Operational and Human Factors Testing to Commission ERTMS Level 2 BL 3 in Denmark

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SUMMARY

This paper is a straightforward account of the strategy and process developed over a number of years to provide confidence that the people in a railway upgrade are ready for operational change. It also includes a small number of examples to demonstrate the benefits gained from the use of the Human Factors approach taken. The methodology described comes from work on an upgrade, replacing legacy lineside signalling to digital traffic and route management systems, including train protection with ERTMS L2; and is reusable as a premise for other similar networks. It could be particularly supportive where a new set of operational rules are introduced alongside the technical changes.

The upgrade process in the context of the Directive is limited to the technical constituents and the availability of the rules. Here, we note that the nature of interoperability provides a dilemma for the Infrastructure Manager and Railway Undertakings, since the responsibilities are distributed for separate safety approvals. The quandary is this: how can those responsible for the safety management and risk profile feel confident the first time all the parts come together, along with the people? This paper notes that whilst the equipment may be technically proven to work together (technical compatibility requirements), the operational railway system is held together necessarily by the human components. This is an overview of work completed by Banedanmark and the Signalling Programme in order to confirm true operational readiness.

1 INTRODUCTION

The Danish Signalling Programme for the mainline (Fjernbane) has been running for over 10 years; and in October 2018 it commissioned the first European Railway Traffic Management System (ERTMS) Level 2 Baseline 3 railway in the World. Its delivery was on a brown-field site; changing from the life-expired equipment. Maintenance and replacement of existing equipment had become very difficult; with faults and failures causing more delays and cancellations than acceptable.

The aim of adopting country wide ERTMS is to have a more homogenous level of safety, as well as improved performance and a more operationally economical and maintainable system, with only two control centres to cover the entire country. The upgrade to ERTMS will cost over 3 billion Euros and has been funded by public money and grants from the European Union. Its success is critical to the country and future railway operations. Since being put into service, some benefit is already noticeable, with regularly excellent reliability and punctuality reports. Plus public and media opinion has been positive and the operational staff are, in the main, pleased with change.

The Early Deployment Line (EDL) in the West of Denmark was switched over to ERTMS L2 BL3 from Level 0; it was using only conventional colour light lineside signals. There was no train control and no protection systems for overspeed or passing red signals, etc. As might be expected when investing heavily in a technical contract, the majority of the signalling system teams (supplier and Infrastructure Manager signalling programme) were focused upon the technical design, development and delivery. It is noteworthy that there were also dedicated teams for Operational Rules for Fjernbane (ORF) and for operational training from the beginning of the Signalling Programme. Further, the Signalling Programme included Human Factors professionals, working at various levels on involvement with the system design and latterly for commissioning.

This paper is written from the perspective of those engaged with the delivery of the Signalling Programme and has been internally reviewed by representatives from rules, interoperability, operational and technical safety integration. Although this paper focuses upon the first deployment of ERTMS, the Danish situation is not unique. Digital railway upgrades onto existing networks Worldwide will be facing similar challenges.

2 BACKGROUND AND CHALLENGES

2.1 Meeting Interoperability Goals

Whilst managed through the European Commission; ERTMS is being adopted across the globe. It is probably because the principles are so well established and the process has attracted involvement from some of the best signalling minds, plus engagement with industry-leading companies. The thought behind interoperability is a philosophy of performance improvement, wider community benefit, longevity, exchange, better capacity and overall improved European cooperation across transportation networks.

Interoperability standards are aimed at having a common delivery (with requirements for safety, reliability, availability, health, accessibility, environmental protection and technical compatibility), whilst allowing for healthy competition within the railway industry. Interoperability means that constituents of the system can be approved individually, so long as they meet the standards and intention in the European Train Control System (ETCS) Technical Specifications for Interoperability (TSIs).

The ERTMS Specifications and Legislation have both detailed technical descriptions and procedures for putting ERTMS systems into service. For the purposes of this paper, there are three key ERTMS elements of interoperability in practice that have impacted upon Banedanmark's development and delivery:

1. The Control Command and Signalling (CCS) TSI (with requirements for subsystems, interfaces, functional and technical specifications, procedures for assessment, etc.)
2. The Operation and Traffic Management (OPE) TSI (with the delivery by member states of their own Operational Rules (OR), following on from National Implementation Plans).
3. The role and interaction with the National Safety Authority (NSA) to gain each Authorisation for Placing In Service (APIS).

2.2 Control Command and Signalling TSI

In the main, the CCS TSI is used as the framework for the system and is "taken as read" and it forms the basis of many of the operational expectations for the supplier's equipment (in Denmark, we have multiple suppliers for ETCS equipment). Signalling Programme members (on all sides) have been involved in many European-level working groups and committees associated with the TSIs in principle, theory and practice. This has provided some feedback into our own understanding for the technical systems as well as operations. The CCS TSI, especially subset 026, is a regular reference document for the technical team. The TSI also features heavily in discussions when the behaviour of the delivered system may not feel aligned with what the operational team anticipated. As far as this paper goes, the CCS TSI contents do what they are designed to: they provide technical interoperability and compatibility such that any selected suppliers equipment can be used for the subsystems. It is assumed that conformance on equipment and subsystem level, leading to the APIS provides us with a safe implementation within the bounds of the technical requirements.

2.3 Operation and Traffic Management TSI

The OPE TSI requires Infrastructure Managers (IM) and Railway Undertakings (RU) to be responsible for developing appropriate Operational Rules (OR), Driver's Rule Books, as well as a Route Book. The needs for Operations and Traffic Management within Denmark was taken very seriously by the Signalling Programme, with the formation of an OR team early on (in our case, for ORF). They were developing OR for the future system in parallel to the technical design and installation. During development, the Banedanmark ORF team were in contact with the various working groups associated with ERTMS. The aim being to generate a collaborative and cooperative understanding across nations and within the industry.

Feedback from the ORF team was that the OPE TSI was a very good starting point but it was not the panacea. There was a great amount of consideration and time invested in the production of a new rule set for Denmark, which was written using language that the main users can read and understand (not written from a judicial standpoint). The production required lessons learnt from the existing legacy 1975 network safety regulations. The IM and RU and other operational groups (maintenance, shunters, etc.) were included in the development. Further, the Danish Railway Trade Unions were engaged alongside other technical expertise. As well as this, the ORF team looked deeply into the supplier equipment differences for potential technical implementation, due to interpretation (whilst the supplier could still be compliant with the technical CCS TSI, there might be different responses needed by operational personnel). The ORF team formed a working group, with suppliers and technical experts from the Signalling Programme. The Suppliers were also included in the review of the draft ORF.

It is noteworthy that supplementary rules relevant to the specific implementation are allowed within each nations' Operational Rules. Also, background instructions, not related to the safety of operation on ERTMS maybe included within the ORF; but are optional. Banedanmark chose to not include much of what could be seen as superfluous, non-operational and equipment-centric content. Where information is not operationally safety-related, it may be recorded in other documentation such as technical manuals and working procedures. This very much applies to the features of timetables, interface operation, maintenance and performance-focused decision-making at a network management level.

A set of Operational Rules for Fjernbane (ORF) was given approval for use in training during 2017 and approved for use in the West of Denmark in 2018 and in 2019 for the East of Denmark. Since then, there have been a few improvements to those Operational Rules at a specific, detailed level. These partially came about due to the Human Factors (HF) and Trial Running (TR) activities, which is the subject of the majority of this paper.

2.4 Authorisation for Placing in Service

There is a perspective that TSIs will provide an integrated railway; with approvals given by the National Safety Authority (NSA), by granting Authorisation for Placing In Service (APIS). The approvals for putting into service take each technical constituent of the railway and handle it separately. To this end, the NSA has a specific, narrow field-of-view with respect to an APIS:

- Each version of the train-based onboard equipment has its own Safety Approval;
- Each safety-related signalling system delivery has its own Safety Approval;
- The Operational Rules and their use have a standalone Safety Approval;
- The training specification has a Safety Approval.

For Banedanmark, this presents a precondition to consider the full delivery, since there is no APIS required for integrated operation.

2.5 No "All-Inclusive" Safety Approval

Due to competition rules (for an open market) and basis of the interoperability standards, there is no requirement for an "all-inclusive APIS" for the whole system that comprises the trains, signalling system and people. The assumption is that each part alone, through meeting standards via safety assessment scrutiny, will suffice; as such, there is no formal way to approve the "whole railway".

Human Factors practitioners and operations specialists realise that this raises a number of concerns associated with the potential for real-life operational issues to fall between the cracks of responsibility. For the organisation that has the overall responsibility for the safety management of operations (affecting both the IM and the RU), there is a need to obtain confidence that they are prepared and ready for full service, with no operational safety issues.

The change in the Safety Management System (SMS) and the use of Common Safety Method (CSM) to manage the risk profile to cover ERTMS operations are part of the means to enforce a thought-process around the whole railway upgrade. The safety certification by the NSA for the updates to the SMS makes visible that people and processes are what holds the subsystems together. However, this does not provide a clear and direct way to prove to ourselves that our people are operationally ready for a brand-new way of running the railway in real-life. On paper, we had the APIS for every item and we had personnel signed off as being trained. For us, however, it was clear that we knew paperwork and a focus on the technical safety would not be enough: we required belief that there were no gaps between the key parts. How could we be sure we understood how the system would be used in practice and how could we identify any concerns associated with the organisation that will take over operations?

Whilst the NSA did not need to assess the integrated digital railway, there were many parties including the internal programme and project teams, the IM and the RU that were very keen to see evidence of the whole system being used in operations, prior to public service. This was the first time for Denmark to use ERTMS and for a wholesale change in operational environment (trains, lineside and rules). In reality, we knew we needed to know more before we could agree to full commissioning. It was clear that convincing the internal and external stakeholders that our first line was operationally ready would take more than gaining an APIS for each of the infrastructure and onboard systems.

The need for confidence included:

- Proof of the systems over a prolonged period in a variety of conditions;
- Proof that the ORF could be applied in practice, not just in training;
- Proof that that competence could be based upon the training provided;
- Proof of operational performance.

The remainder of this paper focuses on the approach taken to ensure we were ready. This includes the preparation of the people, their understanding of the systems and the application of the new Operational Rules for using ERTMS.

3 APPROACH USED

3.1 Evidence using Trial Running and Human Factors Testing

We have sought a way to provide evidence that the integrated railway, at the operational level, is fit for service by introducing a “railway level” safety package. This is not presented for NSA approval and it is not expected to be introduced as legislation. It is a safety package that contains what is needed for the Infrastructure Manager to feel prepared and comfortable (which can be challenged during safety audits but is not a formal safety assessment).

The package is reviewed by an Independent Safety Assessor and requires a large number of critical inputs in order to gain the confidence. A key feature of the railway level safety package is the input of Trial Running (TR), which is the Human Factors testing approach used by Banedanmark. The Trial Running is live, real-life testing of operational scenarios, which differ depending upon the topography of the part of the railway being commissioned, the staff involved and the maturity of the technical and functional delivery.

The foresight of the Signalling Programme was to include the delivery of an Early Deployment Line (EDL) from each supplier, with the option to run a Change Over System (CoS) for part of the line. The CoS allows a change from conventional signalling control to ERTMS control for testing, including points and level crossings. Infrastructure items that could not be part of the CoS (for whatever reason) were otherwise secured or clamped into known positions, using approved methods. An Authorisation for Test was requested specifically for TR testing by Banedanmark and granted by the NSA; based upon TR’s own CSM-RA hazard management and associated system description of the test.

This section provides further details of each of the six important facets of the TR activity:

1. Making TR tests relevant
2. Managing TR sessions
3. Observing and recording
4. TR reporting and improvement cycle
5. Providing inputs to the Railway Safety Package
6. Linking TR to the operational hazard record

3.2 Making TR Testing Relevant

The HF test cases, known as test intentions, are self-contained and re-usable. The test intentions list, of around 220 items, originally came from an analysis of the ORF, the system manuals, failure types and the operational hazard record. An expert panel checked and updated the initial list. For future use, it is possible to add new test intentions when new functionality is delivered (e.g. when the roll-out contains a new type of infrastructure, such as tunnel or bascule bridge). Refinements of the test intentions have been part of the ongoing internal quality assurance activities performed by the testing team, to ensure that tests remain up-to-date and correct. Figure 1 provides a precise of the groups of tests created and coverage of the test intentions used for TR.

Group of Tests	Types of Test Intention Created
Timetable Running	Normal Start of Mission (SoM), cab change normal running with Automatic Route Setting (ARS), through transitions. Normal parking, joining and splitting.
Changes to Normal Operations	Changes to timetable, changes to parking, splitting and joining. Running UN/ UT trains, cross-over with non-ETCS railway. Abnormal SoM, manual routing, train data and code mismatches. Trains stopped, passing end of authority (Written Orders). Handling Trip Mode, movement over undetecting points.
Restrictions	Temporary Speed Restrictions (TSRs), wind restrictions and low adhesion. Unsupervised moves through transitions (both directions). Radio holes, driving with restrictions, snow clearing.
Faults and Failures	Operational response to signalling faults and failures (supervision, level crossings, etc.) - normally a trigger for other test intentions. Maintenance organsiation response to faults & failures (signalling, track, GSM-R, network, catenary, forest).
Permanent Shunting Areas	Train exit from PSA (normal, Written Order, unknown position). Train entry into a PSA (normal, Written Order, HHT controlled). Ownership of PSA (shunting manager, signaller).
Possessions	Booking, planning, updates to possessions. Establishing possession (with/ without Hand Held Terminal (HHT)). Ending possession (with/ without Hand Held Terminal (HHT)). Yellow Fleet entry into/ exit from possessions and movement within and between possessions. Ownership of possessions.
Temporary Shunting Areas	Similar to possessions, but with Temporary Shunting Areas, normally with freight trains. Routes for shunting.
Operational Handover	Signaller handover (whole or part of area, normal and abnormal cases). Signaller handover between locations. Driver handover.
Response to Emergencies	General control area management in emergencies. Emergencies with specific types of infrastructure (bascule bridge, tunnel, catenary). Protecting emergency and non-emergency entry to the track.

Figure 1: Types of Test Intention used for Trial Running

Each of the test intentions were developed into full testing steps. For pertinent steps, a Key Measure Question (KMQ) was developed about the actions and behaviours of the operational staff. For the development of steps and KMQs a basic HF hierarchical task analysis methodology was used. A task analysis was completed for each test intention and for each role; so that there was a clear understanding of all actions and behaviours, including the inter-personal communications required. The test intentions were necessarily at a low level of granularity; therefore, the task analysis was not very large and were checked in a quality review cycle by operations and product experts.

The task analysis method was also taught to non-HF team members, who were easily able to follow the process and develop steps and initial KMQs, including interaction with the experts during the quality review cycle. HF specialists were only needed for guidance, peer review and to make alignments. This is of benefit to Banedanmark, in up-skilling employees and also to appropriately utilise the generally scarce HF resource.

Individual test intentions were put together into scenarios, which helped tests to be relevant in the context of the particular locations and topography. In turn, the scenarios were created in a way that makes them reusable and can be placed one-after-the-other, to effectively escalate a situation, if required.

For each testing session, the Human Factors Team worked with the Test Manager to develop an operationally relevant schedule and place the test scenarios within it. Support from various specialists in the supplier and BDK Projects helped to ensure the fullest understanding of the expected results. Typically, certain tests were run a number of times, in different locations with different pre-conditions. This gave a clearer picture of whether the operational personnel could fully understand the appropriate Human-Machine Interfaces (HMIs), and apply ORF, inter-personal communications and use the equipment correctly.

An important part of the testing ethos was to ensure that everyone involved realised that it was not the individuals who were being "tested". The aim of all of the sessions was to gather action and behaviour results, in order to determine whether any other operational person, undergoing the same training, using the same Operational Rules and equipment would be likely to successfully manage the operational situation. This message was carried in all of the pre-session briefings and it was encouraged that instructors mentioned this to participants prior to their involvement. Further, the test team were made aware when operational personnel had completed their training; only those completing the appropriate level of education and passing required examinations (as they would be in real life), were allowed to participate in the Trial Running sessions.

3.3 Managing the TR Sessions

As with most testing, the Trial Running sessions themselves, are only the delivery of good. The tests are planned in detail and there are nominal, expected outcomes. One key feature of operational testing on a live system, where the people are being placed into adverse situations, is that staff do not do what is expected and unusual things happen. However, it is certainly ***not*** correct to say that anything can happen. With the combination of skills included in running the tests, unusual events are not allowed to escalate into an unsafe condition. This is because the sessions are:

- Triggered as much as possible by "natural" activities/ status changes; and equipment is not placed into dangerous states (simulation is used where necessary).
- Enacted in the native Danish language, this help reduce the likelihood of misunderstanding between operational personnel.
- Briefed out, with the testing team understanding what the test should achieve; including knowledge of how the risks should be manged.
- Well-managed by a TR Coordinator and Test Manager during the session, with timings of trains and tests altered to a pace that matches the current situation.
- Controlled by the ERTMS operational personnel who are told to follow the ORF correctly. They are allowed to ask for guidance or even stop the tests if they feel in anyway insecure or require support to determine the most appropriate course of action.
- Watched over by an ORF expert, who can play both a pro-active and reactionary role.
- Overseen by an independent Test Safety Manager, who can liaise with all parties, stop the testing and report safety breaches, if necessary.

A diagrammatic overview of the TR organisation, including the multiple locations is provided in the figure below.

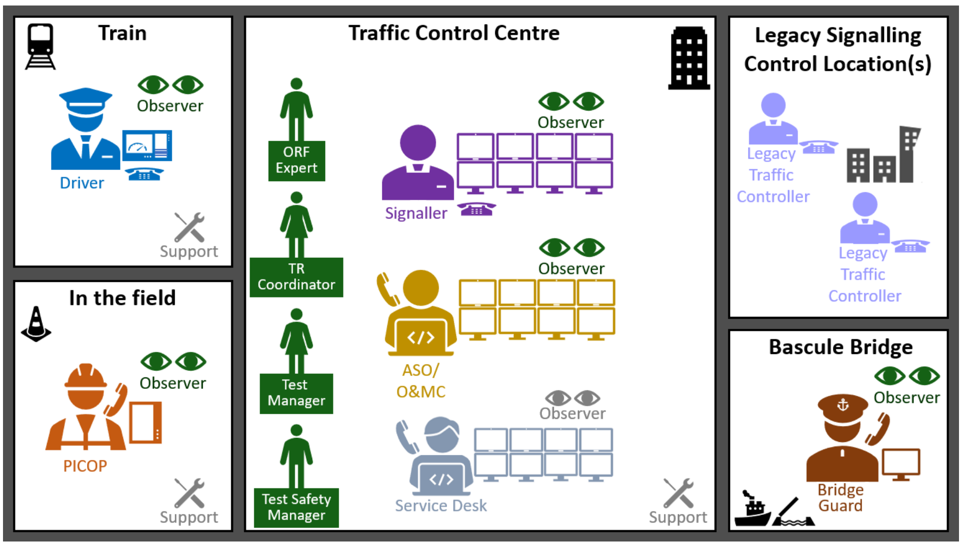

Figure 2: Trial Running involvement across locations (testing team shown in green)

A good example of this TR session management approach is when a test requires a Written Order and the staff do not do what is expected (i.e. the Written Order is incorrectly created and/ or incorrectly communicated). The test is not immediately stopped when the observers notice the errors. Instead it is run as far as safely possible to see if the operational personnel identify the inaccuracies and correct it themselves. Ultimately, an authorisation code is not allowed to be transmitted; the test is interrupted by the testing team and held at this point. The operational personnel are then able to make the appropriate corrections, with the ORF expert supporting them. When this has happened, the feedback from the sessions has been that this approach is:

1. Very beneficial to the participants in terms of learning their own personal lessons;
2. Appropriate to collect observational data, since the people often completed 90% of the other elements correctly and thus the errors can be better pin-pointed, and the most suitable improvements can be made.

3.4 Observing and Recording During the Trial Running

The TR sessions require a number of testing team members who perform an observational role. These TR Observers are provided with some operational training, including information about the ORF and the system behaviour. However, they are not HF specialists, nor are they necessarily operational personnel; instead they are taken from the Signalling Programme, with a variety of backgrounds. The skills of the TR Observer are to review the scenario triggers and KMQs and then observe the operational reality.

As the tests progress, the whole testing team (but not the operational personnel) are aware of the tests that will be performed by following the testing schedule. The TR Coordinator triggers the scenarios and coordinates the TR Observers (using group instant messaging to check in with remotely located team members). The operational personnel (Signallers, Drivers, etc.) do not know what will happen next. They are of course aware that this is a Trial Running condition, however, the operations are live (trains are moving) and staff must behave according to the correct practices laid out in their training.

During the tests, the TR Observers are placed in a one-to-one relationship with operational personal. For each train cab, there is TR Observer; for each Person In Charge Of a Possession (PICOP), there is a TR Observer; for each operational person in the Traffic Control Centre, there is normally a TR Observer (unless the role is very minor or not the focus of the test).

TR Observer sheets delivered on an electronic tablet are used to identify what should be recorded. The TR Observer sheets are entirely based upon the Task Analysis developed for each test intention and placed into the test scenarios. TR Observers are able to complete their observations quickly and the data can be collected into one place for analysis. The observation against each KMQ will normally be “Pass”, “Difficult” or “Fail” (P, D or F); there are other observations that can be recorded, in case of an invalid test. However, the aim is to have a set of valid responses and to know how many of each P, D or F there are for each KMQ. Having re-usable test intentions (and thus KMQ’s) means that repeat observations can be made, against a variety of scenarios. Therefore, feedback and improvements can be more specific; and the justification of a result is more understandable. This leads to easier agreement for the resolution required.

In addition to the “clean” TR observations, the TR Coordinator also ran an immediate debriefing session with the operational personnel who were in the Traffic Control Centre, including the ORF expert, at the end of a testing shift. The benefit of these sessions (outside of the P, D, F against the KMQs) was to gain an understanding of how the operators felt their training prepared them for the session. Specific instances during the shift were discussed and operational personnel were encouraged to provide explanations on where they made new learning for themselves, if anything in their training and real life were different and where ORF or the products and HMIs appeared to be unclear in anyway to them.

3.5 Reporting and Improvement Cycle

There were a large number of TR observations, with thousands of pieces of data collected and over 100 follow-up actions for the first EDL in the West (Jutland). The same is being seen with the second EDL in the East of Denmark. Therefore, clarity is required in the reporting of outcome of TR to the various stakeholders. Immediately following each TR session, the TR Coordinators compiled a list of TR observations and presented them at an operational feedback meeting. These meetings were diarised a long way in advance in order to attain the correct attendance.

The items reported at the operational feedback meeting were grouped together, offering a brief summary of the concern (normally the negative feedback items were the focus of these meetings). There was also some additional content to support the meeting, however, it is never the intention to review logs, data or screen capture. Due to the expertise of the people in the room, the meetings are productive, with a resolution of actions for each issue raised. Typically, 30 to 40 observations were brought to each of the operational feedback meetings; some of which could be discussed together, since they appeared related (although often there were important distinct view points and applications that were resolved in different ways).

The actions from the feedback meetings form the basis of agreements for improvements. In the main, these were related to providing the best alignment of understanding and application for the individual operational people. What that meant was one or more of the following:

- A change to ORF, so that all operational groups read the words in the same, correct way;
- The recognition of a gap in operational procedures outside of the ORF, and a requirement for additional activities to manage the concerns;
- An improvement in the technical or ORF training materials and delivery;
- An agreement to provide in-person "hyper-care" content, when the system was first used for real (the "hyper-care" approach is additional information for the signaller, educated in an on-the-job format);
- A need for a technical improvement (either short-term, prior to commissioning; or a longer-term fix with a short-term use of an agreed workaround).

The operational feedback meetings include the correct attendance from ORF, training, IM, RU, integration and BDK Signalling Programme projects as well as the testing team. This range of people were necessary to help ensure that results were taken on and resolutions were created.

3.6 Inputs to the Railway Safety Package from HF and TR

As explained above, there were a number of TR observations made (both positive and negative), which resulted in engagement with various programme stakeholders. Whilst the initial set of outputs were necessarily called "Trial Running Observations", there was a need for Human Factors interpretation and evaluation. This was especially true where outcomes took some time to feedback and to be re-tested or otherwise proven as closed. The content from the Human Factors team into the Railway Safety Package was:

1. The operational hazard record (see Section 3.7);
2. A spreadsheet which was, in effect, the Human Factors Issues Log, containing details of:
    - Safety Open Points (content that is adjudged to have critical safety relevance and must be resolved with more actions and evidence prior to commissioning).
    - Improvement List Items (content already allocated to an improvement action, awaiting straightforward evidence before train services should commence – whether safety-related or not)
    - Limitations (content whereby TR was unable to provide evidence of testing, therefore no proof that the operational railway was or was not ready for use. The list proposed limitations on the extent of the functional and operational activity for the in-service railway until evidence was collected).
3. A summary test evaluation document, which was a short form overview and summary table of the detailed content provided in the spreadsheet.

The Railway Safety Package was reviewed by the independent safety assessor and delivered for agreement and adoption by an internal group within Banedanmark who are responsible for the Safety Management System and the risk profile for the operational railway.

3.7 Linking TR to the Operational Hazard Record

As with most testing, the individual results and operational feedback actions from the TR itself were not used at the granular level. Instead, the outcomes for TR were a key input to creating closure arguments for the operational hazard record. The operational hazard record, in turn was a key input to the railway level safety package. The railway safety package also points towards the project-level technical hazard records; allowing the operational hazard record to have an operational and HF focus.

In our Operational Hazard Record, we are able to identify which training modules and which Operational Rules are expected to mitigate which risks. Banedanmark have taken it one step further, using a relational database, we identify exactly which test intention provides support for the closure argument in the operational hazard record.

As the reader might imagine, there are hundreds of rules to be followed, multiple training modules to keep track of, a lot of operational risks in the hazard record and over 200 test intentions. Therefore, it is a big challenge to keep track of which result relates to which content. The solution has been the use of a new method called "Human Component Mapping" (HCM), developed by the author in collaboration with others. It is a culmination of approaches started on other projects and further developed with input from other HF practitioners.

The HCM methodology focuses upon the allocation of "Human Components" to each situation, test, hazard, rule, training module, application condition, etc. These Human Components are used as the central hub of a heavy-duty relational database that allows one part of the database to be linked and thus related to one another. The approach is quite simple; the allocation of Human Components requires skill, HF thinking and application knowledge. The result is that you can query the database and find out the answer to any combination of elements.

For example: which rules, training content and risks are relevant to a particular test; or if a rule is changed, what training material needs updating and what TR test intentions should be performed to check out whether the change has filtered through the operational personnel. The basis of HCM is shown in Figure 3.

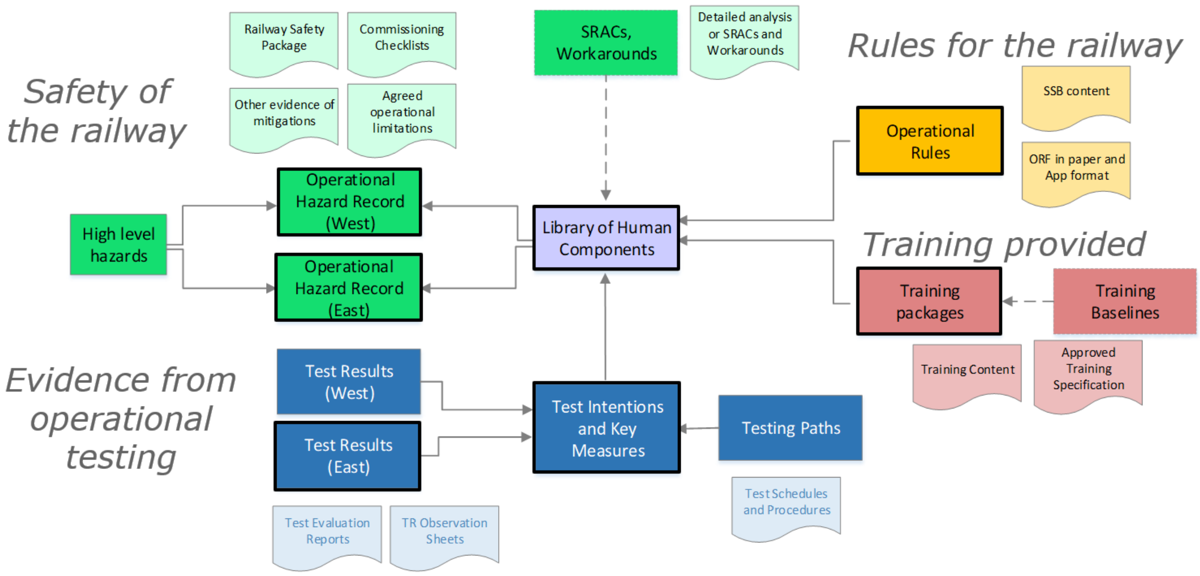

Figure 3: Human Component Mapping (HCM), links safety, testing, rules and training.

4 FINDINGS FROM TRIAL RUNNING

The main content of this paper is to outline the approach taken by Banedanmark. To illustrate the benefits of using Trial Running, a few examples are included in this section in detail. They are not the full set of outcomes; and the examples do not contain all of the issues raised for the type of test. They have been chosen for their relative simplicity of explanation and to show that findings could require technical, rules and/ or training interventions to produce the improvements required.

4.1 Shunting

During the TR, it was found that both signallers and drivers were not able to correctly manage the exit from a non-interlocked Permanent Shunting Area (PSA) into Level 2. Some sources of confusion were the use of "Stop at danger point"; another, the use of hand-worked points and the location at which the train was "visible" to the signaller on the Signalling Control HMI. The TR observations identified that different staff members had different perspectives, so the tests were not performed consistently. Further, the signaller was not always aware of when a train would be seen on the various parts of the CCS HMI. There were two elements to this, firstly the train registers on the RBC some time before track occupation was seen; and since the PSA is not interlocked, it was not known to the Signaller how close to the exit ETCS Stop Marker the train was located on-the-ground. An interesting point is that the centralised control of ERTMS into the TCC means that signallers are not now "locals" and therefore awareness of particular control areas is not as it would be for a local control box.

In another situation, the operators were not so clear about awaking a train with an unknown position in the PSA. The DMI interaction and feedback was not clear to the driver (unsure why SH Mode was rejected) and the signaller did not always manage the use of the CCS HMI to send a manual SH Mode to the train. These observations and feedback revolved around what condition and what messages the system was giving the users and also how verbal communications could only supplement the technical controls.

HF assisted with the different understanding and application of the scenarios for leaving the PSA; and the ORF team, the driver and signaller instructors were involved with improvements. For completeness, a procedure was updated to clarify the normal process, as well as the abnormal. Training materials for both the signallers and drivers were improved to understand each procedure and the use of the CCS HMI commands and the DMI actions and feedback.

4.2 Use of Written Orders and Staff Responsible Mode

The key feedback from operational personal was that using Written Orders (WO) was very different in real life to the training environment. During Trial Running, many of the abnormal scenarios used WO and movement in either Staff Responsible (SR) Mode or with an Isolated train. The tests were designed to use all of the WO types (in Denmark, that's Written Orders 1, 2, 3, 4, 5 and 7). At the outset of the Trial Runs, there were a number of misunderstandings and miscommunications with WO. There were many and varied observations including, but not limited to:

- Understanding the need for the Written Order prior to an unsupervised move in Level 2;
- Stopping at each and every ETCS Stop Marker for the next Written Order;
- The difference between each type and use of Written Orders, especially between WO 1 and WO 7 and WO 2 (and whether a WO remains in force or new one is required);
- When to apply WO 5 for driving with observations;
- How and when to apply WO 3 (to hold a train at the ETCS Stop Marker);
- How to identify and record the location of the train (and who is responsible for determining the location);
- Which of the selection items had to be ticked (and which did not);
- Whether a track number is always required;
- Inclusion of additional information essential for the correct enactment of the Written Order (e.g. stop at the system border, stop before a points prior to clamping, etc.);
- Inclusion of any speed restrictions in place over the area covered by the Written Order;
- Signallers speaking too fast for the driver to complete the form, with subsequent errors and time lost with repetitions;
- Difficulty in adoption of the phonetic alphabet and saying numbers one digit at a time;

- That the Written Order remains to take precedence over the DMI, even after an upgrade to a supervised mode, until the end of the authority given on the Written Order;

It can be argued that doing more and more training with a variety of people may have eventually picked out all of the different errors that are possible on the Written Order forms. However, it is our conjecture that Trial Running has identified the possible issues when applying Written Orders because the two different operational groups are talking: signallers and drivers. When people have made mistakes during TR, those involved were able to realise the issues and to learn the lessons more readily. Further, Written Order errors have occurred throughout all of the Trial Running tests to a greater or lesser extent, whenever signallers and drivers are new to their posts. These observations and feedback from the people taking part have ensured that the training team and instructors have Written Orders as a key focal point and that the RU's are very aware of the potential for a runaway train if drivers do not have the appropriate authorisation prior to movement in SR Mode.

Using WO-based scenarios also provided a much better understanding of some of the technical implementation of the system, that may not have been experienced in a simulation or other training environment, such as:

- That the driver is offered SR Mode in some circumstances/ technical implements and that the driver has to request SR Mode at other times (both complying to the CCS TSI);
- That a train can trip in SR Mode (in some technical implementations, or due to override distance/ time out);
- That the upgrade to a supervised mode occurs differently depending upon the system conditions and the technical implementation;
- That there are some technical bugs that appear only when a train is in an unsupervised mode and workarounds are required.

4.3 Temporary Speed Restrictions

Temporary Speed Restrictions (TSRs) are safety-critical and have been stated in debriefing sessions by many of the operational personnel as one of the key benefits they perceive for using ERTMS. In particular, the ease of placing a TSR onto the operational railway, without a need for personnel to go onto the track and put out sign boards etc. Therefore, there are a lot of different TSR scenarios made up from the various test intentions, including removal of a higher TSR in a similar location to a lower TSR and placing and removing TSRs when there are multiple TSRs across the control area. In general, the performance has depended upon the CCS HMI and the signaller interaction with it. Further, the use of a process of a "second pair of eyes" is critical, in Denmark this is performed by an Assistant Signaller Operator (ASO), who has safety credentials.

There has been a considerable amount of learning associated with the implementation of TSRs. Since there is a preliminary, interim solution, there has been a need for alignment between the original concept, the ORF and how to train people in order to ensure safety. The Trial Running has stress-tested some of the scenarios that are reliant on people communicating specific safety-related information (location and speed) and their ability to use the systems.

Due to the ease of use of the TSR and the existence of the rules that allow a "non-competent" person to report a possible need for a speed restriction, there were TR observations of the potential over-use of TSRs. In some ways, the willingness to use the system has been positive; however, there are two negatives. The first is that the default for such a situation is a 10km/h TSR for 200m either side of the reported location (according to ORF); secondly, to remove a TSR requires an on-site inspection. These two conditions together could mean a service-affecting delay, and drivers having difficulties (since driving at 10km/h for a distance is very difficult on some rolling stock types). ORF have worked with the training team and instructors to clarify the use of TSRs and whether the use of Written Order 5 (observations whilst driving) could be a more appropriate solution to determine whether there is a need to put a permanent TSR into place.

4.4 Usefulness of Trial Running

The few examples above provide to some evidence of the benefit of using a Trial Running approach. In particular, the controlled environment for the first time when operational personnel had been exposed to real-life scenarios.

Going into the TR activity; there was some question of the benefit and whether the TR was simply a box-ticking exercise, a re-run of training with no benefit or even if it was an approach to catch people out. The result was none of these things: from the very first TR activity, it was clear there would be a payback. As well as the benefits from the operations perspective, there was a realisation that the technical system would benefit from being run in the TR scenarios. Some technical issues were identified, and integration concerns recognised; such that improvements were made before commissioning, rather than finding out and looking for a fix in service.

Anecdotally, feedback from participants in the TR sessions was that the workload stresses of performing in TR were comparable to if the scenarios were happening for real. The scenarios presented to the operational personnel were often intense and combined the understanding and application of many different parts of their training, which had not been combined in the same way before. They noted that although they knew it was Trial Running, they also felt under pressure. For many, it was the recognition that the trains were being controlled or driven for real; and real-life incidents could have happened (as well as those presented during the TR).

For the drivers, there are reports of a mostly positive experiences. With recognition that there were also some train movements which could have resulted in a runaway train, had it not been for the testing environment. The lessons from such incidents were registered in the safety monitoring system and the RU and training took a serious note. For the signallers, the experience of using the CCS HMI workstations in the traffic tower was often quite different to the training environment and most expressed a strong positive response for being allowed to participate. All said that they felt they benefited from the experience, whether or not they made errors and suggested that all signallers should be offered a similar exposure, if possible.

The RU and IM operational teams agreed that TR would continue until there was a high level of confidence that all of the safety-related activities performed by operational personnel had been fully tested. Additional sessions were added to ensure that enough knowledge and evidence was collected for all of the tests for the functionality of the systems, the topography of EDL, the rolling stock types and operational roles relevant to the EDL. The operational feedback sessions continue to be well attended and outcomes from the testing remains management-supported decision-making tool for operational readiness.

5 CONCLUSION

There have been many safety and performance related issues identified by using the HF testing approach of Trial Running. The IM and RU have been able to gain confidence that the people are operationally ready and that they can work consistently and safely with the systems provided. Whilst not every scenario has been created and not every person was involved in TR; the feedback into the ORF, training, RU and IM operational teams means that they know more, are more prepared and have more complete support materials.

The examples in this paper (requiring updates to ORF, training or additional on-the-job support) are a sub-set of the issues identified during TR. These show TR can find the potential gaps that will occur if a new or upgraded line takes a simplistic view of applying the interoperability standards and the APIS approach.

6 REFERENCES

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