, Lisette Kanse).
Halcrow Rail (formerly Halcrow-Transmark), UK has its roots in the British Railways Board. Following privatisation, former members of the BRB Safety Directorate, who subsequently joined Halcrow-Transmark, have continued consultation work in rail operation and this expertise was brought to the HUSARE project. (Ray Metcalfe, Roger Merryweather).

European Rail Research Institute (ERRI), Netherlands is a foundation under Dutch law within the Union Internationale des Chemins de Fer (UIC) responsible for carrying out research, studies and tests in fields of common interest.

ERRI carries out a policy of cooperating with various partners (users, railway operators and industry, technical research centres, universities, etc.) knowing that pooling resources will boost the effectiveness of projects and allow more flexibility and responsiveness to research requirements at a European level.

Its role includes co-ordinating long-term research programmes and ERRI is particularly active in:

- Management and execution of studies, research and tests
- Drafting of research and development programmes
- Development and testing of railway equipment
- Monitoring of emerging technologies and their application to the railways

ERRI has extensive in-house expertise in the field of the railway signalling and operation and invaluable connections to European rail operators. Further information about their capabilities and services may be found at their Internet address www.erri.nl. (Bogdan Godziejewski).

Société Nationale des Chemins de Fer Francais (SNCF), France; the human factors department of SNCF contributed invaluable experience and knowledge of French national rail and Eurostar operation. (Yves Mortureux, Coralie Mugnai, Fabrice Ardeois).
3 List of Abbreviations

FRS Functional Requirement Specification of ERTMS/ETCS
HEROE Harmonisation of European Rules for Operating ERTMS
HUSARE Human safe rail in Europe
HTA Hierarchical Task Analysis
MMI Man-Machine Interface (now generally referred to as HMI – Human Machine Interface)
PIF Performance Influencing Factor
SPAD Signal Passed At Danger

Railways:

UK United Kingdom
DB Deutsche Bahn (Germany)
FS Ferrovie dello Stato (Italian railways)
NS Nederlandse Spoorwegen (Netherlands)
ÖBB Österreichische Bundesbahnen (Austria)
SNCF Société Nationale des Chemins de Fer Francais (France)

Automatic train protection and control systems:

ATP Automatic Train Protection
ATB Automatische Trein Beinvloeding (automatic train influence)
ATC Automatic Train Control
AWS Automatic Warning System
ERTMS European Rail Traffic Management System
ETCS European Train Control System
INDUSI Induktive Zugsicherung (inductive train protection)
LZB Linienförmige Zugbeeinflussung
PZB Punktförmige Zugbeeinflussung
4 Objectives of the Project

The EC transport policy proposes that the railways of Europe should be revitalised to attain a more important role in freight and passenger transport within the European community. In the current competitive environment, the EC and the European Railway organisations are seeking ways and means to improve the cost-effectiveness of interoperability. This has led to the requirement that both the train set and train crew continue the journey across national and infrastructure borders. To achieve safe, reliable and efficient cross-border operation, it is now essential for the rail industry to address the additional human factors problems and the associated risks introduced by this requirement.

The train crew need to be familiar with the differing technological systems, operational rules, procedures and practices for both their “home” and the “foreign” infrastructures and to be able to communicate in other languages. An analysis of the risks in rail operations must therefore include an understanding of human limitations within the technological systems.

In the HUSARE project a socio-technological approach was taken to examine the safety critical tasks and to address human factors in cross-border rail operation. The main objective of this two-year research project has been to develop and test a toolkit of human factor analysis techniques. This HUSARE toolkit provides the rail industry with the means to identify and manage the human related risks and so increase safety, efficiency and reliability in trans-European rail travel.
5 Means Used to Achieve the Objectives

The principal steps followed to achieve the objectives of the HUSARE project were to:

• select and generate test scenarios of rail operations based on task analyses of normal, degraded and emergency situations

• survey the use of human factor analysis techniques in European rail organisations

• develop and test human factor analysis techniques

• collect and compare the rules, procedures, operating practices and information about technical systems on different rail infrastructures in a number of European countries for the tasks embedded in the test scenarios

• perform human factor analyses in order to:

⇒ identify the human factor issues associated with cross-border operation within the test scenarios

⇒ identify possible sources of human error which may arise from differences in rules, procedures, operating practices and technical systems

⇒ identify error recovery mechanisms

⇒ identify the potential consequences

⇒ suggest measures to prevent the failure occurring or to reduce the consequences

• perform a human factor analysis of the ERTMS / ETCS Functional Requirements Specification

• identify generic risk reduction measures

• prepare a toolkit of human factor analysis techniques for use by Rail Operators and describe how the toolkit can be used within the risk assessment process

• present the results of the project to the rail industry in a workshop.
6  **Scientific and Technical Description of the Project**

This chapter presents an overview of the approach taken in HUSARE project to achieve the project’s objectives via the steps described in the previous section. Section 6.1 will highlight the importance of considering human factor issues in cross-border rail operations. Section 6.2 contains a description of the work performed during the project. The project results are presented in section 6.3, including a description of the final human factors analysis toolkit, a review of the results of the human factors analyses performed during the project and the conclusions that can be drawn from these analyses. This section also includes a brief report on a workshop that was organised for the dissemination of the project results among European rail operators. Section 6.4 explains how the human factors analysis toolkit can be used by the railway industry. Finally, in section 6.5, several ways are presented to integrate human factors analysis techniques into risk assessment processes currently applied in the rail industry.

6.1  **Human factor issues in rail operation**

The train crew are a vital safety factor in rail operation, however they are also fallible and their ability to adapt while valuable in itself renders them sensitive to the conditions under which they carry out their tasks. There is considerable evidence from the investigations of rail accidents that the major sources of risk lie in human error rather than in the failure of hardware systems. However, human error is not inevitable. A considered approach to the analysis of human factors can significantly reduce the risk of human error. Such a human factors analysis must consider the role of the human in both initiating and mitigating these risks.

Several characteristics of train operation are considered significant from a human factors perspective. These factors include (but are not limited to):

- Time stress (such as meeting timetable/operational requirements, often a significant measure of performance in the railway industry);

- Limited information may be available and only visible for a few seconds - particularly with increasing speeds, (for example linesided signals);

- Automation of control systems and the effects upon human performance (for example, dependence on automatic train control systems or ability to intervene in the event of system failure or unexpected circumstances);

Several features of the European railway industry have led to an increased requirement to consider human factors concerns. Awareness of human factor issues may be attributed to four primary factors:
• In general more emphasis is now given to safety and occupational health;

• The use of new technologies such as computerised signalling and control systems has lead to new human interface/performance issues

• Commercial pressures leading to driver-only operation, higher operating speeds, increased passenger densities, minimum station dwell times and reduced maintenance downtimes;

• A need to improve design standards in line with changing passenger expectations and in order to compete with other modes of transport (or possibly other rail operating companies). For example, services such as the French TGV and the German ICE now compete effectively with air services.

6.1.1 Human factors in cross-border operation

Cross-border rail operation generates new human factors problems and exacerbates several factors associated with traditional railway operations. As trains pass through national and infrastructure borders, the different technological systems, rules, procedures and cultural characteristics all have profound implications for safe operation. These differences become particularly significant in degraded operations and emergencies, where a high level of communication, co-operation and co-ordination between rail staff are essential. In addition, it is noted that the majority of cross-border operations involve high-speed lines, further complicating interoperability issues. For example, the increased line speeds reduce the time that signs and signals are available, in addition to reducing the time available to react in the event of a degraded situation.

The operation of trains across international borders is thus associated with a range of human factors issues. A preliminary list of human factors aspects in cross-border railway operations is presented in Table 1. Further details on each of these categories are presented in the HUSARE Human Factor Toolkit in Appendix 2.
### Human Factor Issue

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<td>Job design, allocation of function and workload</td>
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<td>Documentation, job aids and procedures</td>
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<td>Operational characteristics (e.g. train speed, timetable constraints)</td>
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#### Table 1  Human Factor Issues to be Considered in Railway Operations

6.1.2 Psychological influences on train driver behaviour

Associated with these human factor issues are a number of psychological influences on train crew behaviour which need to be considered when identifying possible human errors.

#### Differences and Similarities between Infrastructures

Rules, procedures, operating practices and the characteristics of technical systems such as signs and signals may be the same, similar or different between infrastructures. If there are differences or similarities, the train crew will need to learn the new features and these may be forgotten or erroneously recalled on the foreign infrastructure. When information is coded as in the use of colour for signals, slight differences may lead to confusion as to the correct meaning. When the same code is used with different meanings on the two infrastructures, misunderstandings and wrong actions are likely. If infrastructure differences are at variance with organisational or cultural stereotypes, reversion to the stereotype behaviour is likely in unfamiliar or stressful situations.
**Experience and skill development**

The train crew and in particular the train driver will have considerable operational experience on the home infrastructure. Over time the train driver will develop, largely subconscious, braking and attention strategies in controlling the train.

Braking strategies will be dependant on infrastructure characteristics such as the distance between the siting of signs and signals in front of crossovers or speed restrictions. Different braking rates and different strategies for controlling low adhesion conditions may also influence braking strategies. If there are significant differences, then these braking strategies may not be transferable to the foreign infrastructure.

The driver’s attention may be divided between the lineside signs and signals, the track ahead and the in-cab displays. Attention strategies will be influenced by a number of factors for example:

- attend to track ahead - route characteristics such as the frequency of level crossings
- attend to lineside signs and signals - when approaching a station where these are more frequent
- monitor in-cab displays more frequently - when more information for example permitted speed, distance to next speed change, or route and timetable information are displayed.

Differences in these infrastructure characteristics may mean that attention strategies applied by the train driver are less appropriate in the foreign infrastructure and he may fail to see important information.

**Dependence on automatic train control (ATC) systems**

ATC systems permit expansion of the safe operating envelope so that the train driver is able to control the train at higher speeds. Train control is now shared between the ATC and the driver. Various forms of interaction may develop and the driver may become dependant on certain functions of the ATC such as intervention to brake the train where speed restrictions are in operation.

When there are differences in the functionality of the ATC systems, particularly the conditions under which the ATC intervenes, for example the margin between actual speed and permitted speed, the driver’s reliance on the ATC may be inappropriate and increase the likelihood of speeding and SPADs.
Unusual and stressful situations

In general there will be a tendency for train crew to revert to behaviour appropriate to their home infrastructure in situations when they are under time stress or when faced with unfamiliar or emergency situations.

6.2 Description of work performed

In this section the steps followed in the process of developing and testing the human factor analysis techniques will be reviewed. The results and findings from the project work are presented in the next section.

6.2.1 Test scenario selection and generation

To serve as a basis for the development and testing of an appropriate methodology for the analysis of human factor issues, a set of test scenarios were selected and generated for use in the HUSARE project. Scenario generation aimed at creating an environment within which hazards related to human behaviour may occur. The following were taken into consideration:

- analysis of rail incident reports,
- experience of rail experts
- the factors and conditions expected to influence train crew performance.

Eight test scenarios were generated from the list of tasks for a journey to include normal and degraded mode operation and specific emergency incidents.

The eight test scenarios are:

- S1: Hot axle box.
- S2: Train speed adjustment.
- S3: Approach to a level crossing.
- S4: Events before and after a SPAD (Signal Passed At Danger)
- S5: Detection of errors in track routing.
- S6: Depart station.
- S7: Assisting a failed train as a result of complete loss of traction power.
- S8: Accident and incident response to a major train accident.

Descriptions of these test scenarios together with a discussion of the main human factor
issues involved are given in Appendix 1.

6.2.2 Collection and comparison of data on infrastructures

After the selection, generation and initial validation of the scenarios, a data collection process was started, whereby for each of the test scenarios, a small number of infrastructure borders were selected to serve as an example. For the selected combinations of test scenarios and infrastructures, relevant data about the infrastructures was collected and a cross-border data comparison was performed. A detailed description of the data collection and comparison process is given in the explanation of the HUSARE Human Factors Analysis Toolkit in Appendix 2.

Two different data collection and comparison approaches were adopted in the project:

- Hybrid-analytical approach
- Empirical approach

**Hybrid-analytical approach**

After having chosen and specified a scenario and a cross-border route, the hybrid-analytical approach aims at extracting data on the scenario relevant Performance Influencing Factors from documented sources such as rulebooks, procedure handbooks and standards. Performance Influencing Factors (PIFs) are those factors which influence the likelihood of effective human performance.

The information gathered is documented on data collection proformas (see Appendix 2). For each task agent (person involved in performing the task), the relevant information is stated by providing the reference to the source document*. Data is collected for each task involved in the scenario. If found appropriate, the tasks may be grouped and data is collected for each group of tasks. Information gaps are addressed through structured interviews with infrastructure experts.

Eventually, using the collection proformas, the rules, procedures and technical systems are compared among different infrastructures. However, prior to the comparison, a Hierarchical Task Analysis (HTA) may be performed to identify the analysis steps that have to be carried out in the comparison.

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* Note that the data collection in the hybrid-analytical approach is founded on the choice of the information collector and is thus subjective. The person doing the data collection selects documents and information according to their opinion on relevant issues.
Figure 1  Hybrid-analytical data collection & comparison approach

Figure 2  List of task agents, influencing factors and competency issues
The data comparison is guided by the list of task agents, influencing factors and competency issues presented in Figure 2. This list is also reproduced on the data comparison proformas as a guide. These proformas are used to record the identified differences and to state the relevant human factor issues resulting from the identified differences. Depending on whether a task agent, an influencing factor or a competency issue is concerned, the identified difference is recorded in narrative form in the appropriate place on the comparison proforma.

Eventually, the relevant human factor issues for each identified difference are recorded in the comparison proforma.

**Empirical approach**

In the empirical approach, the data collection process is effectively the same as in the hybrid-analytical approach. However, the data comparison process takes place in face-to-face discussions between railway operations experts from each infrastructure involved in the analysis. Specific questions about each scenario are used to focus these interviews and the experts' judgement on the importance of the Performance Influencing Factors is collected. The main advantage of this approach is that time may be saved as the experts can quickly identify differences; they can also assess the potential significance of the differences, thus contributing to the human factor analysis.

Both the analytical and empirical approach are described in more detail in HUSARE deliverable D11, together with definitions for the selected Performance Influencing Factors.

6.2.3 The development of the human factors analysis methodology

Following data collection and data comparison for a selected combination of test scenario and infrastructure borders, human factor issues associated with that scenario for the infrastructures under consideration were identified and recorded. This formed the basis for further human factor analysis. The first step in this stage aimed at the identification of potential human errors or failures that could result from identified differences and human factors issues. A checklist to support this step has been developed and fine-tuned during the project. Realising the importance of the potential to recover from a failure before the occurrence of unwanted consequences, the project team also included an evaluation of the recovery potential in the methodology. The potential consequences of the possible human errors/failures were also assessed as part of the methodology.
The next step of the methodology deals with the identification of risk reduction measures. After a few iterations of this step, it was decided to distinguish between three types of measures: those that reduce the likelihood of the failure, improve recovery potential, or reduce the severity of the consequence. Appendix 2 contains the final version of the human factors analysis methodology that has been developed during this project, complete with checklists and proformas.

6.2.4 Experience in application of the developed methodology

An iterative approach has been adopted in this project whereby the data collection and analysis methodology was applied to a selection of the test scenarios and then the lessons learnt from this exercise were used to refine the process. All methodology descriptions have in effect been ‘living documents’, requiring continual development and revision as the techniques have been tested on the representative scenarios. A full description of the experiences of the project team in this process is documented in the deliverable D11 Volume II: ‘Description of the Development of the Data Collection, Data Analysis and Human Factors Analysis Methodology’.

As an example of the benefits of adopting such an iterative approach in the project, it was concluded that the collection and documentation of rules, procedures and technical specifications for the test scenarios prior to data comparison was a resource-intensive process. Following trial applications, it was proposed that the formal data collection stage be replaced by a discussion between the experts from the infrastructures under examination. This discussion would involve such personnel describing the working practices in their respective infrastructures, followed by a discussion of the key differences.

The strength of this approach is that any differences between the infrastructures are identified rapidly in real time as the scenarios are discussed between the relevant infrastructure experts. This process is considerably preferable to non-infrastructure experts reviewing available documentation. However, it is essential that some degree of structure be placed on these discussions to ensure that the resulting analysis is comprehensive and defensible. Again, the participation of human factor specialists, as well as infrastructure experts, is considered important in these interactive sessions.

The data collection proformas were found, however, to ensure a systematic approach and facilitate the comparison / human factor analysis meetings between infrastructure experts and human factor specialists. The documentation developed throughout the process thus provides a structured and documented working process. Whether the data collection forms are completed or not, partly depends on the experience of the team
undertaking the analysis.

Throughout the project, attempts were made to involve a combination of human factors specialists and infrastructure experts in trial applications of the process, and to incorporate representative end-users of the approach wherever possible. It is considered that this combination of expertise is essential to the success of the methodology. The most significant difficulties in the application of the developing process occurred where such a multi-disciplinary team was not employed and this finding has implications for the adoption of the toolkit by industry. It was concluded that infrastructure experts best perform data collection and that the data comparison and human factors analysis stages require a multi-disciplinary approach. The data comparison methodology and the subsequent human factors analysis rely on the completeness and relevance of the data that has been collected and its presentation in a suitable format that aids comparison.

Employing appropriate infrastructure experts in the analysis reduced the resources required and enhanced the validity of the analysis results. In particular, discrepancies between the documented and actual working practices only became apparent through discussion with industry experts from the appropriate infrastructures.

6.3 Results of the HUSARE project

This section contains an overview of the findings and results from the HUSARE project. It begins with a discussion of the current application of human factors analysis techniques by rail operators, based on a review conducted during the project. The human factors analysis toolkit, which constitutes one of the main outputs of the HUSARE project, is then introduced. The results of the human factor analyses performed during the project are presented, including analyses performed for a selection of the Functional Requirements Specification of the ERTMS/ETCS, and conclusions are formulated with regard to generic risk reduction measures for cross-border rail operations. The section concludes with a brief report on the workshop that has been organised to disseminate the HUSARE project results.

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1 European Rail Traffic Management System / European Train Control System
6.3.1 The application of human factor analysis techniques in the European rail industry

It is clear from the brief review conducted for this project that although the importance of human factors is recognised by many of the European railway operators, formal human reliability techniques are not widely applied. Research conducted by specialist consultancy companies, such as Human Reliability Associates, has however, illustrated the utility of formal human reliability techniques in the railway industry. Such techniques have been used for the analysis of incidents (for example, the Clapham Junction incident) and in human factors assessments (for example, the evaluation of in-cab displays). Although they were developed for, and have been mainly applied in other industries (such as oil and gas, nuclear, military), the utility of these techniques in the railway industry has been demonstrated.

Although an awareness of human factors has increased and it is widely acknowledged that these factors have a role to play in the design of faster, safer and more comfortable rail systems; such issues do not yet have the priority that they deserve. Recent major incidents in several countries have served to increase this awareness, especially in the use of such techniques for the retrospective determination of root causes. Several European railway organisations carry out extensive analyses of accidents and incidents, which incorporate categorisation of root causes and take into account human factors.

In addition, effort of a human factors nature in the European railway industry is more oriented towards the recruitment of suitable personnel for the existing traffic safety rules rather than the adaptation of rules, procedures and systems within human factors guidelines. This may include psychometric profiling for the recruitment of personnel to safety critical positions.

Recently, however, the increased development of high-speed railway transportation for both passengers and freight have generated interest in human factors both as a means to improving operational productivity and enhancing safety.

6.3.2 A toolkit for the analysis of human factors in cross-border rail operations

This project has developed a toolkit that will enable railway operators to examine and manage the human aspects of existing and proposed cross-border railway operations. The toolkit consists of several stages:

- Select and describe scenarios for cross-border operation. These scenarios include human interfaces and safety critical tasks and are expected to involve differences in cross-border operation.
• Produce task analyses for the main tasks in the scenario. Task analyses are structured lists of the main tasks that are carried out by the people involved such operations.

• Collect data on the relevant national safety rules and procedures, working practices, technical/operational systems and standards for the scenarios selected. The scenarios are used to structure the collection of data for further analysis.

• Compare the data collected for two or more rail infrastructures in order to identify differences and potential human factor issues.

• Conduct human factor analyses in order to identify, assess and prevent human failures, including an examination of the factors that influence human performance.

This toolkit is presented in full in Appendix 2.

6.3.3 Results from the human factor analyses performed during the project

This section contains a discussion of the results from the analyses of selected scenarios, based upon a comparison of the rules, procedures, technical systems, standards and working practices in the following European rail infrastructures:

• Sweden / Denmark / Germany

• UK / Eurotunnel / France

• Netherlands / Germany

• Austria / Germany

• France / Italy

• Germany / Belgium

A detailed discussion of the results of the analysis work and the complete human factor analysis tables are given in the HUSARE project deliverable D10: “Human factors in cross-border operations – Hazard identification and possible risk reduction measures”.

Swedish / Denmark / Germany

A future cross-border operation from the South of Sweden to Northern Germany, i.e. from Malmö via Øresund, Copenhagen, Storebælt and Padborg to Hamburg was taken as a basis for the human factors analysis.

Functional Swedish and Danish ATP systems are required for cross-border operations between Sweden and Denmark, and a similar requirement is also expected for cross-
border operations between Denmark and Germany. Therefore, many likely human failures were screened out in an initial phase of the human factor analysis, as the automatic train protection system would intervene and recover these human failures.

However, in the event of non-functional ATP (automatic train protection) systems en route, for practical reasons, the driver will have to continue to the next station according to the National rules & procedures for driving without functional ATP. This justifies analysing some human factor risks that only arise when driving without functional ATP system.

*Test Scenario S2: Train speed adjustment*

For the selected speed adjustment scenarios human factor issues arise from differences in the information presentation, that is, the way information is presented to the driver by either in-cab display or lineside signals and boards. ATP systems with in-cab display are extensively used in Sweden and Denmark, whereas the ATP system on the line of interest in Germany (Indusi) has limited functionality and no in-cab display. In Germany the driver depends largely on route knowledge and the information given in the route plan as written documentation (Fahrbuch), which may also be displayed electronically in the cab. In addition to this, the ATP system is less extensive on the line of interest in Germany, so that potential human failures by Swedish and Danish drivers relying on the in-cab display may not be recovered.

A potential human failure for a Danish or Swedish driver, who relies on the in-cab display and extensive protection by the ATP system, is to miss speed restrictions that are only stated in the route plan in Germany. In some cases the acquired attention strategy based on experience within-cab displays may even result in the driver not noticing lineside speed boards. The potential consequence of such human failures is obviously speeding with possibly catastrophic outcome.

Another human factor issue arises from the differences related to technical systems, i.e. the varying distance from the distant signal to the main signal or the varying distance from the warning sign to the starting point of the restrictive area. Assuming longer braking distances, a driver may apply the brakes too late. This will, however, normally not result in severe speeding.

*Test Scenario S4: Events leading up to a SPAD*

Again in this scenario human factor issues arise from differences in information presentation. There are different signalling aspects in the selected infrastructures to indicate the same meaning, e.g. the permission to proceed at reduced speed. On the other
hand, some similar signalling aspects have different meanings in the selected infrastructures.

As a consequence, the driver may misinterpret the information displayed by the lineside signal. However, only in the case of driving without functional ATP system will the failure result in adverse consequences. The lack of failure recovery when driving without functional ATP thus emphasises the importance of imposing severe speed restrictions for driving under these conditions.

**Test scenario S6: Depart station**

Regarding the depart station scenario, most of the identified human factor issues stem from different task characteristics. A harmonisation of the depart station procedure has already been achieved between Sweden and Denmark, where also language differences may be easiest to overcome. Yet, the tasks and task agents are different in Germany compared to Sweden and Denmark, bearing the hazard that tasks are not performed correctly or that tasks are omitted because it is assumed that another person has performed the task.

These failures may result in doors being closed too early and trapping passengers or train personnel. In the worst case a train may depart before passenger exchange is completed and the doors closed and locked.

**UK / Eurotunnel / France**

**Test Scenario S1: Hot Axle Box**

There is only one human factor issue for this scenario, relating to the speed at which a train can proceed following the confirmation of a hot axle box. The UK rules are more stringent than those in France. A French driver in the UK may apply the speed limits for his home infrastructure putting the train at increased risk of derailment, particularly when travelling over points. The suggested control measure is harmonisation of rules.

**Test Scenario S2a: Permanent Speed Restriction**

Human factor issues were identified for five task steps. These issues primarily relate to differences in the design of signs and signals. Also the unit of speed in the UK is mph whereas in France it is kph (only the values and not the units are shown on the signs). In considering this human factor issue, the question to be considered is: How does the driver use this number (speed information)? Two possibilities are:
Possible Response 1: He compares the numbers presented by a signal to the numbers presented by his speed indicator.

There is a high probability of error if the two forms of information presentation (infrastructure speed signs and in-cab display) do not use the same unit of measurement. Even if the speed is presented on two in-cab displays, each in a different unit, there would still be a potential for human error.

Possible Response 2: The driver makes a conversion between the units of speed. This solution is dependant on whether or not the driver does this calculation to convert (correctly) the speed expressed in the unfamiliar units to a speed in the units with which he is familiar.

A detailed discussion about the issue of units of speed is given in D 10 “Human Factors in cross-border operations: Hazard identification and possible risk reduction measures”.

Additional human factor issues arise from the different philosophies that have evolved in the two infrastructures (route versus speed signalling). These identified differences may lead drivers in both infrastructures to apply an excessive speed limit (or to apply an incorrect speed for the type of train), increasing the risk of SPADs or derailment. For all of these Speed Restriction scenarios, infrastructure characteristics may in some cases act as a recovery mechanism. The different shapes of speed signs may not be a sufficient means for preventing strong stereotype takeover and may need to be supplemented by additional measures such as an in-cab reminder.

**Test Scenario S2b: Differential Speed Restriction**

As for permanent speed restrictions, the design, layout and content of the speed signs vary between the two infrastructures. For example, the lower value speed may be presented above the higher value speed or vice-versa. In addition, acronyms, e.g. HST (High Speed Train) versus shape coding may be used to signify that speeds apply to a certain class of trains. As well as these issues, there are also differences in the maximum numbers of differential speeds displayed at a single location. The human factors resulting from these differences may lead to over-speeding, with increased potential for SPADs and derailment.

**Test Scenario S2c: Temporary Speed Restriction**

Again, there are differences in the actual sign design, which may lead to incorrect speeds being applied across the restriction.
Test Scenario S2d: Emergency Speed Restriction

Three main differences were identified for this scenario. The most significant of these relates to the situation before the emergency speed restriction equipment is installed. In the UK, drivers are informed of the location by phone or radio. In France, drivers are given written instructions or dictated advice on emergency speed restrictions. In this case, a French driver in the UK may fail to fully understand the location or importance of the restriction, possibly leading to over-speeding and/or derailment. Although the emergency speed indicators in the two infrastructures are completely different, they are highly distinctive and different from normal signing; therefore it is considered unlikely that they would be missed.

Test Scenario S4a: Events leading up to a SPAD

Two issues relate to the observation of caution signals. Although both infrastructures utilise an in-cab display to indicate that the last signal was at caution, these indicators differ in design and in the UK are audible as well as visible. There is also a major difference relating to minimum sighting times of signals, which are greater in France. Drivers may develop attention strategies based on experience with these requirements that are incompatible with the sighting times in the foreign infrastructure: however, errors should be recovered by AWS (automatic train warning) activation.

Test Scenario S4b: Events following a SPAD

For this scenario, a difference relates to the resumption of movement following a SPAD. In France this is controlled by the marche à vue rules which stipulate that a driver must proceed with caution at a fixed maximum speed, whereas there is no such formal procedure in the UK. A UK driver in France may therefore continue as normal and approach a subsequent signal at speed, passing it at danger. This particular error would be prevented by implementing the marche à vue rules in the UK.

Test Scenario S5a: Errors in Track Routing

The first function in this scenario relates to controlling trains in compliance with signalling. However, very different signalling philosophies are used in the two infrastructures – route versus speed signalling. This difference may lead to aspects being

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2 The French command ‘marche à vue’ stands for ‘drive on sight’
incorrectly interpreted or unauthorised/unfamiliar routes being accepted resulting in collision / derailment.

Test Scenario S7: Assisting A Failed Train

In the UK, trains on the adjacent line must be stopped before examining the outside of a train alongside another line; however in France a driver may perform this task provided there is a competent member of crew available to act as a lookout. There is also a requirement in the UK for detonators to be placed behind a failed train and it is possible that a French driver would fail to use this protection in the UK. However, the signaller should not allow the assisting train to approach until detonators are in place. When approaching the failed train, it is a requirement in the UK to stop 2 metres short; however no distance is specified in France, which may lead to impact.

Germany / Netherlands

There are a number of existing cross-border routes between Germany and Netherlands that were used as a basis for the infrastructure comparison. However interoperability is not fully implemented as both locomotives and train crew may be changed at the border. There are specific rules and procedures, e.g. for the Emmerich route, in addition to the general operational, and signal handbooks. The functioning of the ATP systems, PZB (also known as Indusi) and LZB in Germany and in the Netherlands was taken into consideration in analysing the scenarios. For the purposes of this analysis it was taken that all three systems were installed in the locomotives and the corresponding human-machine interface installed in the driver's cab.

Test Scenario S3: Approach to a level crossing

In this scenario human factor issues are associated with differences in information presentation, communication, and fluency in foreign language

Information presentation

Different approach signs for level crossings are used in Germany and the Netherlands. The German sign is similar to the Dutch sign warning of a hazardous section ahead so the Dutch driver may be confused about the exact meaning of the sign. While he will be prepared for some eventuality, he may not be expecting the approach of a level crossing. The German driver may not recognise the Dutch sign as indicating the approach to a level crossing.

However as the locations of level crossings are given in the written documents (Buchfahrplan) and the level crossing barriers operate automatically on the train’s approach, human error is unlikely. If for some reason (e.g. an unplanned stop) there is a time delay before the train approaches the level crossing, it is possible in Germany that the level crossing barriers will have reopened. Such an event can distract the driver so that he forgets that the previous signal showed caution as he speeds up the train.

Error recovery will be influenced by how the driver divides his attention between in-cab displays and looking ahead at the track.

Communication
With respect to the human failures that can arise in communication two aspects were considered: interface problems of using different radio systems and foreign language competency.

Even if a driver follows the correct procedure for sending radio alert messages, because of the different interfaces of radio systems for each of the two infrastructures, there is a possibility that the driver will send the emergency signal via the inactive radio system. Potential recovery mechanisms include feedback information that may be available from the radio interface to indicate that the alarm message has not been transmitted. Alternatively when response from the radio partner is received, then the driver will re-examine his action and possibly discover the mistake.

These possible failures can lead to delay in sending the alarm to warn other trains. The role of the signaller in reducing the negative consequences of this delay is significant. Possible measures to prevent the failures occurring relate to the ergonomic design of the radio interface in the cab. A further human factors requirement is to investigate the application of a common radio interface for all radio systems installed in the train.

It would be expected that a train driver involved in cross-border operation will have had some training in the languages spoken in the foreign infrastructures, so that he can communicate with the signaller or other agents. The possible failures that are considered here are misunderstanding or insufficient information exchange which can occur when an unusual situation arises. In these situations specific well learnt messages or coded massages may be too restrictive to support the necessary exchange of information. Delay in passing on sufficient details about the situation, may lead to inappropriate and delayed responses from other task agents. A pragmatic approach with respect to the resources needed for initial and refresher training in the foreign language is suggested as a possible measure to prevent these failures.
Test Scenario S4a: Events leading to a SPAD

There are human factor issues arising from differences in information presentation and differences in tasks and procedures.

In Germany main and warning signals can be given in two ways; as combinations of lights and form signals, which are supplemented with lights for visibility at night. The Dutch driver is unused to the German form signals, so there may be a delay in response to the signal. This information is also repeated in-cab via the ATC (automatic train control) systems so that error recovery by the driver before ATC intervention is likely. Signs for speed restrictions are similar in design and meaning so that errors are unlikely.

There are differences in the in-cab signalling of the danger signal as ATB continues to show a yellow warning light whereas PZB and LZB show red lights. The German driver in the Netherlands may not respond to the yellow light. Error recovery potential will be high as the lineside signal shows red and the train speed is low (in response to the previous warning signal). Otherwise ATC intervention will be initiated.

Procedural differences exist when an unplanned stop occurs. In Germany the driver is required to inform the signaller when the stop exceeds 5 minutes and again before he continues the journey. After an unplanned stop in the Netherlands, the driver proceeds at a slow speed to the next main signal (cf. march à vue in UK- France analysis). A possible error is that the Dutch driver in Germany may proceed without informing the signaller. As he proceeds at low speed, he will be able to respond to the next main signal.

Test Scenario S4b: Events following a SPAD

The major human factor issue to be considered in the second part of this test scenario is the different functionality of the three ATC systems – ATB, LZB and PZB (Indusi).

One of the three ATC systems will be functioning in this scenario. A train driver will have had more experience of the ATC system operating in his home infrastructure. From this experience the driver may become reliant on ATC intervention, particularly when he is uncertain of e.g. the meaning of the signals. As the ATC systems differ in their functionality, a driver may expect the ATC to intervene and brake the train if train speed is too high, whereas for example PZB would only brake the train after a danger signal has been passed or ATB only intervenes for speeds above 40 kph. This human factor issue may increase the likelihood of a SPAD on lines with ATC of restricted functionality.
Communication and fluency in a foreign language are also relevant human factor issues; these have been discussed above in the section on test scenario S3, Approach to a level crossing.

*Test Scenario S6: Depart station*

In this scenario, the following human factor issues are considered as a result of differences in the depart station procedures between the two infrastructures: procedures, allocation of tasks and responsibilities, and information presentation.

The depart station procedure in both the Netherlands and Germany should not be initiated until the proceed signal permitting the train to leave the station appears. However the initiation of the depart procedure in Germany is also regulated by the timetable – the procedure commences at a specific number of seconds prior to the timetable departure time. The Dutch train manager will initiate the procedure when the proceed signal shows. It is possible that the depart station procedure will be completed before the exact departure time. At the departure time, the driver will drive the train from the platform possibly while passengers are still disembarking or boarding the train.

There are some differences in the allocation of task and responsibilities between the infrastructures. In Germany the depart station procedure is carried out between the train manager and the driver with some task steps allocated to the train crew, and at some stations, the platform manager. In the Netherlands only the train manager and the driver are involved.

These variations in procedure may lead to actions being omitted, delayed or the procedure started before the train manager is ready. The consequence is limited to delaying train departure, however error recovery is likely.

There are several differences related to information presentation. The German form signals are unfamiliar to the Dutch train driver and manager. The depart station procedure may be delayed or commenced too early with the consequence that the train may depart the station before passenger exchange is complete.

The German train driver either checks the lineside main signal or the LZB in-cab display before departure. In the Netherlands the train driver must always check the main lineside signal even when ATB is functioning. A possible error is that the German driver may omit this check in the Netherlands. As there will be no LZB in-cab signal the error recovery potential is high but train departure may be delayed.
Test Scenario S8: Accident and incident response to a major train accident

In this scenario there are specific differences between the infrastructures in the initial actions to warn other trains and in the measures taken to ensure protection of adjacent track.

In Germany the train driver will give the warning of danger to other trains by transmitting the emergency radio call, sending the LZB emergency signal and reporting to the signaller. The Dutch driver only sends out the radio alert and reports directly to the signaller. In this emergency situation, either driver may follow the procedures corresponding to his home infrastructure. Actions specific to the foreign infrastructure may be omitted. The drivers may also be unsure of the responsibility of the person they are contacting by radio, as this may be the signaller or the operator at the radio control centre or the operator at the emergency control centre. Delay in warning other trains may result and the communication of important details about the incident may be less effective.

Different actions are taken to secure the adjacent track. Omission of these infrastructure actions may lead to non-secure track with danger to train crew and emergency teams. There is a high potential that this danger will be averted as a result of the actions to warn other trains in the vicinity.

In addition, the human factor issues associated with communicating with the signaller, radio control or emergency centre are particularly relevant in a stressful situation. (These issues are discussed above in the section on test scenario S3, Approach to a level crossing.)

Infrastructure Austria / Germany

The analytical approach to data collection on the basis of existing rulebooks was followed. In addition, detailed information to support the analysis was sought in interviews with the experts from DB and from ÖBB.

Two scenarios have been analysed:

S2b: Temporary speed restriction

S2e: Change to deviated route setting over track crossover

Similarities rather than differences in the operation of trains in Austria and Germany
were confirmed by the analysis work. Although language, technical systems (Indusi) and operational rules are closely related they are not the same. Significant differences were found in the signalling aspects in the two countries. However, no major issues in relation to the human factors analysis have been identified. Some minor items are described below.

After detailed analysis of eight border crossings the comparison between infrastructure was focussed on the main lines equipped with the HV signalling system and with Indusi ATP.

**Test Scenario S 2b: Temporary Speed Restriction**

In both countries temporary speed restrictions are communicated to the driver with via a special written list and through dedicated lineside signals (announcement, beginning and end of speed restriction area). Misunderstanding of messages is avoided as the train crew and signalling personnel speak the same language.

The signal aspects indicating speed limits are slightly different in the two infrastructures. As a result the train driver may be confused as to the meaning of the signal. Error recovery is possible as are equipped with Indusi, which is an ATP system dependant on signal aspect.

Driver behaviour is an important factor when the temporary speed restriction has been implemented to protect an engineering works site. In Germany the works site is ‘cleared’ only a very short time before the arrival of a train. It is imperative that the train driver adheres to the temporary speed restriction as specified in the written list. In Austria working sites are first ‘cleared’ and only subsequently is the train permitted by interlocking to enter the corresponding block section.

To reduce the associated risks, it is recommended that a common MMI indications are implemented.

**Test Scenario S2e: Change to deviated route setting over track crossover**

In Germany there are additional route direction indicators, which are not used in Austria. Therefore a German driver may have a problem to interpret the appropriate speed restriction indicated by the coded signal aspect on the approach to the crossover on the Austrian infrastructure. As in the case of the temporary speed restriction scenario, drivers’ knowledge of the route and the signalling system is an important human factor issue in this scenario.
This difference between the infrastructures may eventually lead to the train driver approaching the crossover at the incorrect speed. However, potential error recovery is provided by the technical systems (e.g. Indusi)

Intensive driver training is a suggested risk reduction measure in relation to both scenarios.

**Infrastructure France / Italy**

The empirical approach to data collection and comparison was followed. The test scenario S2: speed adjustment, was discussed with experts from SNCF and FS, and the following test scenarios were considered:

- **S2a** Permanent speed restriction (test scenario 2a)
- **S2c and S2d** Temporary/Emergency speed restriction
- **S2e** Change to deviated route setting over track crossover

After comparison of the rules, procedures and technical systems, some differences in operational characteristics, documentation, job aids and procedures were identified.

There are different philosophies for speed restriction between the two infrastructures. In Italy continuous speed signalling is used. In France there is a general route speed with specific zones where speed restrictions are in force (*reprise de zone*). There are lineside signs to indicate the beginning and sometimes the end of these zones. The actual speed may be indicated on lineside signs or in the route documentation.

In Italy, the train drivers have documented information about the points where they must slow down. In France, the drivers rely on route knowledge for the general route speeds and written documentation for speed restrictions.

Furthermore, the location of the signals (the distance from the point where the driver must slow down) is not calculated in the same way.

In France, drivers have a document that informs them about engineering works on the line before departure. In Italy this information is not provided.

**Human Factor Analysis**

The question of how a French driver will behave when he is on the Italian infrastructure with a different signalling system was examined.
Potential human errors may arise because similar knowledge is represented in different ways. In the comparison of the infrastructures, some differences were identified, particularly concerning the warning signal and the main signal.

In France, situations are symbolised by means of fixed or flashing signal lights and the horizontal or vertical relative positioning of the lights. In Italy, the different situations are indicated by the status of the warning signal. The location of the main signal is implicitly assumed to be at a fixed distance. Consequently, the Italian signalling system seems to be less complex, but with less inherent redundancy, so that there is a lower potential for error recovery.

Then, if we examine how situations are symbolically represented by the signals, it is necessary to consider how the train drivers comprehend the association between the « symbolisant » (colour, state, location of a signal) and the « symbolised » (the meaning of the situation). Here, there is a risk of human error if two « symbolisants » represent the same situation. However, the potential for human error would be higher, if the same « symbolisant » represents two different situations.

**Infrastructure Belgium/ Germany**

The analytical approach to data collection on the basis of existing rulebooks was followed. In addition, detailed information to support the analysis was sought in interviews with the experts from DB and from SNCF/NMBS.

Extensive use was made from the results of the Thalys project group, which has developed a set of standard messages to be exchanged between the driver and the operator (signaller). These messages are translated into three languages and cover a range of basic situations for normal and abnormal scenarios.

Between Belgium and Germany the language, infrastructure and operating rules differ significantly. In the case of Thalys, it was not possible to harmonise all the rules as the content of standard messages in each language differs from country to country, particularly with respect to specific actions to be taken by the driver, for example different release speed limits. In these situations there is a higher exposure to risk in cross-border operation. Two scenarios have been analysed:

- **S1** Hot axle box detection
- **S3** Approach to a level crossing
After analysis of the existing rulebooks, differences in procedures and operational characteristics were identified.

Differences such as left-hand side driving in Belgium (as opposed to right-hand side driving in Germany), unique signalling principles and operating procedures have developed over the years.\(^4\)

*Test Scenario S1: Hot axle box detection*

The human factor analysis focused on the communication between driver and operator (signaller) to identify possible misunderstandings and on possible errors when the driver inspects the train.

There is a higher risk of making the wrong decision during the train inspection in cross-border operation as a result of:

- driving on the opposite side of the line
- the use of different detection systems
- different regulations concerning the alarm.

Differences in language are particularly important when:

- communicating to the train driver that a hot-axle box has been detected
- agreeing about actions after a hot axle box have been located.

As the result of the analysis of the human factors, the importance of improving fluency in the foreign language and intensive training related to abnormal situations should be emphasised.

*Test Scenario S3: Approach to a level crossing*

In this analysis, similar conclusions have been reached as in the case of cross-border operation between Germany and the Netherlands. In particular, foreign language competency is vital when exchanging messages between driver and operator in abnormal situations. The differences in technical systems (radio, signalling) increase the possibility of incorrect action by the driver. Short term measures such as appropriate training and improving language skills are recommended to mitigate the higher exposure to risk.

\(^{4}\) Similar differences were described by W. Cauer 80 years ago in ‘Sicherungsanlagen in Eisenbahnbetriebe’; Springer (1922).
6.3.4 Generic risk reduction measures / Measures to support interoperability

In the final step of the human factor analyses specific risk reduction measures are identified. From these individual measures, generic measures were suggested, which may have a wider application for tasks and scenarios in a number of infrastructures.

These suggested risk reduction measures have been identified and categorised according to where they can be applied:

- Technical systems, e.g. infrastructure and train
- Human resources, e.g. selection, training and competency
- Organisation, e.g. rules & procedures, operating standards and safety culture

Although these measures may be widely applicable, it is nevertheless essential that they should be individually selected according to the application and the associated risks, and be integrated into the risk assessment and safety justification process of the rail operator and subject to the company’s own safety investment criteria.

It would be a significant contribution towards interoperability between different rail infrastructures, if it were feasible to introduce such generic measures into cross-border operation. The identified generic risk reduction measures are described below.

Technical systems / Infrastructure and train

- Consider the provision of a single emergency alert device for the driver to use, which automatically communicates with the signalling/control centre.

- Where different standards apply to the operation of safety critical systems in the driving cab, for example direction of the brake controller, consideration should be given in the design of the system to prevent the hazard arising from "strong stereotype take-over errors".

- Assess the benefits from standardising the shape and information display of lineside signs or signals in order to avoid confusion and possible risk.

- Consider the provision of power-operated doors with closed-door detection interlocks that prevent the train from moving when the doors are open or when a person is trapped in the door. This technical system should be supported by “harmonised” operational procedures that require a visual check that people are not trapped in the doors and that the signal is clear before giving the signal to the driver to start the train.
• Assess the benefits and safety justification of providing an automatic train protection system that supervises the movement authority and permitted speed. Attention should be given to the functional requirements and the train driver interface to the system.

• In cases where an automatic train protection system is provided but is not functional, establish if a harmonised lower permissible speed needs to be enforced and/or other conditions need to be applied, including the policy for removing the trainset from operation.

• Give consideration to the transition between technical systems, e.g. ATP / Radio systems / Power Supply etc, in order to minimise the involvement of the driver. During the transition the driver should be informed of the status of the system. Where the transition is not made successfully, the system should default to a safe condition. The location where transition takes place should take account of the risk associated with driver distraction in managing the technical systems for the transition, for example make the transition on an open line rather than on the approach to junctions.

• If a train is equipped with several automatic train protection systems, consider the benefits of standardising the interface with the driver. Yet, if the systems are different in their functionality, consider having different interfaces.

• Consider the provision of continuous lineside signing for all infrastructure-based speed restrictions where speeds are not displayed in-cab.

• Where speed information is displayed in the cab it should not conflict with the information displayed through the lineside signals

• If speeds are not displayed in-cab, use colour/shape coding of speed restriction boards to assist the driver in identifying the speed applicable to the trains that operate at higher speed than the normal trains.

**Human resources / Selection, training and competency**

• Provide selection tests for train drivers, such as ability to respond calmly and logically in an emergency situation and in the language used by the foreign infrastructure manager. Alternatively, make sure that at least one person in the signalling /control centre can communicate fluently in the language of the foreign drivers.
• Provide appropriate training and competency assessment for the nature of the operation and in the languages involved. This should cover normal, degraded and emergency situations. The use of simulation of a range of scenarios should be used during basic and ongoing assessments.

• Set training and competency assessment standards specific to the nature of the cross-border route and the train type used. This should take account of particular high-risk characteristics of the route and the infrastructure differences. This could include minimum amount of practical experience for qualification for cross-border operations etc.

**Organisation / Rules & procedures, operating standards and safety culture**

• Agree on a phonetic alphabet for the specific cross-border operation. Numbers should be said digit by digit to avoid misunderstandings.

• Simplify communication language with standardised text messages for different situations, such as passing a signal at danger etc.

• Consider appropriate categories of orders / instructions which should be written down when given by train radio, e.g. where there is a potential for high risks, such as passing a signal at danger or emergency speed restrictions.

• Consider the need for repetition of messages to ensure clear understanding.

• Assess the benefits of requiring a driver to proceed by "driving on sight" [as in the formalised SNCF “marche a vue” rules] to the next signal after the occurrence of SPAD or after an unplanned stop on the line.

• Assess the benefits of standardising departure procedures from stations, taking into account language differences and the system available on the train / station.

• Ensure that the system for communication of information and the identification of temporary and emergency speed restrictions are appropriate for the application and are capable of being easily understood and complied with by the drivers involved.
6.3.5 Human Factor Analysis of the ERTMS /ETCS Functional Requirements Specification

During the HUSARE project, the function requirements defined in the core ERTMS/ETCS\textsuperscript{5} Function Requirements Specification (FRS) have been analysed. One advantage of this approach is that possible risks resulting from human behaviour can be taken into account during the formulation of the HEROЕ\textsuperscript{6} rules and procedures. Therefore, the ERTMS/ETCS FRS (Version 4.0 was available at the time of the analysis) was reviewed, and those sections relevant to the test scenarios developed in the HUSARE project were selected. These sections were then examined in relation to the identified human factor issues associated with the test scenarios.

**Approach to Analysis**

Relevant functions from the FRS were examined in relation to the human factor issues identified in the human factor analysis, to determine the following:

- Does the function requirement address the human factor issue, so that the related risks may be avoided or reduced?
- Does it generate new human factor issues?
- Are there human factor issues that are not considered in the FRS?

On the basis of this analysis it was possible to assess whether the FRS would lead to safer cross-border operations with respect to the human factor issues and differences between infrastructures identified in the analysis of the test scenarios.

Table 2 gives an overview of those function requirements from the core FRS that were selected for analysis, together with the relevant test scenarios.

\[5\] European Rail Traffic Management System / European Train Control System

\[6\] The main objective of the HEROЕ project is to develop harmonised rules for the use of ERTMS
### HUSARE Test Scenario

<table>
<thead>
<tr>
<th>FRS Section</th>
<th>HUSARE Test Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.2 Train and driver data entry</td>
<td>S2b Permanent speed restriction with differential speed</td>
</tr>
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</table>
| 4.3.6 Indication on the man-machine interface (MMI) of movement authorities and speed limits | S2a Permanent speed restrictions  
S2e Change to deviated route setting over a track crossover |
| 4.3.7 Supervision of movement authorities and speed limits | S2a Permanent speed restrictions  
S2e Change to deviated route setting over a track crossover |
| 4.3.8 Supervision of driver activity | S2a Permanent speed restrictions  
S2e Change to deviated route setting over a track crossover |
| 4.6.3 Emergency alert message to train | S8 Accident and incident response to major train accident |
| 4.6.4 Emergency stop to train | S8 Accident and incident response to major train accident |
| 4.6.6 Speed restriction related to level crossing | S3 Approach to level crossing |
| 4.6.7 Level crossing protection | S3 Approach to level crossing |
| 4.6.8 Activation and de-activation of a level crossing | S3 Approach to level crossing |
| 4.6.11 Route suitability protection | S5 Detection of errors in track routing |
| 4.6.12 Train trip | S4b Events after SPAD has occurred |

Table 2 Allocation of the analysis of the selected section of the ERTMS/ETCS FRS

**Conclusions from the analysis of the ERTMS / ETCS FRS**

As would be expected, the selected sections of the ERTMS/ETCS Functional Requirements Specification in general improve and control the human factor issues for normal operations. However, for degraded operations there remain human factor risks, which may not be dealt with by ERTMS/ETCS. These risks may even be greater if drivers become dependent on ETCS/ERMS when adapting their driving techniques under normal conditions to a stringent ETCS, e.g. drivers wait for ETCS to take actions.

**6.3.6 Workshop**

Upon completion of the analysis and development work involved in the HUSARE project, a workshop was organised to share and discuss the methodology and results with key representatives from the European rail industry. Thirtyone participants from 27 organisations - infrastructure owners, train operators and regulators – took part. Completed feedback forms were received from 75% of the attendees and on the whole, these indicated that the participants found this a valuable event and considered the project outcomes to be of high value. From discussions with participants, together with the questionnaire feedback, it is therefore considered that the event was successful in
meeting its objectives.

Based upon comments received from participants during the workshop, a number of modifications were made to the Final Report and the final version of the Human Factors Toolkit presented in Appendix 2.

6.4 Potential applications of the developed methodology

The human component in complex railway systems is not always considered in risk analyses. The proposed methodology provides a structured and transparent consideration of human factor issues in railway operations and it is therefore considered that the methodology is capable of playing a significant role in the improvement of safety in such operations. There are two main applications of the methodology and these are discussed below.

6.4.1 Analysis of cross-border operation

The reduction of risk from the human component has been described from a cross-border perspective. That is to say, the toolkit has been developed in order to identify sources of human risk in the comparison of operations that involve one or more borders, whether national or geographical.

This analysis may be performed on existing routes, as described in the HUSARE project. Alternatively, the methodology may enable the assessment of human factor implications for a proposed cross-border route. The effectiveness of human factor interventions is greatly improved where they have an input into the design stage rather than later in the system design life cycle. At this early stage, there may be more scope to implement risk reduction specifications.

6.4.2 Analysis of a single infrastructure

In addition, the methodology may be applied to the consideration of human factor issues within a single infrastructure. That is to say, the toolkit may inform the analysis of human factors in railway operations that do not involve crossing borders. In this case, there are two possible scenarios. First of all, the analysis may be driven by the comparison of two situations, such as the introduction of new technology, or major operational or organisational changes. In this case, the methodology described in the toolkit may be followed, making a comparison of the before and after situations (instead of comparing infrastructures A and B).

In the second case, there may be situations where no direct comparison exists. In such instances, a detailed task analysis of the particular situation will be required in order to
provide the input for the human error analysis (see the description of Hierarchical Task Analysis in the toolkit, Appendix 2). The Data Comparison stage of the process will therefore not be appropriate and the Data Collection stage will thus feed directly into the human factor analysis.

6.4.3 Application to Human Factors Issues

This framework provides a logical structure through which human factors principles and techniques can be applied to railway operations in an efficient and practical manner. The methodology provides a wealth of information including a record of the actions that personnel carry out, the information that they require for these actions, how they respond to this information, how they plan their actions and the human failures that may occur. The results of applying this process may thus be used to inform a range of human factors issues in the rail sector:

Design of human–machine interfaces

The analysis of tasks at a high level allows functional objectives to be specified, enabling decisions about hardware requirements to be made at an early stage in design. This analysis may be important, for example, when allocating functions between personnel and automatic systems. An understanding of the tasks that are performed (using Hierarchical Task Analysis, HTA) serves to inform the nature of controls and displays that are required in order to achieve the task goals efficiently and safely.

This approach to interface design ensures that the appropriate information is presented to personnel in a manner that assists them in completing tasks and that they are provided with the controls to respond effectively to this information. This understanding may be applied to human-machine interfaces such as in-cab displays and control room environments. The provision of relevant information in a format that is easily assimilated by the operator is especially critical in emergency or degraded conditions, where the operator is under increased levels of stress.

Development of rules, procedures and other documentation

The systematic analysis of scenarios using the toolkit may be used as a basis for the development or modification of rules and procedures. The analysis of tasks performed presents a detailed description for the content of these documents. In addition, addressing informal working practices in this process, as stressed in the toolkit, ensures that discrepancies between the documented procedures and working methods do not occur. Where differences are identified between infrastructures, there may be opportunities to modify procedures. However, where differences cannot be removed,
appropriate personnel may at least be made aware of critical issues.

**Specification of training requirements**

The methodology also provides the basis of a training programme, both in structure and content. The analysis of tasks using HTA provides a list of areas where training may be necessary. In addition, the identification of potential human failures highlights particular aspects of tasks that may require special training needs. In addition, the benefits of structuring training itself around a series of scenarios such as those adopted in this project may be considered.

**Job Design**

A comparison of practices between infrastructures may suggest that jobs are redesigned, perhaps through addressing allocation of roles and responsibilities. For example, the task analysis may be employed to organise a person’s tasks and roles so that they form a more coherent job or to provide personnel with more responsibility for achieving the goal itself rather than subordinate tasks. Differences in the allocation of roles and responsibilities between infrastructures may form an input into such job redesign.

Furthermore, the methodology identifies the areas where human factors play a critical role, enabling resources to be focussed on the areas where interventions will have the greatest effect.

### 6.5 Integration of the methodology into risk assessment processes

The proposed methodology provides for a stand-alone assessment of the human factor, enabling the identification and assessment of human factor issues and the generation of appropriate risk reduction measures. In section 6.4 several applications of the methodology are described, including its application outside of the scope of cross-border operations and the analysis of new routes or proposed modifications.

However, where railway operators already perform formal risk analyses, it is necessary to describe how the human factor analysis toolkit may be integrated within such a process. Given that the different railway operators responsible for cross-border operation may have adopted different approaches to risk analysis, it is only possible in this document to illustrate in general terms how such integration may be performed.

Traditionally, there is a tendency for risk assessments to be largely hardware or engineering based, with little consideration of the human factor. Therefore, important failure mechanisms may be under-represented or overlooked entirely in such analyses. In a system that depends highly on the performance of the human component, no risk
analysis can be complete without formally including an assessment of human error in the equation. In order to fully ‘manage’ the human factor, such integration is not only highly desirable, but a necessary condition.

Accidents and incidents rarely stem from a single cause, and a full understanding of such events requires a consideration of several factors, including hardware systems, management systems and human factors. These three areas are themselves interdependent, for example, failures of the management system may arise from human causes that are underlying rather than direct (see Figure 3).

![Diagram of risk assessment](image)

**Figure 3  The three components of risk assessment / accident causation**

It is considered that the toolkit developed within the project provides an opportunity to include human factors into a hardware-orientated risk assessment. There are several advantages to integrating the methodology into an existing risk assessment process, primarily that it will enable a consideration of the relative contribution of human and hardware failures to the overall risk level. An integrated approach to risk assessment will also ensure that human factor issues are considered in the generation and implementation of risk reduction measures. Where the human component is not accounted for in the determination of risk reduction strategies, it is possible that the measures implemented may create additional human factor issues.
Hardware/reliability analyses frequently make use of fault trees and event trees. These two methods represent combinations of failure mechanisms and event sequences respectively, and, if the appropriate data are available, can be used to calculate overall accident or event frequencies/probabilities. The toolkit developed within the HUSARE project may be employed to identify human actions that contribute to accident sequences. The representation of failure mechanisms and event sequences can benefit significantly from the use of task analysis and human error identification techniques. Human actions may include those actions that initiate an event sequence; those required to stop the accident sequence and actions that may make the situation worse. The modelling of such actions in an event tree allows the combination of human and hardware failures within the same model, allowing for the contributions of the different components to be assessed.

In order to construct an event tree, the information produced in the task analysis stage of the toolkit may be used to form the ‘top events’. For example, an event tree for the scenario ‘Response to Hot Axle Box Detection’ is presented in Figure 4.

![Event Tree Diagram](image)

**Figure 4** Event tree representation of ‘Response to Hot Axle Box Detection’

The use of fault or event trees to model the human contribution to an incident or accident sequence will thus help to integrate the human reliability assessment into a
quantified risk analysis. The use of common representation methods will also facilitate further analysis, for example, when conducting sensitivity analyses.

The proposed methodology consists of several distinct stages, from scenario description through data collection, data comparison to human error analysis. The various components of the toolkit are presented in Figure 5. It is important to stress that it is not necessary to adopt the full methodology as described. Each of the individual components in Figure 5 may be incorporated within an existing risk analysis where required. The adoption of each of these components will depend upon the exact nature of the existing risk analysis process.

![Diagram of the toolkit components]

**Figure 5  Components of the toolkit**

In the following sections, potential routes to integration of the toolkit in the risk assessment process are considered.
6.5.1 Organisations currently performing formal human reliability assessment

Organisations may currently perform human reliability analyses, for example, using techniques such as HEART (Human Error Analysis Reduction Technique) and THERP (Technique for Human Error Rate Prediction), as part of their risk management programme. Formal Human Reliability Assessment techniques like HEART and THERP provide an estimate of the probability of specific human errors, although they are mainly concerned with human actions as direct causes of accidents. These probability estimates may then be factored into traditional risk assessment processes; for example, it is possible to combine hardware and human failures on fault trees or event trees. The toolkit described in this report may provide an input into such a process in several ways, as described below.

- The structured approach to scenario descriptions, data collection (including task analysis), data comparison and human error analysis identifies the potential human errors or failures that may require quantification using Human Reliability Assessment. The methodology includes a checklist of human factor issues along with a classification of human error types to assist the analyst in this critical stage. The identification of errors/failures is arguably the most important stage in Human Reliability Assessment, for errors that are not identified will not be considered further in the analysis. Therefore, organisations currently quantifying human reliability (regardless of the particular techniques employed) will be able to adopt these stages of the proposed methodology as a structured human error identification tool. This process will help to ensure that all potential human failures are considered in the subsequent quantification stage.

- An important aspect of the Data Collection phase focused on the identification of issues and factors that may influence human performance in carrying out tasks. The toolkit includes a description of several of these Performance Influencing Factors (PIFs), including signs/signals and communication systems. The collection of data (on rules and procedures, working practices and technical systems) would also include information on the influencing factors considered to be particularly relevant for the scenario being considered. This information on influencing factors will provide a useful input into the quantification of human reliability, regardless of the techniques used for this process. It is becoming increasingly recognised that a consideration of such PIFs is an important aspect of the quantification of human
reliability. These PIFs effectively provide the context in which the human failure occurs and therefore it is necessary to gain an understanding of these factors if the failure is to be assessed and thus prevented.

- The human error analysis addresses the potential for recovery once an error has occurred and different types of recovery are discussed in the toolkit. Where Human Reliability Assessments are currently being conducted but do not include this important aspect, the probability of human failure may be overestimated. Therefore, the recovery analysis stage of the toolkit may form a useful input to such analyses.

- Where risk reduction measures have been generated following a risk assessment, the toolkit provides a structured methodology to ensure that those measures will not introduce new or additional human factor concerns.

- Where the toolkit is applied to a range of scenarios (as in the HUSARE project), common human factor issues and concerns may be identified. This will enable the identification of ‘common causes’ and risk reduction strategies will be more effective when targeted at these causes.

6.5.2 Organisations not currently performing formal human reliability assessment

Where organisations do not conduct formal analyses of human failures, the toolkit provides a complete methodology for the identification of potential errors or failures. As suggested in Section 6.4, this methodology may be applied to either cross-border or within-infrastructure situations. As previously mentioned, error identification may be considered to be the most important aspect of a human factors input into risk assessment. Where errors are not identified they will not appear in the risk assessment, with the result that the risk may be underestimated.

6.5.3 Quantification of the human error analyses

Following the qualitative analysis described in the toolkit, it may be considered necessary to quantify the likelihood of human errors. In order to perform such analyses, field data is required as input into the quantification phase and to validate the risk calculations. Such data was not available to the HUSARE project team, although individual railway operators may have access to such human performance and incident data. Therefore, specific errors identified in the example analyses have not been quantified, however, the section below outlines how the results of the human factor analyses may be prioritised.
6.5.4 Calculation of the human factor ‘risk’

The proposed human factor analysis can be developed to include a system for estimating the risk levels associated with each of the identified failures. Where several human factor issues are identified in the analysis, a method to rank these in terms of prioritisation may be required. Such a process does not necessarily include the quantification of absolute human error probabilities, merely tabulating the identified human failures in terms of relative importance.

Risk levels for each of the identified failures can be estimated by using a risk rating approach. In this approach, values are assigned to the items in each of the main columns in the human factor analysis proforma and then multiplied to arrive at an estimation of risk. An assessment would need to be completed for each of the following columns in the proforma and a suggestion as to how such information may be assigned is provided.

*Human Factor Issues*

It is first necessary to assess how frequently these identified issues occur and so for example, each issue could be placed into one of the following categories and a value assigned to each category:

- Frequently in normal operation, for example, each time a signal is passed (high)
- Infrequently in normal operation, for example, only for some signals in some locations (medium)
- Only in deviated situations, for example, technical failures (low)
- Infrequently in deviated situations (very low)

*Human Failures*

Given a human factor issue, it is then necessary to estimate how likely each human failure is to occur. This estimate may be a function of the nature of the task, particularly its complexity. The time available to the personnel will also have an input into the failure probability:


**Task Complexity**

<table>
<thead>
<tr>
<th>Low Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of Human Failure</td>
<td></td>
</tr>
<tr>
<td>Little time to react</td>
<td>Medium</td>
</tr>
<tr>
<td>Sufficient time to react</td>
<td>Low</td>
</tr>
</tbody>
</table>

**Recovery Potential**

An estimate may be made of the likelihood of error recovery, for example:

- Very likely (>80%)
- Likely (30-80%)
- Not likely (<30%)

**Consequence severity**

An estimate may be made of the severity of the potential consequences, for example:

- Very severe, for example, causing injuries and fatalities
- Severe, for example, causing damage to infrastructure and/or train vehicles
- Not severe, for example, passenger discomfort, delays

If numbers are then assigned to the categories above (for example, high=9, medium =5, low=1), an estimation of risk may then be made using the following formulae:

\[
Frequency = F_{\text{HumanFactorIssue}} \times P_{\text{HumanFailure}} \times (1 - P_{\text{RecoveryPotential}})
\]

**Risk** = **Frequency** \* **Consequence**

Where:

- \(P\) = Probability
- \(F\) = Frequency

It is recognised that this is a simplistic approach to risk estimation, however, such a system may prove valuable in the prioritisation of risk reduction strategies.
6.5.5 Cost-benefit analyses

The end product of the proposed human factor analysis toolkit is a set of risk reduction measures. In addition to an assessment of the risk arising from the human factor issues, it may also be necessary to conduct cost-benefit analyses to determine which of those measures are practicable. This analysis would be a function of the risk associated with the errors along with the costs of implementing risk reduction measures. This would need to take into account measures that may be able to prevent more than one potential error or failure.
7 Summary and Conclusions

In this final section, the main outputs of the HUSARE project are briefly summarised, followed by the concluding remarks, in which an indication is provided of the potential use and implications of the project’s results and its contribution to safe cross-border rail operations.

7.1 Summary of the HUSARE project outputs

The main outputs of the HUSARE project are summarised below:

*Identification of human factor issues*

A series of broad areas where human factor concerns may play a role in the safety of cross-border railway operations have been identified. These human factor issues have been grouped into ten categories, including (but not limited to) information presentation, roles & responsibilities and documentation. These issues were identified through the analysis of differences between infrastructures in relation to a set of defined example scenarios. A checklist of human factor issues to aid future analysis of cross-border operations is included in the human factor analysis toolkit (Appendix 2).

*A toolkit to identify and address areas of concern in cross-border rail operations*

A toolkit has been produced to aid the analysis of human factor issues in cross-border rail operations. This methodology provides a structured approach to the identification and management of such issues. It consists of a set of defined procedures for collecting the necessary data on rules, procedures, technical systems and working practices for the infrastructures involved; comparing the collected data in order to identify potential human factors based problem areas, and performing a detailed human factors analysis on the identified problem areas.

The toolkit is outlined in section 6.3.2 and described in detail in Appendix 2. The applications of this methodology and its potential integration into existing risk assessment processes are discussed in sections 6.4 and 6.5.
Specifications for risk reduction measures

As a result of the human factor analyses, specifications for risk reduction measures to support interoperability have been generated. These measures act to reduce risk by one of three means:

1. Preventing the failure from occurring
2. Improving the potential for recovery
3. Reducing the adverse consequences.

Examples of generic risk reduction measures have been documented in the three categories of technical systems, human resources and organisational factors.

Although these measures may be widely applicable, it is nevertheless essential that they should be individually selected according to the specific application. The associated risks should be integrated into the rail operators risk assessment and safety justification process and subject to the company's own safety investment criteria.

Potential application and implementation of the toolkit

Potential applications of the developed human factors analysis methodology and its integration into risk analyses have been described in Sections 6.4 and 6.5 above. The methodology developed provides for a structured approach to the management of human factors in cross-border operation (both existing and proposed routes) and may also be applied to the consideration of human factors within a single infrastructure. Furthermore, the toolkit may be employed in a stand-alone manner, or may be integrated into formal (traditionally hardware-oriented) risk analyses. Such an integrated approach is necessary for the effective management of the human aspect within a complex system, such as the European railway industry.

The proposed methodology consists of several distinct stages, from scenario description through data collection, data comparison to human error analysis. It is not necessary to adopt the complete methodology and railway companies may thus decide to utilise individual elements of the toolkit in their risk analyses as appropriate.
7.2 Concluding remarks:

The HUSARE project and its contribution to cross-border safety

This report is a record of the development and testing of a toolkit of analysis techniques, designed to be applied by the railway industry to identify and manage the human factor safety issues in cross-border operation. These techniques may also be applied within a single infrastructure and between different rail operators as a systematic way of improving human reliability within an existing framework.

The HUSARE project was presented to representatives from European rail operators and rail safety organisations at a workshop organised by the project team. As discussed in Section 6.3.6, a positive response to the methodology developed within the project was received at this event.

It is considered that the objectives of the HUSARE project have been achieved. However the success of the project lies in the application of the toolkit within the rail industry. Progress in this direction is dependent on the recipients of this report, who have responsibility for safety, to promote the use of the HUSARE toolkit within their organisation and to support the dissemination of the HUSARE toolkit and the underlying principles as a European rail standard. These are the necessary prerequisites to achieve implementation at the international level for safe and effective rail operation throughout Europe.
Appendix 1 Descriptions of the Selected Test Scenarios

A1.1 S1. Hot axle box

Narrative

A Eurostar train is in service in UK with a French driver. A lineside based Hot Axle Box Detection system installed on the lineside is activated as the train passes and this system sends a signal to a control centre. The signalman in the control centre stops the train and informs the train driver of the potential problem. The driver is informed of the location of the hot box and the driver proceeds to confirm the fault by checking the particular axle(s) and determining whether the train is safe to proceed.

In this scenario the safety critical task is the correct identification and diagnosis of the hot axle box. There are many opportunities for human error that could lead to the train with a fault continuing on its journey as normal. It is possible that the fault may escalate to the extent that the train is derailed and, in a worst-case scenario, an on-coming train collides with the derailed train.

A1.2 S2: Train speed adjustment

An essential task in safe train operation is to adjust the train speed according to the conditions set by the signalling, lineside signals and the train route settings. Factors such as rolling stock, train composition, the braking characteristics, infrastructure restrictions and how these are communicated to the driver/train have to be taken into account. Failure to adjust the train speed or to stop the train at appropriate locations may lead to both incidents and accidents such as derailment or collisions. Accident data has been used to develop five possible scenarios where speed adjustment and braking are the safety critical tasks.

The following variations are included in this test scenario:

A1.2.1 Scenario S2a: Permanent Speed Restriction

Narrative

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. On Infrastructure A, a train protection system is in operation, which supervises the train speed on the approach to and over speed restrictions.

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7 This test scenario has also been examined for Swedish, Danish and German Infrastructures and the narrative has been amended to consider passenger trains other than Eurostar.
The train driver from Infrastructure A is less accustomed to the signalling system and speed signs on Infrastructure B, so possible errors are not seeing (omitting), misreading or misunderstanding the signals and signs on Infrastructure B. There can be differences in the layout, design and visibility of signalling devices and signs. There may also be differences in how specific information is communicated to the driver via:

- Lineside signals and signs
- Information displayed in-cab
- Written instructions

Once the train driver decides it is necessary to brake to comply with the speed restriction, train speed adjustment is dependant on the timely application of sufficient braking force.

Significant differences between the “home” and “foreign” infrastructures may require braking strategies to be modified. For example, warning signs for permanent speed restrictions may or may not exist. In one infrastructure they may be placed at a fixed distance; in another infrastructure at the braking distance in front of the start of the speed restriction. Different braking rates and different strategies for controlling low adhesion conditions may also influence braking strategies. Therefore a driver’s behaviour will be influenced by his experience of the “home” infrastructure, his knowledge of the route speed profile and his competence in speed adjustment. The consequences of the error e.g. if braking is commenced too late, will be dependant on the magnitude of the speed reduction as well as the safety margins inherent in the infrastructure.

A1.2.2 Scenario S2b: Permanent Speed Restriction with Differential Speeds

The speed limits for curves are set by passenger comfort and to avoid overturning/derailment. There is a significant safety margin – between 50 to 60 % above the permissible speed for non-tilting trains. Failure to adhere to speed limits leads firstly to passenger discomfort and minor in-train injuries and if the safety margin is exceeded, overturning and derailment. Trains with a tilt capability are designed to travel faster through curves than trains without this facility. However, the tilt system is for passenger comfort purposes only and as tilting trains travel faster through curves the safety margin will be reduced significantly. However, tilting trains are normally fixed formation trains with a lower centre of gravity than traditional trains with independent locomotives and carriages. This increases their overturning speed and some of the reduced safety margin is regained. Additional cross-border related differences may have a detrimental influence on speed adjustment. These differences may be related to factors such as:
• infrastructure (track standards, route speed signing, signalling, driving cab speed displays or train speed protections systems)

• train characteristics (different trains, with different tilting capabilities and speed profiles) together with,

• increased task complexity (additional sub-task to calculate speed limit for tilting train)

As a consequence an unacceptable risk situation may arise.

Narrative

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. The train has a tilt capability, which enables the train to travel at a higher permissible speed around a curve. On Infrastructure A, a train protection system is in operation, which provides the driver with an in-cab display of the enhanced permissible speed for the curve ahead and over the length of the enhanced speed section. Additionally it supervises the train speed on the approach to and over the enhanced permissible speed section.

The method of route signing for speed restrictions is different on Infrastructure B to that on Infrastructure A. On Infrastructure B, speed boards are used to indicate the permissible speed for non-tilting trains but the driver of the tilting train has to read a book of speed diagrams for the higher speed that the tilting train is permitted to travel at over the enhanced permissible speed section.

The safety critical task for the driver is to compute the actual permissible with regard to the tilting characteristics of the train he is driving. Speed diagrams may be available as a task aid to determine the correct speed to enter the curve. Failure to carry out this task correctly may result in the train travelling at excessive speed around the curve, resulting in the train overturning.

A1.2.3 Scenario S2c: Temporary Speed Restriction

A temporary speed restriction is normally implemented during or following engineering work and is indicated to drivers via lineside speed boards. As well as the lineside signs there are various methods in different countries of giving written information to the drivers, such as including temporary speed restrictions in operating notices or by written orders passed to the driver before he enters that section of line. On some railways the train speed is supervised by a train protection system.
Narrative

A train with driver and crew from Infrastructure B is travelling on Infrastructure A. There is a planned temporary speed restriction over a distance of 1 km. There is an automatic train protection system in operation on Infrastructure A, but not on Infrastructure B. Route signing is also different on infrastructures A and B. For some reason the driver has not received the weekly route information that includes details about the speed restriction. Along the route the speed restriction may be indicated by signs and in-cab signalling where appropriate.

The critical task for the driver is to respond to the warning sign so that he applies the brakes to slow down the train sufficiently before the commencement of the speed restriction. Possible errors that may arise include that, as the driver has not received the written information about the temporary speed restriction, he may not respond correctly to the temporary speed restriction warning signs and does not apply the brakes until he sees the commencement signs of the speed restriction. In this case the braking performance is insufficient and the train enters the temporary speed restriction at excessive speed.

If the driver's attention is distracted for some reason e.g. trespassers on the line, he may also fail to notice the temporary speed signs.

A1.2.4 Scenario S2d: Emergency Speed Restriction

An emergency speed restriction is normally implemented following a report of a serious track defect and the speed over the line section is usually highly restrictive. Until the lineside speed signs are in position, special arrangements for informing the driver are implemented.

Narrative

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. Different languages are spoken on infrastructures A and B. The driver is stopped by the signaller and informed about the emergency speed restriction. The safety critical task for the driver is to slow the train to the permissible speed at the correct location. Possible errors are that he misunderstands the content of the message in terms of the permissible speed or the location of the track section. A likely outcome is that the train enters the speed restriction at excessive speed.
A1.2.5 Scenario S2e: Change to Deviated Route Setting over a Track Crossover

Between infrastructures, different conventions are used in the method to indicate route and speed restrictions over a track crossover. Various signals and colours, which may also vary in geometric form, or cab signalling systems can be implemented and may be misinterpreted by drivers from other infrastructures, particularly when changes to the accustomed route include a track crossover.

Narrative

A freight train (composed of a large number of wagons) with a driver from Infrastructure A is routed over a main track crossover (with intermediate main signals) on Infrastructure B. Due to engineering works the usual route over a track crossover is closed so that the train is to be switched to a diversion route. Signals direct the driver to the diversion route that the driver has not taken before. The points leading to the diversion route are some 100 m on the approach side of the points for the usual route. A lower speed is required on the diversion route throughout the station compared to the usual route. The critical task for the driver in this scenario is to reduce the train speed in preparation for the crossover. The braking action must be implemented earlier than usual, as the crossover to the diversion route will be reached before the usual crossover.

A1.3 S3: Approach to level crossing

From accident data it is evident that an incident where an obstacle blocks a level crossing is an important safety issue in cross-border operation.

The response of the train driver will be dependant on parameters such as visibility, train speed and distance to the level crossing as well as his level of attention, understanding of the signals and reaction time. In this scenario the braking distance of the train exceeds the distance to the level crossing at which the obstacle is recognisable to the driver, so that a collision with the obstacle on the crossing is inevitable.

Narrative

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. The level crossing is protected by an automatic system with barriers that are activated by approaching trains via an activation device. The status information sent to the main signal (via interlocking or block system) or indicated on a special protecting signal, includes feedback that the level crossing equipment is working correctly, i.e. that the barriers have been lowered and are intact. The driver sees a main

---

8 Crossover: Two “turnouts” connected to form a continuous passage between two parallel tracks.
(or special protecting signal), which displays a ‘proceed’ aspect, indicating that the level crossing is closed for road traffic. An obstacle (e.g. car) is blocking the track. There is no obstacle detector on the level crossing. When the train driver sees the obstacle he will brake, but a collision cannot be avoided because the braking distance is not sufficient. The safety critical tasks for the driver and crew are to stop the train, protect the train from the danger of approaching trains and ensure that the passengers are safe.

**A1.4 S4: Signal passed at danger**

This test scenario is divided into two parts:

- **Scenario 4a:** Events leading up to a SPAD. Here one possible example of driver error leading to a signal being passed at danger (red) is examined.

- **Scenario 4b:** Events following a SPAD incident. The actions to be taken after a SPAD has occurred are analysed.

Only SPADs that arise from non-technical causes have been considered. In these cases it would be expected that the driver should have been able to stop the train before reaching the Danger (red) signal.

There are a number of errors that can lead to a SPAD. The driver can disregard and start against a danger signal. Or he responds to the wrong signal. These errors are considered in the test scenario "Depart station" (S6). A further case which may lead to SPAD can occur when a driver misunderstands verbal instructions from the signaller as different languages are spoken on infrastructures A and B. A miscommunication error is considered in test scenario S2d.

Another error, which may lead to a SPAD, is when the driver misjudges the track conditions i.e. poor adhesion and does not adjust his train handling techniques to compensate e.g. to allow a longer braking distance. Similarly a SPAD can occur if the brakes are applied too late to stop at the danger signal when there is an incorrect response to a warning signal within a sequence of signals. This may happen because the driver anticipates the signal clearing before he reaches the stop signal. In scenario 4a, the driver has seen the caution signal but he is then pre-occupied with an intermediate event and subsequently does not respond to the caution signal and as a consequence passes the danger signal.
A1.4.1 Scenario 4a

_Narrative_

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. Shortly after passing a caution signal; the train comes to a stand because of a temporary traction fault. The train then proceeds after a few minutes delay but the driver has forgotten that the last signal was showing caution and passes the next signal at danger.

A1.4.2 Scenario 4b

_Narrative_

The driver has applied the brakes of the train but has passed the danger signal. He must follow the procedures to inform the signaller that a SPAD has occurred. The signaller will ascertain whether the driver is fit to continue the journey and give the necessary instructions to the driver.

A1.5 S5: Detection of errors in track routing

In this test scenario the concept of a driver's route knowledge and the authorisation to use specific routes are examined. When a driver is authorised to use a given route, he must not only be familiar with that specific route but also be competent for the planned diversionary routes. All these routes constitute the route knowledge of his "operating field". However, it is not necessarily within the competence of the driver to judge the technical compatibility of the route for his train. A driver who drives the train beyond the route for which the train type has route acceptance creates a potentially unacceptable risk situation. Safety problems can also arise through measures taken to bring the situation back to normal.

A driver must be able to recognise the boundaries of his "operating field", so that he can decide whether a signalled route is a deviation, and if this route is within his "operating field". Diversionary routes are generally infrequently used, so that such decisions, particularly on a foreign infrastructure can be difficult and the driver may be unsure as to whether he should follow the signalled deviation.

This judgement is combined with a dilemma between operational safety and effectiveness. The driver is directed to halt the train if he has doubts about the diversion, however at the same time he is under pressure to adhere to the timetable, avoid delays and hold up other trains. This decision requires a choice between these two opposing
actions based upon route knowledge and route acceptance for the train, which on the foreign infrastructure is possibly incomplete; both aspects are important stress factors.

When the signaller decides to send a train along a specific diversionary route, he must determine if the route is suitable for the train. He will assume that the train driver is authorised to use the deviation route. In re-routing trains the signaller may make a mistake and route the train incorrectly.

In this context, wrong judgements by both the train driver and signaller can occur when there is a large number of similar parallel tracks as is the case in approaching large train termini for example Gare du Nord, Paris.

The initiating event in this test scenario is a Signaller error. The signaller has directed the train to an unplanned deviation route.

Narrative

A passenger/freight train with driver and crew from Infrastructure A is travelling on Infrastructure B. The foreign infrastructure (Infrastructure B) differs from the home infrastructure with respect to technology, language, railway culture, signals, rules, landscape, and track topography. The train is to be diverted to another route. The train driver is given the appropriate lineside signals. The safety critical task for the driver is to judge whether he is authorised to take the route to which he is being diverted. He must decide whether to accept or reject the signalman’s directions. Three possible driver behaviours are considered:

A1.5.1 Scenario S5a

The driver is uncertain about the routing signal. He has to decide whether to accept the signal or to stop the train and confirm the routing with the signaller.

A1.5.2 Scenario S5b

The driver has taken the diversion, but then realises en route that he has made an incorrect judgement and must now decide what action to take in a situation where he has incomplete route knowledge. In other words the driver and the route are not compatible.

A1.5.2 Scenario S5c

This scenario is based on S5b but involves a freight train and the actions to be taken will be influenced by the train characteristics. In this scenario the train and the route are not compatible.
A1.6 S6: Depart station

It can be seen from the validated function inventories that the procedures for "depart station" vary in the different countries and between cross-border routes. For this reason a test scenario to examine the critical tasks in this function has been generated. The train crews will learn specific procedures for cross-border operation, which may differ from those that they normally follow on the home infrastructure. Non-compliance with such procedures will be more likely when an unexpected situation arises.

Narrative

An international passenger train from Infrastructure A, with passengers, driver and one guard (as the only crew member), arrives at a scheduled stop on Infrastructure B. The depart station procedures and the allocation of responsibility for giving the depart station signal are different on infrastructures A and B. Also different languages are spoken.

Depart station procedures are followed. Passenger exchange takes place at the platform. The station staff indicate to the train driver that station duties are complete upon which he closes the train doors.

Two possible incidents which may happen if the depart station procedures are followed incorrectly are:

- Trapping a passenger in the doors because an inadequate check is made after the doors have closed. e.g. the train driver has taken responsibility for the final check of the passenger doors and he has an inadequate view of the doors along the train.

- Starting against a stop signal because the driver has misunderstood a depart station message from the train crew or station staff and omits to check that the signal is showing a proceed aspect.

A1.7 S7: Assisting a failed train

A wide range of equipment failures can result in complete loss of traction power. Some of these are within the capabilities and approved procedures for the driver to identify and remedy.

There are some, however, which the driver cannot rectify so that the failed train must be assisted by another train. Normally, this assistance is provided at the front of the failed train except for fixed trainsets (where train control is possible from the leading driving cab to the assisting train) in which case it is normal to assist from the rear.
Narrative

A freight train with a driver and crew from Infrastructure A is travelling on Infrastructure B. The driver receives an indication of complete loss of traction. He follows the procedures to restore traction power whilst still moving but without success. If possible, the driver stops the train at an appropriate location on the open line between stations at a position with direct communication with the signaller. The driver informs the signaller he has a technical problem and will attempt to find and rectify the fault.

Following investigation the driver concludes that he needs assistance from another train. He reports to the signaller and they agree the arrangements to be made including the direction from which the assisting train will arrive.

The signaller, train crew of the failed train and the assisting train carry out the necessary rules and procedures for that infrastructure associated with connecting the two trains and the onward journey. This will include the use of shunting procedures.

A1.8 S8: Response to major train accident

In this scenario the events after a major train accident such as a derailment or collision with an obstacle on a level crossing are considered.

Narrative

A passenger train with driver and crew from Infrastructure A is travelling on Infrastructure B. The train collides with the rear end of a freight train ahead and a derailment occurs obstructing the adjacent track. The driver is seriously injured and is not able to follow the required procedures such as radio alert and protection of line. The remaining train crew apply the track protection procedures. The passengers are in danger because a train is approaching on the adjacent line. The crew evacuate the passengers. A freight wagon containing dangerous goods has derailed and there is a danger the cargo will be released.
Appendix 2

HUSARE Human Factor Analysis Toolkit
# HUSARE Human Factor Analysis Toolkit

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1 About this Toolkit

This Appendix to the Final Report of the HUSARE project contains the final version human factor analysis toolkit that was developed during the project. It describes the process to follow for the analysis of (cross-border rail operations related) factors that influence human performance. This human factors analysis process has gone through a sequence of development, testing and fine-tuning stages during the HUSARE project (as described in section 6.2 of the final report).

The toolkit developed provides rail operators who are or will be involved in cross-border operation with a means to identify and analyse human factors issues and include them in risk analyses. The toolkit provides a structured, step-by-step process to:

- Collect the necessary data on rules, procedures, technical systems and working practices for the infrastructures involved
- Compare the collected data in order to identify potential human factors based problem areas
- Perform a detailed human factor analysis on the identified problem areas.

In the next sections of this Appendix, a brief overview of the complete human factor analysis process is given, followed by a detailed explanation of each of the steps in the process.

2 Overview of the Complete Process

An overview of the complete process for the analysis of (cross-border operation-related) factors that influence human performance is shown in Figure A2.1. The process starts with the selection of specific scenarios on which the analysis will focus. These scenarios both determine the boundaries for, and drive the rest of, the analysis process.

A detailed description of each scenario is developed; specifying the situation, tasks and task steps relevant for the scenario. A scenario can involve a task or set of tasks that need to be performed during normal train operations, degraded mode operation, and emergency response tasks, depending on the focus chosen for the analysis. A scenario description consists of a narrative outlining the situation to be considered and technical information concerning that situation that may influence task performance.

A technique called Hierarchical Task Analysis (HTA) is then used to provide an overview of the tasks involved, breaking them down into their respective task steps and identifying when each of the task steps have to be performed and by whom. For each of
the task steps identified in the analysis, relevant data about rules, procedures, working practices and technical systems are recorded on data collection proformas.

After completion of the data collection phase, when scenario-relevant data has been collected from each of the infrastructures involved in the scenario, the data comparison phase can start. In this phase of the process, differences between the infrastructures in rules, procedures, working practices or technical systems from which human factors issues are likely to arise are identified. These differences and human factors issues are recorded on data comparison proformas.

This information is used as input for the next phase, the detailed human factors analysis. In this phase, potential human failures are identified together with their recovery potential and the potential consequences if the failure is not recovered. Specifications for measures to prevent the failure from occurring, to promote recovery chances or reduce the negative consequences of the failure are then identified.

Each phase in the human factors analysis process is discussed in more detail, complete with examples, in the following sections. The proformas developed for this process are contained in the Appendices of this toolkit.

3 Step I: Select Scenario

The analysis process commences with the selection of a specific scenario (or scenarios) on which the analysis will focus. The scenario will determine the boundaries for the rest of the analysis process and drive all further analysis-related activities. A scenario is a specific feature of railway operation and is a description of a particular work situation and tasks involved in that work situation. It specifies what tasks have to be performed, when and by whom, in that particular work situation and specifies the technical issues (regarding train, systems and infrastructure) relevant for the scenario. Scenarios that should be considered for analysis are those that reflect work situations involved in (cross-border) rail operation with the potential for human factors concerns. Scenarios should be selected with regard to safety critical human tasks and to expected variance in cross-border operation, such as variations in:

- Language, communications, culture and social conditions
- Training, selection and assessment of competence
- Infrastructure technology and systems
- Rules, procedures and standards
- Information environment - this includes signalling, in-cab displays and documents
- Geographical / topographical differences
4 Step II: Develop Detailed Scenario Description and Collect Data

When a scenario has been selected, further specification of the tasks and situations involved in the scenario is necessary to prepare for the analysis of factors that influence human performance. As a starting point, a description (in narrative format) is needed for the scenario. A useful structure to follow for describing the scenarios is based on the progression of a potential incident from the "initiating event" to the "consequences". The structure elements are:

- **initiating events**
  (occurrences, such as failures or errors, that set the scene for the tasks that need to be performed following this event)

- **pre-consequence recovery**
  (recovery from the initial error or failure before the negative consequences arise – the attempt to return to the normal situation)

- **consequences**
  (of the failure or error - usually unwanted, negative consequences)

- **post-consequence mitigation**
  (all attempts focussing on limiting the negative consequences)

- **final consequences**
  (of the initiating event after all recovery and mitigation attempts).

The narrative is a brief textual description of the scenario, outlining the sequence of events, with details about tasks involved (when to be performed and by who) and contextual details about the situation in which the tasks have to be performed. This includes the pre-conditions, the initiating events, the safety critical tasks and possible errors. In some cases, notably for scenarios involving degraded mode operations or emergency response, possible actions for pre-consequence recovery or post-consequence mitigation are also described. The scenario description should also contain technical details relevant for the scenario about the train, systems and infrastructure that are likely to influence human performance.

When collecting data in order to specify the scenario further, special consideration should be given to issues and factors that may influence human performance. Figure A2.2 provides an overview of such Performance Influencing Factors. An indication is given of which factors or issues influence the performance of specific personnel (task agents). A more detailed description of each of these influencing factors is given in Figures A2.3 and A2.4.

In this data collection phase, it is necessary to collect information on ‘informal’ working
practices in addition to reviewing documented rules and procedures. In practice, tasks may be performed in ways that differ significantly from the ‘official’ procedures, for a variety of reasons. It may be the case that the formal procedures are unworkable in practice, because they are out-of-date or because people prefer to rely on their own skill and experience. When collecting information on these informal working practices it is necessary to involve task experts in addition to rules and procedures experts.

Figure A2.2: Performance Influencing Factors to Consider in the Data Collection Phase
<table>
<thead>
<tr>
<th>Influencing Factor</th>
<th>Focus</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trackside signs &amp; signals</td>
<td>Train / Signalling</td>
<td>Signs &amp; signals presenting information to the driver. Information about content and meaning, location, design and layout, visibility, shape, size and reflectivity of trackside sign and signals is collected.</td>
</tr>
<tr>
<td>On-board &amp; in-cab information system</td>
<td>Train</td>
<td>Visual or auditory systems to present information within the cab, e.g. speed restriction, line signals etc.</td>
</tr>
<tr>
<td>Information systems for signallers</td>
<td>Signalling</td>
<td>Visual or auditory systems to present information to the signaller, e.g. location of trains, position of signals etc.</td>
</tr>
<tr>
<td>In-cab train control system</td>
<td>Train</td>
<td>Systems for the driver to control the train, e.g. train brake, speed control etc.</td>
</tr>
<tr>
<td>Control systems for signallers</td>
<td>Signalling</td>
<td>Systems to control traffic, e.g. controls to set signals to danger, block lines etc.</td>
</tr>
<tr>
<td>Automatic train protection systems</td>
<td>Train</td>
<td>Automatic system that has the potential to override the driver's control of the train and stop or to slow down the train in the event of operational violations, such as over-speeding or failure to stop (ATP).</td>
</tr>
<tr>
<td>Automatic warning systems</td>
<td>Train</td>
<td>Automatic systems that warn the driver about lineside signal aspects and speed restrictions. It requires the driver’s acknowledgement but but gives no further warning...</td>
</tr>
<tr>
<td>Vigilance monitoring system</td>
<td>Train</td>
<td>System that requires driver interaction, repeatedly within predefined time intervals, to remain assured that the driver is still alert.</td>
</tr>
<tr>
<td>Train diagnostic systems</td>
<td>Train / Signalling</td>
<td>External or on-board systems (passive) providing information about the state of the train, e.g. hot axle box detectors, door status (open/closed) etc.</td>
</tr>
<tr>
<td>Infrastructure diagnostic systems</td>
<td>Train / Signalling</td>
<td>External or on-board systems (passive) providing status information about the infrastructure, e.g. level crossing status indicator etc.</td>
</tr>
<tr>
<td>Communication systems</td>
<td>Train / Signalling</td>
<td>Two-way communication systems for communication between driver and signaller/controller between drivers, e.g. in-cab radio, track-side telephones etc.</td>
</tr>
<tr>
<td>On-board personnel</td>
<td>Train</td>
<td>On-board personnel may warn or pass on information to driver directly or using one of the communication or warning systems above</td>
</tr>
<tr>
<td>Information dissemination system</td>
<td>Train / Signalling</td>
<td>System for disseminating information about changes in track infrastructure status, e.g. temporary speed restrictions, work on track etc., or changes in train route and traffic conditions and the system for acknowledging receipt of information. The information is either written or verbal and is given to the driver/signaller in form of periodic bulletins or extra notices.</td>
</tr>
<tr>
<td>Other external sources of information</td>
<td>Train / Signalling</td>
<td>Direct information to the driver or signaller from other external sources, e.g. passengers, people along the track etc.</td>
</tr>
</tbody>
</table>

Figure A2.3: Description of Performance Influencing Factors
<table>
<thead>
<tr>
<th>Factors Influencing Competence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train handling knowledge</td>
<td>The ability to correctly control the train for the route, taking account of the braking and traction performance of the train for the route conditions. Regulations on the criteria for retention of competence in train and route knowledge.</td>
</tr>
<tr>
<td>Route / Infrastructure knowledge</td>
<td>Degree of familiarity with route and the infrastructure, e.g. geography, topography, location of signs and signals etc. on all relevant infrastructures.</td>
</tr>
<tr>
<td>Attention strategies</td>
<td>In relation to attention strategies such aspects as: awareness of concept; inclusion in training programme; consideration in the design of on-board or track-side signs etc., inclusion in incident analysis within the infrastructure, should be examined.</td>
</tr>
<tr>
<td>Signs and signals knowledge</td>
<td>Degree of familiarity with the meaning of signs and signals on all relevant infrastructures.</td>
</tr>
<tr>
<td>Driver performance record</td>
<td>Record about the driver’s performance in the past. The use of these records as a basis to assign or not assign tasks to a driver, e.g. record of SPAD</td>
</tr>
<tr>
<td>Fluency in foreign language</td>
<td>The fluency the train driver and crew have in language of foreign infrastructure</td>
</tr>
<tr>
<td>Selection process</td>
<td>Rigorousness of selection process for train driver recruitment, e.g. age, aptitude, fitness, health etc.</td>
</tr>
<tr>
<td>Training for incidents and emergencies</td>
<td>Degree of training, simulation training for incidents and emergency situations, e.g. derailment, collision with Approach to level crossing etc.</td>
</tr>
<tr>
<td>Supervision &amp; management</td>
<td>The processes, which ensure medically acceptable and competent personnel, are utilised.</td>
</tr>
</tbody>
</table>

**Figure A2.4: Description of Factors Influencing Competence**

The detailed scenario description and collected data will provide a basic insight into the tasks involved in the scenario, by whom and when these tasks need to be performed. At this stage it is essential to obtain a fuller understanding of the tasks and persons (task agents) involved in the scenario. A technique called Hierarchical Task Analysis (HTA) is proposed for this purpose. HTA is a systematic method of describing how work is organised in order to meet the overall objective of the job. In performing this analysis, it is important to involve task experts, that is, the people who actually perform the tasks. The HTA (and other aspects of the data collection process) should not be solely based upon an analysis of documentation or discussion with senior personnel.

HTA commences by stating the overall objective that the person (or group of persons) has to achieve. This ‘goal’ is then re-described into a set of tasks along with a plan specifying when they are carried out. The plan is an essential component of HTA since it describes the information sources that the worker must attend to in order to signal the need for various activities. Each task can be re-described further if the analyst requires, again in terms of other tasks and plans. Complex tasks are thus represented as a combination of the following:
a. a hierarchy of **tasks** - different things that people must do within a system

b. **plans** - the conditions which are necessary to undertake these operations.

There are two main ways for representing a HTA description: the diagrammatic and tabular format. Diagrams are more easily assimilated, but tables often are more thorough because detailed notes can be added. It is possible to work with a diagrammatic format and finally record the analysis in a tabular format. This allows other aspects of the task to be considered such as information about the human-machine interface, communications with other team members, time characteristics, side-effects caused by failure to follow the correct plan, and the knowledge required to carry out a plan. Including this information in the task analysis is very useful for gaining an insight into the workload imposed by various task components, the various points where performance may degrade, and finally into the methods which are likely to optimise human performance. In Figures A2.5 and A2.6 below, examples of both the diagrammatic and tabular HTA representations are given.

---

**Figure A2.5: Example of Diagrammatic HTA Representation for the Task ‘Depart Station’**

[Diagram showing the HTA representation for 'Depart Station']
<table>
<thead>
<tr>
<th>No.</th>
<th>Task step descriptions</th>
<th>Task agent: who performs the task?</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Set route and signal</td>
<td>Signaller</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Check signal for safe departure indicates proceed aspect</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Close doors</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan: do 3.1 to 3.3 in order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.1 Check passenger exchange is complete</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.2 Whistle (or use whistle built-in into door closing system)</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3 Close doors except door from which closing system is operated</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ensure train is safe to depart</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan: do 4.1 to 4.2 in order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.1 Ensure doors are closed</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2 Ensure no passengers are trapped</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Give ready to depart signal to driver</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Check signals</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan: do 6.1 to 6.2 in any order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.1 Check main signal</td>
<td>Driver</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.2 Check doors closed - ready to depart signal (in-cab or from guard)</td>
<td>Driver</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Control train in accordance with signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan: do 7.1 to 7.2 in order</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.1 Close last door</td>
<td>Guard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.2 Control train</td>
<td>Driver</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.6: Example of Tabular HTA Representation for the Task ‘Depart Station’

Re-describing tasks into more detailed sub-tasks should only be undertaken where necessary. The question of whether it is necessary to break down a particular task to a finer level of detail depends on whether the analyst believes that a potential human error is likely to be revealed by a more fine-grained analysis. For example, the task ‘4.1 – Ensure doors are closed’ may be an adequate level of description if the analyst believes that the likelihood of error is low, and/or the consequences of error are not severe. However, if this task was safety-critical, it could be further re-described. If the consequences of not ensuring that the doors are closed are considered serious and/or omitting this task step was likely, then it would be necessary to break down this task into its component steps.

In practice, a consideration of the quality of the Performance Influencing Factors (e.g.
training, supervision, procedures) in the situation being evaluated will give a good indication of the overall likelihood of error in the specific operation being evaluated. Similarly, the consequences of errors can be evaluated in terms of the overall vulnerability to human error of the sub-system under consideration. By considering these factors together, it is usually clear where the analysis should be terminated.

Analysing complex tasks that entail considerable skill is usually performed in collaboration with people who are knowledgeable about the job. Information can be collected from a variety of sources including operating procedures, emergency procedures, and records of critical incidents. This data collection phase is ideally performed by an expert from the infrastructure under analysis. However, if this is not possible, it may be performed by a Human Factors expert through collecting documentation (such as rules, procedures and standards) and structured interviews with a range of personnel.

The output of the scenario description and data collection phases is thus a narrative and a representation of the task steps or group of closely related tasks/task steps in the form of a Hierarchical Task Analysis. The relevant data about rules, procedures, technical systems and working practices relevant for the scenario (task(s) and situation) needs then to be recorded, for which a data collection proforma has been developed (see Figure A2.7).

For each task step, the task agents (personnel involved in performing the task) have to be indicated, so that in the data recording process a differentiation can be made between data relevant for one task agent and data relevant for another. For each task step, per task agent, infrastructure-specific data about technical systems and operational standards related to the task step is recorded in the second column, data about relevant rules and procedures in the third column and any additional information about working practices which may not necessarily be captured in documentation, in the fourth column. Where the persons performing data collection are familiar with the relevant data, a reference to the source documents may be inserted into the appropriate column rather than a full textual description. These source documents may be required in the subsequent data comparison stage.

A separate proforma has been developed for the collection of data on competency issues. For each infrastructure, only one data collection proforma for factors influencing competence needs to be completed, as most information regarding competencies is relevant for all scenarios that consider a certain infrastructure, not just one scenario in particular. During Step III, the data comparison phase, only the information relevant for the scenario under consideration will be employed. Figure A2.8 contains an example data collection proforma for factors influencing competence. Appendix 1 to the Human Factor Analysis Toolkit contains blank versions of both types of data collection proformas.
# DATA COLLECTION PROFORMA

<table>
<thead>
<tr>
<th>Scenario: Depart Station</th>
<th>Infrastructure: The Netherlands (NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task agent</td>
<td>Technical Systems &amp; Operational Standards</td>
</tr>
<tr>
<td><strong>Task 2 of 7: Check signal for safe departure</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Train manager / Guard</strong></td>
<td>The main signal shows proceed aspect (yellow (max 40 km/h) or green) to the driver. In larger stations, separate departure signal visible for guard linked to main signal (showing same aspect: white light from vertreksein on = safe for departure).</td>
</tr>
<tr>
<td><strong>Signaller</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Task 3 of 7: Close doors</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Train Manager / Guard</strong></td>
<td>On-board control system for door closing, operated by guard</td>
</tr>
<tr>
<td><strong>Driver</strong></td>
<td>Driver receives information about doors being closed (via automatic light + sound in cab, or via whistle from guard)</td>
</tr>
<tr>
<td><strong>Task 4 of 7: Give ready to depart signal</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Train Manager / Guard</strong></td>
<td>Whistle and hand-held signal (white lamp at night) from guard to alert driver about ready to depart, doors are safely closed, for trains that don’t have automatic monitoring system linked to door closing. On train sets with door closing monitoring system: Light in cab that shows doors have been closed successfully, linked to door-closing system.</td>
</tr>
</tbody>
</table>

| Task ... of total: Name of task (or task step or group of closely related tasks/task steps) |
| Task agent 1 | | |
| Task agent 2 | | |

*Figure A2.7: Data Collection Proforma*
**DATA COLLECTION PROFORMA: FACTORS INFLUENCING COMPETENCE**

<table>
<thead>
<tr>
<th>Infrastructure: The Netherlands (NS)</th>
<th>Technical Systems &amp; Operational Standards</th>
<th>Rules &amp; Procedures</th>
<th>Undocumented working practises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors influencing competence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Train handling knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route/infrastructure knowledge</td>
<td></td>
<td>RnV normblad P-015, paragraph 2.3 (infra) &amp; 2.4 (route).</td>
<td></td>
</tr>
<tr>
<td>Attention strategies</td>
<td></td>
<td>RnV normblad P-015 2.1k: A driver should know all signs and signals from the signal book (“Seinenboek”)</td>
<td></td>
</tr>
<tr>
<td>Signs and signals knowledge</td>
<td></td>
<td>RnV normblad P-015, chapter 7 and paragraph 1.3: A driver who operates on the Dutch network should be fluent enough in the Dutch language to understand &amp; be able to exchange safety &amp; operational messages, to read and understand instructions and announcements and to write down short announcements and messages.</td>
<td></td>
</tr>
<tr>
<td>Drivers performance record</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluency in foreign language</td>
<td>Dutch drivers operating on foreign infrastructure should have the same fluency in the foreign language as specified in the box to the right for (foreign) drivers on Dutch infrastructure.</td>
<td>RnV normblad P-015, chapter 7 and paragraph 1.3: A driver who operates on the Dutch network should be fluent enough in the Dutch language to understand &amp; be able to exchange safety &amp; operational messages, to read and understand instructions and announcements and to write down short announcements and messages.</td>
<td></td>
</tr>
<tr>
<td>How are tasks addressed in selection process</td>
<td></td>
<td>Psychological and medical tests are standard for safety-critical jobs (as specified in several RnV normbladen). Certain educational level is required, plus fluency in national language. Depending on job experience, a training program is designed to ensure competency, after which a theoretical and practical exam has to be passed.</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.8: Data Collection Proforma for Factors Influencing Competence
Upon the completion of this detailed scenario description and data collection phase for both infrastructures involved in the scenario (or for both the situation before and after, or any other situations in need of comparison and analysis), the data comparison phase can commence.

5 Step III: Compare Data

The detailed scenario description and data collection phase provides a list of all the tasks relevant for a particular scenario, either implicitly or via a more analytical approach using the Hierarchical Task Analysis technique. In the data comparison phase, differences between the infrastructures in terms of rules, procedures, working practice, operational standards or technical systems are identified. These differences are identified at the level of each task step in the scenario. Also, differences between the infrastructures with regard to the various relevant Performance Influencing Factors (refer to Figures A2.2, A2.3 and A2.4) need to be identified.

Four kinds of data comparison proformas have been developed to support the recording of results from this phase (see Appendix 2 to Human Factor Analysis Toolkit). These proformas focus on four areas:

- The train, which is most appropriate for tasks where only train-based task agents (personnel) are involved.
- Signalling, which is most appropriate for tasks of personnel involved in signalling.
- Jointly on train-based and signalling tasks, for those tasks where both train-based task agents and signalling task agents are involved at the same time and co-operation between the two is important.
- Factors influencing competence. This proforma needs to be completed only once for a particular scenario, to record differences between the infrastructures regarding scenario-relevant competence influencing factors.

A choice needs to be made between one of the first three data comparison proformas, based upon the task agents involved in the scenario. For those cases where any of the factors influencing competence as listed in Figures A2.2 and A2.4 seem to be relevant for the scenario, the fourth data comparison proforma provides a systematic way of recording differences between infrastructures with regard to those factors.

Figure A2.10 is an example on how to record information on a data comparison proforma, where the focus is on the train as well as the signalling. Guidance for the use of the data comparison proformas (focus train, focus signalling, or focus train including signaller’s tasks) follows.

In the two top rows, space is provided to specify the scenario and the specific task step from that scenario for which this data comparison exercise is being performed. Under
these two top rows, a section named ‘Tasks’ is provided to identify differences between the two infrastructures with regard to the task or task step, for each task agent involved in that task. Rows for task agents that do not have a role in the task under consideration can simply be deleted. The bottom half of the proforma contains a section named ‘Influencing Factors’. Differences between the infrastructures with regard to performance influencing factors from Figure A2.2 and A2.3, such as signs and signals, communication systems and train control systems can be recorded here. Again, those influencing factors that are not relevant for the task step under consideration in a proforma can be deleted.

To record information on factors influencing the competence of a task agent, another data comparison form has been developed (See Appendix 2 to Human Factors Analysis Toolkit). The data comparison proformas described above (focus train, focus signalling, or focus train including signaller’s tasks) have to be completed for each task or task step involved in the scenario where differences exist between the two infrastructures for which the comparison is carried out. However, the instructions for the use of the comparison proforma for factors influencing competence are slightly different. Where relevant, this proforma needs to be completed only once per scenario. Competence issues generally influence more than just one task or task step and thus may influence overall performance for the complete set of tasks involved in the scenario.

The third column on all of the data comparison proformas is labelled ‘Human Factors Issues’. In this column, an indication can be made of what human factors issues are to be expected when performing the tasks involved in the scenario, based on the differences identified in the comparison exercise (and recorded in the second column). The ‘Human Factors Issues Checklist’ at Figure A2.9 provides guidance in identifying such issues. For the purpose of this toolkit, ten different categories of human factors issues have been identified, including information presentation, roles and responsibilities, and procedures.

Applying this checklist to each of the recorded differences, the associated human factors issues category can be identified in which human performance problems are to be expected. Although many of the human factors issues that can be identified in this exercise will probably stem from differences between the two infrastructures, the user of this toolkit is encouraged to also consider human factors problems for areas where no real differences between the infrastructures exist, but where the task or work situation itself inherently has some associated human factors problems.

On completion of the data comparison phase, the differences between the infrastructures under consideration and related human factors issues have been identified. This information provides the starting point for the detailed human factors analysis, described in the next section.
## Human Factors Issues Checklist

### Information presentation (e.g. content, mode, source, frequency)

- Are there differences in the ‘signal to noise ratio’; for example, trackside signs less visible, signs and signals contain more information, radio performance less clear?
- Do signs/signals/messages have different or opposing meanings?
- Are there differences in the frequency of the presentation of signs/signals or other communications?
- Do different signs/signals (or other communications) control tasks or subtasks?
- Does the mode of information presentation change (for example in-cab signals as opposed to trackside signals)?
- Do personnel require more information, different information, or have to obtain the same information from a different source?
- What is the availability of prior written information (for example, driver’s notices)?

### Human-machine interfaces

- Are the task interfaces different?
- Does the same information display have a different meaning or require a different action?

### Communication systems and feedback (e.g. mode, source, language)

- Is feedback or confirmation obtained from a different source?
- Are there differences in the confirmation or checking of communications?
- Does the mode of communication change for a particular task?
- Are there variations in the nature or frequency of feedback from the system (either directly from the train or indirectly from a signalman/control centre)?
- Is communication in a common language, a readily understood format or in standardised protocol (especially for safety critical messages)?

### Technical / hardware systems

- Are there variations in the presence of technical / hardware safety systems on which the driver may be reliant (e.g. obstacle detectors on level crossings)?
- Are there differences in safety systems, for example, the degree of warning signs, visual and/or audible stimuli, the length of signal ‘overlaps’ etc.?

### Roles and responsibilities – task agents

- Does the task agent (person who performs the task) change?
- Are roles and responsibilities different or less formally defined?
- Is the safety culture different in the organisations for which the task agents work?
- Are roles and responsibilities clearly defined for degraded or emergency conditions?
- Is team performance impaired due to communications, changes in roles/responsibilities etc.?
- Do personnel have experience of team training with members of other infrastructures, particularly for degraded or emergency conditions?
## Job design, allocation of function and workload

- Is there an increase in the number of secondary tasks or a change in their nature such that performance on the primary task may be degraded?
- Do other factors (such as number of personnel) significantly affect the workload of drivers or other safety critical personnel?
- Is the allocation of function between human and machine different (for example, is train speed controlled manually, or is there some automatic intervention from a system such as ATP)?

## Task characteristics

- Is the order of tasks different?
- Are there tasks / sub-tasks present on Infrastructure B that are not required on Infrastructure A?
- Are tasks performed more or less frequently on Infrastructure B (compared with A)?

## Documentation, job aids and procedures

- Quality/accessibility etc. of procedures, depth of documentation, including procedures for degraded and emergency situations?
- Support for rules and procedures – job aids etc.?
- Scenario training and assessment?
- Company safety management systems?

## Operational characteristics (e.g. train speed, timetable constraints)

- Are there significant differences in operational features, for example, is the train speed increased such that response times / safety margins may be reduced?
- Does the infrastructure influence critical characteristics of the train (for example, adhesion qualities of the line influencing braking)?
- Are there variations in the frequency of trains?
- Are there variations in the reliability of control systems?
- Are there variations in the potential conflicts between operational pressures and safe working practices?
- Are there differences in operational factors, such as increased timetable demands on Infrastructure B?
- Are operational procedures perceived to be ‘better’ in one infrastructure than another, increasing the likelihood of ‘optimising violations’?

## Personnel, training and competency issues

- Are there significant differences in the competence of personnel from the different infrastructures, for example, in terms of selection, qualifications, training and assessment of competence?
- Competency assessment systems?
- Language capabilities?
- Experience on simulators? (Particularly degraded/emergency situations)?
- Manning levels?
- Supervision?
- Shift patterns and hours of work?

---

**Figure A2.9: Human Factors Issues Checklist**
# Data Comparison Proforma: Focus Train with Signaller's Tasks

<table>
<thead>
<tr>
<th>Scenario: Depart Station</th>
<th>Infrastructures: Netherlands (NS) and Germany main lines (DB)</th>
<th>Identified differences: Short description of difference with reference source documents</th>
<th>Human Factor Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 4 of 7: Give ready to depart signal to driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tasks</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Driver</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Signaller</strong></td>
<td>In NS only TM involved, no interaction with platform manager necessary. In DB the TM communicates with Platform manager if involved.</td>
<td></td>
<td>Roles and responsibilities; Documentation, job aids and procedures</td>
</tr>
<tr>
<td><strong>Train Manager</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Train Crew</strong></td>
<td>In DB Platform manager sets ready to depart signal (Zp9) on long platforms e.g. Cologne</td>
<td></td>
<td>Roles and responsibilities</td>
</tr>
<tr>
<td><strong>Station Personnel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Presentations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>On-board and in-cab information systems</strong></td>
<td>Linked to successful door closure in NS if system fitted.</td>
<td></td>
<td>Information presentation</td>
</tr>
<tr>
<td><strong>In-cab train control systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Information systems for signallers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control systems for signallers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Automatic train protection systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Automatic warning systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vigilance monitoring systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Train diagnostic systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infrastructure diagnostic systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communication systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>On-board personnel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Information dissemination system</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other external sources of information</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure A2.10: Data Comparison Proforma: Focus - Train Including Signaller’s Tasks**
6 Step IV: Analyse Human Factors

The human factor analysis commences on completion of the scenario selection, scenario description, data collection and data comparison phases. The detailed human factor analysis process provides a tool for a structured and complete analysis of identified cross-border differences and human factors issues. The aim of this phase is to predict and analyse, for the identified differences and human factors issues for the selected tasks, the possible human errors or failures that may occur in the task. In addition, this phase will:

- Identify, for each possible human failure, the potential to recover from that failure before the negative consequences of that failure arises;
- Describe the potential consequences if the failure is not recovered;
- Identify specifications for additional measures to prevent the failure from occurring, to promote recovery chances or reduce the negative consequences of the failure.

A ‘human factor analysis proforma’ has been developed to assist in the further analysis of those tasks or task steps where cross-border differences and related human factor issues have been identified and documented on the data comparison proforma. Two examples of this proforma are displayed on the next two pages in Figures A2.11 and A2.12, one for a task step from a scenario focussing on the tasks involved in train departure from a station and one for a task step from a scenario focussing on accident and emergency response tasks. Appendix 3 to the Human Factors Analysis Toolkit contains a blank human factor analysis proforma.
### Scenario: Depart station

Infrastructures: Netherlands (NS) and Germany main lines (DB)

<table>
<thead>
<tr>
<th>Task or task step description</th>
<th>Summary of identified differences or human factor issues involved</th>
<th>Likely human failures as a result of such differences or issues (for support see error types checklist)</th>
<th>Potential to recover from the failure before consequences occur</th>
<th>Potential consequences if the failure is not recovered</th>
<th>Measures to prevent the failure from occurring</th>
<th>Measures to reduce the consequences or improve recovery potential in the event of a failure</th>
<th>Comments, references, questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 4 of 7 Give visual/audible ready to depart signal</td>
<td>Roles, responsibilities, and task agents, procedures, information presentation: In Germany at specific stations (with long platforms) the platform manager gives the signal ready for departure (sets Zp9 signal). In the Netherlands the platform staff do not carry out this task.</td>
<td>Failure to change procedure: On a Dutch train in Germany, the train manager (guard) might carry out this task, not using the Zp9 signal. On a German train in NL, the train manager might expect the platform manager to do this.</td>
<td>Not Applicable</td>
<td>High recovery potential: discovery that there is no platform manager will lead to changing of procedure used.</td>
<td>No negative consequences as long as home infrastructure’s procedure is followed completely.</td>
<td>For the German train in NL, there may be delay as result of waiting for platform manager to perform the task.</td>
<td>Training in procedures. Harmonised procedures when train crew/platform staff from different infrastructures interact.</td>
</tr>
</tbody>
</table>

Figure A2.11: Human Factors Analysis Proforma: Example 1
Scenario: Accident and Incident Response to a Major Train Accident  
Infrastructures: Netherlands (NS) and Germany (DB)

<table>
<thead>
<tr>
<th>Task or task step description</th>
<th>Summary of identified differences or human factor issues involved</th>
<th>Likely human failures as a result of such differences or issues (for support see error types checklist)</th>
<th>Potential to recover from the failure before consequences occur</th>
<th>Potential consequences if the failure is not recovered</th>
<th>Measures to prevent the failure from occurring</th>
<th>Measures to reduce the consequences or improve recovery potential in the event of a failure</th>
<th>NOTES</th>
</tr>
</thead>
</table>
| Task 1 of 5 Immediate actions to warn trains in vicinity | Different task characteristics in foreign infrastructure. German driver has three immediate actions:  
- emergency radio call,  
- LZB emergency signal and subsequently report to signaller,  
- warn train crew; (with possible variations when train radio is not available).  
The NL driver sends out radio alert and reports directly to signaller.  
(Other issues, details discussed elsewhere: Different radio systems are used, so there are differences in both the communication system and the MMI for operating the radio. & Different task agents involved in the task (who responds to driver’s alert)). | Both drivers follow procedures related to their own train’s equipment (radio and ATC). Drivers operating in a foreign infrastructure may need to carry out additional actions to pass on warnings to other trains (particularly with other equipments). These actions may be omitted. This is particularly so for the driver in Germany as he already has three specific immediate actions to carry out. Alternatively, a harmonised procedure may omit infrastructure specific actions. These redundant actions may still be carried out if the driver regresses to normal procedure for own infrastructure. These may delay or interfere with essential actions. | In Germany, the radio control centre can pass on the warning to other trains.  
In Germany recovery depends on the radio control operator or signaller realising that the driver has not passed the warning on.  
In Netherlands the signaller, who receives the radio alert ensures that the message is passed onto other trains.  
This is also dependent on communication issues (details elsewhere). | There will be a delay in warning all trains in the vicinity.  
There is danger (collision or derailment) for on-coming trains if neighbouring track is not clear.  
Technical compatibility between radio systems, so that independently of radio system used for emergency warning all trains in vicinity receive warning.  
One, harmonised action for driver to pass on emergency warning to infrastructure system as a whole.  
This can be equipment-based or through an intermediary task agent such as radio control centre or emergency control centre. | | Interaction with other trains from foreign infrastructure that will have various non-compatible equipments. German procedure already has two action routes to cope with trains with different equipments on home infrastructure. Assigning additional actions to driver to cover all trains with different equipments operating in the infrastructure is not a recommended solution. This solution would be liable to failure from omitted actions with dangerous consequences. |
Guidelines for completing each of the columns of the Human Factor Analysis Proforma are given in the text below.

### Human Factor Analysis of Current Situation

- **Task or task step description**

  The task or task step from the list of tasks where a difference or human factor issue exists in the rules / procedures / working practice / technical systems / operational standards is described here. These task (or task step) descriptions can be taken from the data comparison proformas.

  *Example: ‘Task step 2 - Check station departure signal’*

- **Summary of identified differences or human factors issues**

  This column is used to present a summary of the identified difference or cross-border human factor issue for this task or task step. These differences/issues will again be taken from the data comparison proforma.

  *Example: ‘Information presentation: the departure signal varies between the two infrastructures in both its content and placement’*

- **Likely human failures as a result of such differences or issues**

  This column records the types of human error that are considered possible for this task or task step, given the differences or issues recorded in the previous column. It also includes a brief description of the specific error. Note that more than one type of error may arise from each identified difference or issue. Figure A2.13 provides a checklist of the common types of errors that may occur.

  *Example: ‘Correct check on wrong object: the driver reads the lineside departure signal for an adjacent line and departs early’*

  *Example: ‘Wrong information obtained: the driver misreads a signal aspect and departs early’*
Human Error Types Checklist

The following checklist is intended to act as a prompt for the completion of column 3 in the human factor analysis proforma: ‘Likely human failures’. It is not intended as a comprehensive checklist of human error types. Note that more than one type of error may be relevant for each identified difference / issue.

It is important to note that a task may be a physical action, a check, a decision-making activity, a communications activity or an information-gathering activity (for example, from memory or from a sign/signal/display). A driver, signaller or other personnel may perform these tasks. A task may involve teamwork, which means more task agents or persons involved in performing the task.

As a result of a cross-border difference or human factor issue identified in the data comparison exercise, a task may:
- Not be completed at all
- Be partially completed (too little or too short)
- Be completed at the wrong time (too early or too late)
- Be inappropriately completed (too much, too long, on the wrong object or in the wrong direction)
- Be completed by another (the wrong?) person

Or,
- Task steps may be completed in the wrong order
- The wrong task or procedure may be selected and completed

Additionally, there may be:
A deliberate deviation from the rule (a ‘procedural violation’)

Figure A2.13: Human Error Types Checklist

✔ Potential to recover from the failure before consequences occur

Not all human errors or failures will lead to undesirable consequences. Following an error, there may be opportunities for recovery from the error before reaching the consequences detailed in the following column. It is important to consider recovery from errors in the assessment; otherwise the human contribution to risk will be overestimated. A recovery process generally follows three phases: detection of the error, diagnosis of what went wrong and how, and correction of the problem. During each of these three phases, one or more of the following can support the recovery process:
• The operator who originally committed the error, that is, the human component in the process (e.g. when the operator immediately or subsequently realises he has committed an error and corrects the problem);

• The organisation in which he works (e.g. when another person detects and corrects the problem, or brings it to the attention of the operator who committed the error, who then corrects the situation);

• The system (technical system & work environment) in which the person operates, via in-built barriers and defences (e.g. where ATP, reduces train speed when a driver fails to do so, or when in-cab audible/visible alert messages are given to a driver to notify him of a problem detected by the system).

✔ Potential consequences if the failure is not recovered

This column records the consequences that may occur as a result of the human failure described in the previous columns. For the railway industry, severe undesirable consequences include derailment, collisions and impact with obstacles.

Example: ‘As a result of the driver passing a signal at danger when departing from a station platform, the train may be in collision with a correctly departing or arriving train on an adjacent line, with possible damage to train and infrastructure and injuries to passengers’

| Specifications for additional measures to deal with human factor issues |

✔ Measures to prevent the failure from occurring

Practical suggestions as to how to prevent the error from occurring are detailed in this column, which may include changes to rules and procedures, engineering modifications to the train or infrastructure, or changes to signal aspects and locations. Any such proposals should of course be subject to suitable risk assessment / cost benefit analysis.

Example: ‘A departure signal may be transmitted to the in-cab display rather than via a lineside signal. This would, for example, reduce the likelihood of a driver starting on the depart signal given to an adjacent line’

✔ Measures to reduce the consequences or improve recovery potential in the event of a failure

This column details suggestions as to how the consequences of an incident may be
reduced or how the potential to recover can be increased should a failure occur. Such measures may include the use of overlaps following signals before a junction, so that if a SPAD occurs, the train may come to a stop before the point of possible collision. Again, any suggested measures will be subject to risk assessment / cost benefit analysis.

NOTES

✓ Comments, references, questions

This column provides the facility to insert additional notes or comments not included in the previous columns and may include general remarks, or references to other tasks, task steps, scenarios or detailed documentation. Areas where clarification is necessary may also be documented in this column.

Although a human error analysis is resource-intensive, the amount of effort required for the analysis is reduced by only considering those tasks where cross-border differences or human factor issues have been identified in the data comparison exercise.

Appendix 4 to the Human Factor Analysis Toolkit provides a job aid for completing the Human Factor Analysis Proforma, in which both guidelines and examples are included.
Annex 1 to Human Factor Analysis Toolkit: Data Collection Proformas

**DATA COLLECTION PROFORMA**

<table>
<thead>
<tr>
<th>Scenario: [Name of scenario]</th>
<th>Infrastructure: [Name of infrastructure]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task agent Fill in below:</td>
<td>Technical Systems &amp; Operational Standards</td>
</tr>
<tr>
<td>Task 1: Name of task (or task step or group of closely related tasks/task steps)</td>
<td></td>
</tr>
<tr>
<td>Train driver</td>
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<tr>
<td>Train manager</td>
<td></td>
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<tr>
<td>Signaller</td>
<td></td>
</tr>
<tr>
<td>Task 2: Name of task (or task step or group of closely related tasks/task steps)</td>
<td></td>
</tr>
<tr>
<td>Task n: Name of task (or task step or group of closely related tasks/task steps)</td>
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</tr>
</tbody>
</table>

**DATA COLLECTION PROFORMA: FACTORS INFLUENCING COMPETENCE**

<table>
<thead>
<tr>
<th>Infrastructure: [Name of infrastructure]</th>
<th>Technical Systems &amp; Operational Standards</th>
<th>Rules &amp; Procedures</th>
<th>Undocumented working practises</th>
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</thead>
<tbody>
<tr>
<td>Factors influencing competence</td>
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<tr>
<td>Train handling knowledge</td>
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<tr>
<td>Route/infrastructure knowledge</td>
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<tr>
<td>Attention strategies</td>
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<td></td>
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<tr>
<td>Signs and signals knowledge</td>
<td></td>
<td></td>
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<tr>
<td>Drivers performance record</td>
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<tr>
<td>Fluency in foreign language</td>
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<tr>
<td>Selection process</td>
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<tr>
<td>Training for incidents and emergencies</td>
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<tr>
<td>Supervision &amp; management</td>
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</tbody>
</table>
**Annex 2 to Human Factor Analysis Toolkit: Data Comparison Proformas**

**DATA COMPARISON PROFORMA: FOCUS TRAIN**

<table>
<thead>
<tr>
<th>Scenario: [Name of scenario]</th>
<th>Infrastructures: [Name of infrastructures]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task x of n: [Name of Task]</td>
<td><strong>Identified differences:</strong> Short description of difference with reference source documents</td>
</tr>
</tbody>
</table>

### Tasks
- Driver
- Train Manager
- Train Crew
- Station Personnel
- Other Task Agents

### Influencing Factors
- Trackside signs & signals
- On-board and in-cab information systems
- In-cab train control systems
- Automatic train protection systems
- Automatic warning systems
- Vigilance monitoring system
- Train diagnostic systems
- Infrastructure diagnostic systems
- Communication systems
- On-board personnel
- Information dissemination system
- Other external sources of information
## DATA COMPARISON PROFORMA: FOCUS SIGNALLING

<table>
<thead>
<tr>
<th>Scenario: [Name of scenario]</th>
<th>Infrastructures: [Name of infrastructures]</th>
<th>Identified differences: Short description of difference with reference source documents</th>
<th>Human Factor Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task x of n: [Name of Task]</td>
<td></td>
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</tr>
</tbody>
</table>

### Tasks
- Signaller
- Station Personnel
- Other Task Agents

### Influencing Factors
- Trackside signs & signals
- Information systems
- Control systems
- Train diagnostic systems
- Infrastructure diagnostic systems
- Communication systems
- Information dissemination system
- Other external sources of information
**DATA COMPARISON PROFORMA: FOCUS TRAIN WITH SIGNALLER'S TASKS**

<table>
<thead>
<tr>
<th>Scenario: [Name of scenario]</th>
<th>Infrastructures: [Name of infrastructures]</th>
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</thead>
<tbody>
<tr>
<td>Task x of n: [Name of Task]</td>
<td>Identified differences: Short description of difference with reference source documents</td>
</tr>
<tr>
<td>Human Factor Issues</td>
<td></td>
</tr>
</tbody>
</table>

### Tasks
- Driver
- Signaller
- Train Manager
- Train Crew
- Station Personnel
- Other Task Agents

### Influencing Factors
- Trackside signs & signals
- On-board and in-cab information systems
- In-cab train control systems
- Information systems for signallers
- Control systems for signallers
- Automatic train protection systems
- Automatic warning systems
- Vigilance monitoring systems
- Train diagnostic systems
- Infrastructure diagnostic systems
- Communication systems
- On-board personnel
- Information dissemination system
- Other external sources of information
## Data Comparison Proforma: Factors Influencing Competence

<table>
<thead>
<tr>
<th>Competence Issues</th>
<th>Identified differences: Short description of difference with reference source documents</th>
<th>Human Factor Issues</th>
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</thead>
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<td>Train handling knowledge</td>
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<td>Route/infrastructure knowledge</td>
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<td>Supervision &amp; management</td>
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</tbody>
</table>

Scenario: [Name of scenario]

Infrastructures: [Name of infrastructures]
### Scenario: [Name of scenario]

### Infrastructures: [Name of infrastructures]

<table>
<thead>
<tr>
<th>Task or task step description</th>
<th>Summary of identified differences or human factor issues involved</th>
<th>Likely human failures as a result of such differences or issues (for support see error types checklist)</th>
<th>Potential to recover from the failure before consequences occur</th>
<th>Potential consequences if the failure is not recovered</th>
<th>Measures to prevent the failure from occurring</th>
<th>Measures to reduce the consequences or improve recovery potential in the event of a failure</th>
<th>Comments, references, questions</th>
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**Annex 3 to Human Factor Analysis Toolkit: Human Factor Analysis Proforma**
## Annex 4 to Human Factor Analysis Toolkit: Job aid for completing Human Factor Analysis Proforma

This column is used to present a summary of the identified differences or cross-border human factors issue for this task step or task description. These differences/issues will be taken from the data comparison proforma.

### Task or task step description
Example: ‘Task step 2 – Check station departure signal’

### Summary of identified differences or human factor issues involved
Example: ‘Information presentation: the departure signal varies between the two infrastructures in both its content and placement’

### Likely human failures as a result of such differences or issues
Example: ‘Correct check on wrong object: the driver reads the lineside departure signal for an adjacent line and departs early’
Other example: ‘Wrong information obtained: the driver misreads a signal aspect and departs

### Potential consequences if the failure is not recovered
Examples: when the operator realises he has committed an error and corrects the problem; when another person detects and corrects the problem, or where ATP reduces train speed when a driver fails to do so.

### Potential to recover from the failure before consequences occur

### Measures to prevent the failure from occurring
Example: ‘A departure signal may be transmitted to the in-cab display rather than via a lineside signal. This would, for example, reduce the likelihood of a driver starting on the departure signal given to an adjacent line’

### Measures to reduce the failure’s consequences or improve recovery potential
This column provides the facility to insert additional notes or comments not included in the previous columns and may include general remarks, or references to other tasks, task steps, scenarios or detailed documentation. Areas where clarification is necessary may also be documented here.

### Human factors specifications for additional measures to deal with human factor issues
This column records the types of human error that are considered possible for this task, given the differences or issues recorded in the previous column. It also includes a brief description of the specific error. Note that more than one type of error may arise from each identified difference or issue. Figure A2.13 provides a checklist of the common types of errors that may occur.

### Potential consequences if the failure is not recovered

### Measures to recover from the failure

### Summary of the identified difference or issue
Not all human errors or failures will lead to undesirable consequences: There may be opportunities for recovery before reaching the consequences detailed in the following column. It is important to take recovery from errors into account in the assessment, otherwise the human contribution to risk will be overestimated. A recovery process generally follows three phases: detection of the error, diagnosis of what went wrong and how, and correction of the problem. During these three phases, the recovery process can be supported by one or more of the following: the human component in the process; the organisation in which he works; and the system (technical system & work environment) in which the person operates, via in-built barriers and defences.

### Human factors specifications for additional measures to deal with human factor issues
These tasks or task steps will be taken from the data comparison proforma.

### NOTES
Practical suggestions as to how to prevent the error from occurring are detailed in this column, which may include changes to rules and procedures, engineering modifications to the train or infrastructure, or changes to signal aspects and locations.

### Comments, references, questions
This column provides the facility to insert additional notes or comments not included in the previous columns and may include general remarks, or references to other tasks, task steps, scenarios or detailed documentation. Areas where clarification is necessary may also be documented here.

### Version 2

**Figure A2.13 provides a checklist of the common types of errors that may occur.**

---

**NOTES**

### Potential to recover from the failure before consequences occur

### Potential consequences if the failure is not recovered

### Summary of the identified difference or issue
Not all human errors or failures will lead to undesirable consequences: There may be opportunities for recovery before reaching the consequences detailed in the following column. It is important to take recovery from errors into account in the assessment, otherwise the human contribution to risk will be overestimated. A recovery process generally follows three phases: detection of the error, diagnosis of what went wrong and how, and correction of the problem. During these three phases, the recovery process can be supported by one or more of the following: the human component in the process; the organisation in which he works; and the system (technical system & work environment) in which the person operates, via in-built barriers and defences.

### Human factors specifications for additional measures to deal with human factor issues
These tasks or task steps will be taken from the data comparison proforma.

### Summary of the identified difference or issue
Not all human errors or failures will lead to undesirable consequences: There may be opportunities for recovery before reaching the consequences detailed in the following column. It is important to take recovery from errors into account in the assessment, otherwise the human contribution to risk will be overestimated. A recovery process generally follows three phases: detection of the error, diagnosis of what went wrong and how, and correction of the problem. During these three phases, the recovery process can be supported by one or more of the following: the human component in the process; the organisation in which he works; and the system (technical system & work environment) in which the person operates, via in-built barriers and defences.

### Human factors specifications for additional measures to deal with human factor issues
These tasks or task steps will be taken from the data comparison proforma.